Hindawi
International Journal of Polymer Science
Volume 2021, Article ID 2462873, 8 pages
https://doi.org/10.1155/2021/2462873

Research Article

Synthesis and Characterization of Polypropylene/Ramie Fiber with Hemp Fiber and Coir Fiber Natural Biopolymer Composite for Biomedical Application

T. Sathish ,[1] Kumaran Palani ,[2] L. Natrayan ,[1] Anjibabu Merneedi ,[3] Melvin Victor De Poures ,[1] and Dinesh Kumar Singaravelu [4]

[1]*Department of Mechanical Engineering, Saveetha School of Engineering, SIMATS, Chennai-, 600 125 Tamil Nadu, India*
[2]*Department of Mechanical Engineering, Wolaita Sodo University, Wolaita Sodo Post Box-138, Ethiopia*
[3]*Department of Mechanical Engineering, Aditya College of Engineering, Surampalem-, 533437 Andhra Pradesh, India*
[4]*Department of Mechanical Engineering, St. Peter's Institute of Higher Education and Research, Avadi, Chennai-, 600 054 Tamil Nadu, India*

Correspondence should be addressed to T. Sathish; sathish.sailer@gmail.com, Kumaran Palani; pkumaran2003et@gmail.com, and Melvin Victor De Poures; melvin.victor02@gmail.com

Received 24 June 2021; Accepted 31 August 2021; Published 17 September 2021

Academic Editor: Senthilkumar Rajagopal

In the current scenario, many natural fibers available in the world can be used in various applications in the day-to-day life of biomedical products, automobile parts, industrial products, etc. Biocomposites can replace or serve as a framework allowing the regeneration of traumatized, degenerated tissues, and organs, thus, improving the patients' quality of life. This research work is aimed at fabricating and investigating the natural biopolymer composites for biomedical applications. There are two sets of fiber composites fabricated in this research work. Ramie fiber considers a common base fiber for both composites. Hemp fibers and coir fibers were considered as filler in this research work. Biodegradable and bioresorbable polypropylene resins are used to fabricate the biocomposite using the compression moulding technique. Different proportion specimen mechanical properties were compared for bone fixtures and joint applications. The contour plots and bar charts were plotted to identify the variations in the volume percentage. The individual fiber specimens also have significant properties when compared with the composite fibers. Then, the individual superior property-based combinations such as hemp and coir fiber mixed with biodegradable and bioresorbable polypropylene/ramie fiber were recommended to produce joints and bone fixtures to alleviate pain for patients.

1. Introduction

Synthetic polymer and biodegradable polymers are commonly used in bioplastic production. Biomedical applications are currently fulfilled by using natural fibers; it can be eco-friendly and offer a safe environment. The natural fibers considered for this investigation such as (a) ramie fibers, (b) hemp fibers, and (c) coir fibers were mentioned in Figure 1. Mamtaz et al. [1] give information about the composites of natural fibers through the water absorption basis with the help of various experiments. They mentioned the impact of sodium hydroxide concentration and different theoretical considerations with the number of mathematical relation equations and definitions. Van Krevelen [2] entirely explained the various details of the polymers such as natural fiber with different verities list in a clear approach. He also gives details about the fiber matrix by way of interfacial bonding. He also produced straightforward potentials summaries regarding numerous fibers mainly the hemp fiber.

Shahzad [3] studied the important and necessary characteristics such as thermal characteristics, time versus residual weight plots, temperature versus weight plots, and heat flow for the hemp fiber. They concluded that hemp fibers are good for glass fibers based on their basic characteristics

(a) (b) (c)

Figure 1: Schematic view of natural fibers: (a) ramie, (b) hemp, and (c) coir.

except for the variability. Similarly, the matrix of biodegradable polymers, thermoset, and thermoplastic produced the greater results of the mechanical characteristics over the glass fibers. But the major disadvantage of the hemp fiber is moisture absorption which the surface treatment on the composites can reduce.

Rajak et al. [4] give the basic details of the various natural fibers like Luffa, palm, jute, banana, rice husk, kenaf, cotton, sisal, hemp, ramie, flax, and abaca also mentioned the synthetic fibers. They provide the reinforcement details and the matrix with the corresponding applications and production technique in a neat presenting method. Shahzad [5] reviewed various papers and gave details about the hemp fiber composites, and he mentioned that they could be used for automotive parts and domestic furniture. This fiber is also used as a good replacement for reinforcement of the glass fibers. The compression moulding is suitable for hemp fiber which can be used with resins like polyethylene and polypropylene. They also give recommendations for the thermoset and thermoplastic materials related to composite reinforcements.

Munde et al. [6] discussed the coir fiber, and they focused on the characteristics based on the damping and vibration. The epoxy resin, polyethylene, and polypropylene were identified as suitable for this coir fiber. The injection moulding or the extrusion methods were used to produce the components based on the structural of automobiles. Chen et al. mentioned the resins like polypropylene and polyolefin were suitable for the ramie fibers in the injection moulding method. This fiber can be used in various biomedical applications [7].

Sebe et al. [8] clearly explained the hemp fibers reinforced composites with polyester for basic mechanical properties like impact strength and flexural strength. They used the moulding method as resin transfer. The considered mechanical characteristics are improved concerning the percentage of the fiber content in the composite. Aziz and Ansell [9] investigated the polyester reinforcement of hemp fiber with Kenaf fiber composite mechanical characteristics. They used two conditions like alkali-treated and without treatment. The flexural modulus and strength reached the greatest values for the alkali-treated composites compared with the treatment condition. They also focused on the resins used for the composite preparation and concluded that polyesters had produced greater strength.

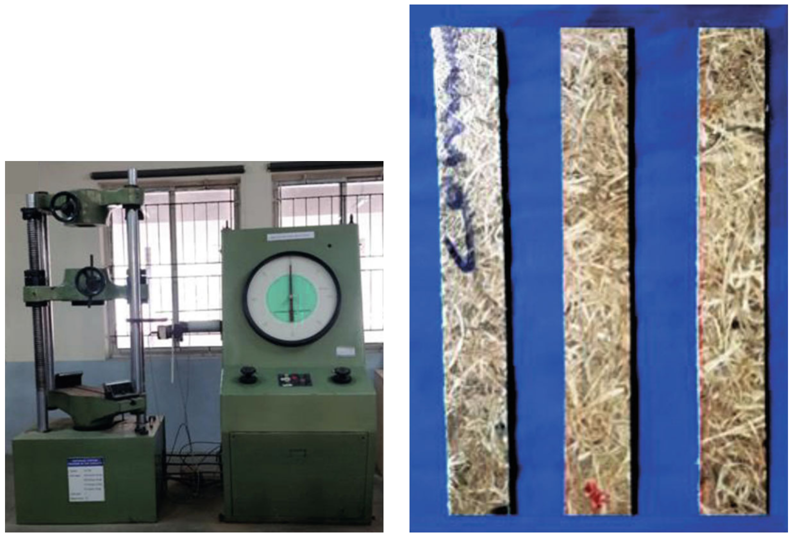
Table 1: Natural fiber composite of ramie fiber and hemp fiber set including the resin.

Sl. no	Ramie fiber (wt%)	Hemp fiber (wt%)
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100

Table 2: Natural fiber composite of ramie fiber and hemp fiber set 2 including the resin.

Sl. no	Ramie fiber (wt%)	Hemp fiber (wt%)
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100

Panthapulakkal et al. [10, 11] expressed that the hybridizing method is suitable for the composites of the natural fibers and synthetic fibers based on maximum mechanical characteristics. But they preferred the natural fibers because of their biodegradability. Djafar et al. [12] experimentally analysed the reinforced composites of the ramie fibers with epoxy resin and woven ramie fibers. They only focused on bending and tensile stress with SEM images and Fourier transform infrared spectroscopy analysis results. Yu et al. [13], Paiva et al. [14], and Goda et al. [15] studied and expressed ramie fiber is the suitable fiber for the reinforcement composites when compared to other fibers. It has the maximum usage in textile productions. It has the greatest tensile property from four hundred to a maximum of 1600 MPa; these values are greater than jute and flax fiber. Ramie is the preferred fiber for the research.



(a) (b)

Figure 2: Tensile test: (a) UTM machine and (b) composite specimens—ASTM D3822.

Table 3: Experimental results of set 1 and set 2.

Fiber with ramie fiber %	Percentage of elongation %		Tensile strength (MPa)		Density (g/cm^3)		Young's modulus (GPa)	
	Hemp	Coir	Hemp	Coir	Hemp	Coir	Hemp	Coir
0	2.6	2.6	512	512	1.57	1.57	43	43
25	2.394	6.88	608	455.6	1.552	1.514	48.25	35.8
50	2.188	11.16	704	399.2	1.534	1.458	53.5	28.6
75	1.982	15.44	800	342.8	1.516	1.402	58.75	21.4
100	1.57	24	992	230	1.48	1.29	69	7

Srinivas et al. [16] explained natural fiber composites and mentioned the basic properties of the coir, ramie, and hemp fiber. Lakshumu Naidu et al. [17] mentioned various natural fiber basic physical properties and chemical properties. Mwaikambo [18], Ticoalu et al. [19], and Sen and Reddy [20] explained the various applications of the various natural fibers among the important applications were discussed. Hemp fiber is used in products for construction, furniture, packaging materials, textiles, etc. Similarly, coir fibers are also used for roofing sheets, casing of mirrors, ropes, brushes, paper weights, etc. Likewise, ramie fiber can be used as nets for fishing, filter cloths, materials for backing the products, sewing threads, furniture, etc.

There are many reports on the mechanical and physical properties of natural fiber reinforced polymer composites, but the effect of coir fiber and hemp fiber on the mechanical behavior of ramie fiber reinforced polymer composites is scarcely reported. The objective of this research work newly attempts to prepare the biopolymer for biomedical applications using different natural fibers. The prepared composites were tested to find the tensile strength, percentage of elongation, and Young's modulus properties. Ramie fiber considers as the base fiber. The different volume percentages of hemp fiber and coir fiber were taken. There are two sets of fiber composite fabricated for the properties comparison. One set is the composites of the ramie fiber with hemp fiber and another composite created with ramie fiber with coir fiber in various combinations of volume percentage of the fiber. The basic desirable mechanical properties were measured and compared to identify the fibers' maximum output-based volume percentage contribution.

2. Experimental Setup

There are two sets of composites fabricated. They are increasing hemp fiber concentration and decreasing ramie fiber concentration in total volume. In this investigation, two sets of composite fiber combinations in each set contain the ramie fiber's participation in the percentage of volume in total volume. The fiber composite of set 1 contains the ramie fiber with hemp fiber in various proportions as per Table 1. Similarly, the composite of set 2 contains the ramie fiber with the coir fiber in different proportions as per Table 2 with reducing ramie fiber volume with the incremental volume of the coir fiber volume in the total volume of the composites.

In this investigation, the two sets of composite fiber combinations in each set contain the ramie fiber's participation in the percentage of volume in total volume. There are two sets of composites fabricated. The fiber composite of

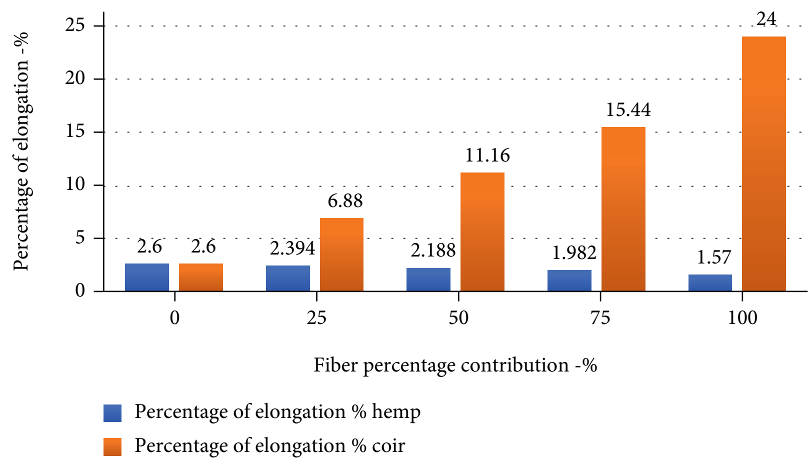


Figure 3: Comparison of the experimental results of percentage of elongation.

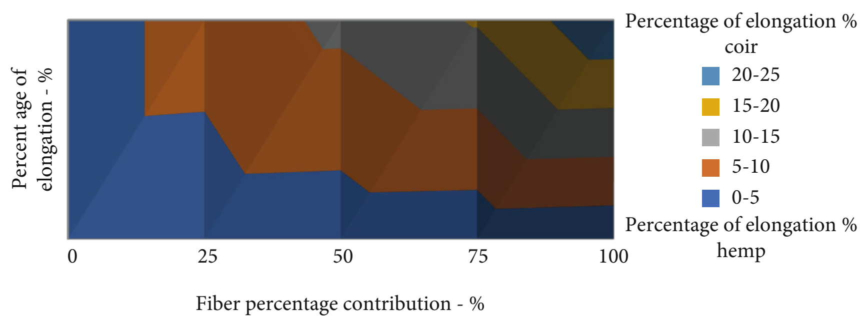


Figure 4: Comparison of the experimental results of elongation as contour plot.

set 1 contains the ramie fiber with hemp fiber in various proportions as per Table 1, like increasing hemp fiber concentration and decreasing Ramie fiber concentration in total volume. Similarly, the composite of set 2 contains the ramie fiber with the coir fiber in different proportions as per Table 2 with reducing ramie fiber volume with the incremental volume of the coir fiber volume in the total volume of the composites.

There are five composites created for each set of combinations. The biodegradable and bioresorbable polypropylene is used as a resin because it can be suitable for these three fibers. Hemp and coir have the individual mechanical properties higher and lower, respectively, when compared with the ramie fiber. So, the impacts of the combinations were considered for this investigation. The ancient method like compression moulding is selected to ASTM D3822 standard produce the specimens in 120 mm × 150 mm × 10 mm [21]. The two sets have similar dimensions. There are nine different specimens prepared because 100 percentage ramie fiber results can be used for both sets.

There are four different mechanical properties identified through testing. Tensile strength, percentage of elongation, and Young's modulus can be done with Figure 2 mentioned universal testing machines with the standard specifications of the specimens. Tensile test and percentage of elongation were done in the same specimen. Based on these two values, Young's modulus can be derived by the relation of the stress-strain equation-based calculations. The measuring weight comparison can identify the density of the specimens with the volume occupied relation such as unit mass per volume. Then, the corresponding values are identified for the analysis.

3. Results and Discussion

The experimental results were tabulated in Table 3 for set 1. They set 2 of the composite combinations, but the table mentions both coir and hemp fiber only because the ramie fiber covers the remaining percentage of the composite for both sets of composites. So the comparisons were also created with the coir and hemp fiber only, and there is also the mention for ramie fiber which is understood.

Figure 3 mentioned the percentage of elongation result comparison as a bar chart. 100% of coir have the highest percentage of elongation which is the individual composite. But the combination of 25% of ramie and 75% of coir fiber composite reached the maximum elongation (15.44%) and the minimum percentage of elongation (1.982%) obtained by the composite of the composite 25% of ramie and 75% of hemp fiber. These percentage elongation variations are also represented as the contour plot in Figure 4 with various colours. The minimum and maximum percentage variations were mentioned as the various intensity in the diagram with different colours. The minimum range starts from 0 to 5%,

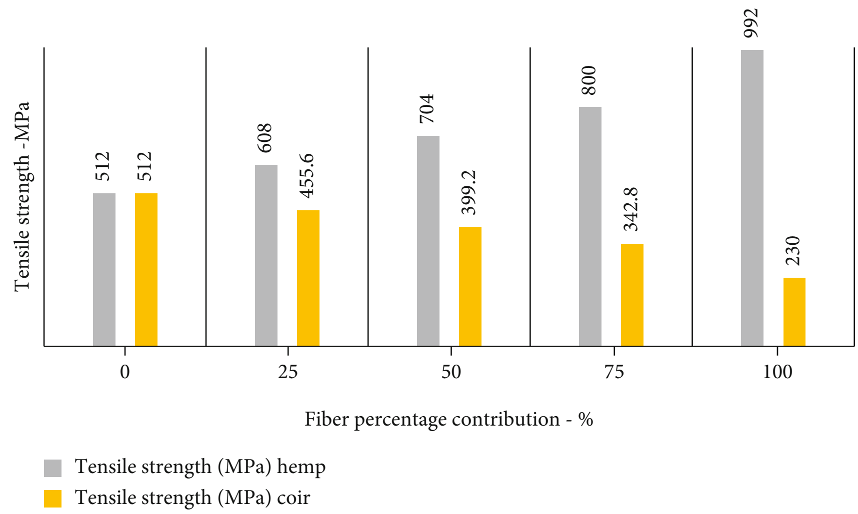


Figure 5: Comparison of the experimental results. Tensile strength as a bar chart.

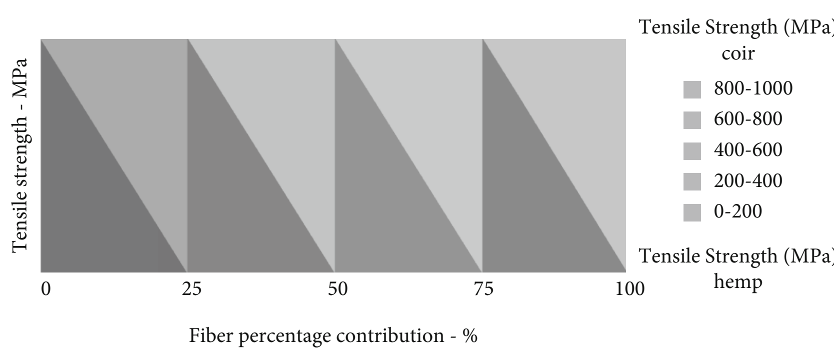


Figure 6: Comparison of the experimental results. Tensile strength as a contour plot.

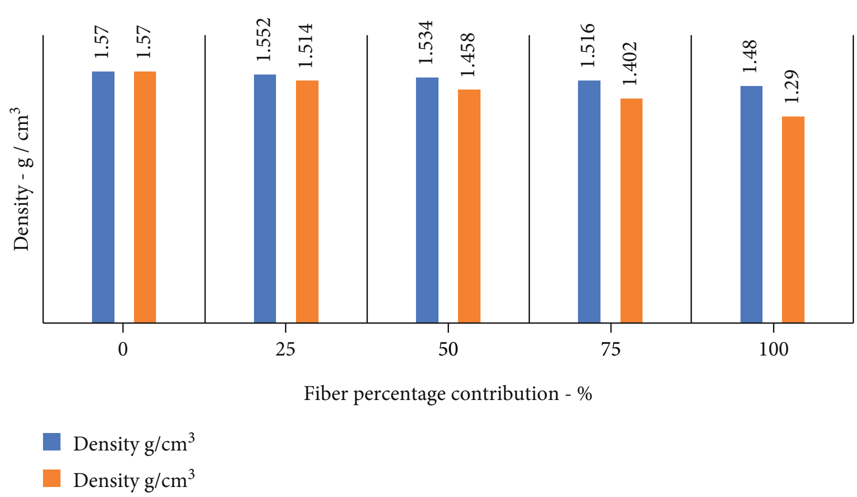


Figure 7: Experimental consequence of density as a bar chart.

and the highest intensity is reached for the 20 to 25% of elongation percentage.

The tensile strength-based result was mentioned in the bar chat in Figure 5 and the contour plot in Figure 6 for clear identification. The highest tensile strength is achieved for the 100% of the hemp fiber composite specimen. There is no ramie fiber contribution. So the maximum tensile strength such as 800 MPa is obtained for the composite with 75% of hemp fiber with 25% of the ramie fiber composite [18]. Similarly, the lowest tensile strength was obtained for the 25% ramie fiber with 75% coir fiber composite. But the coir fiber-based maximum tensile strength is obtained at

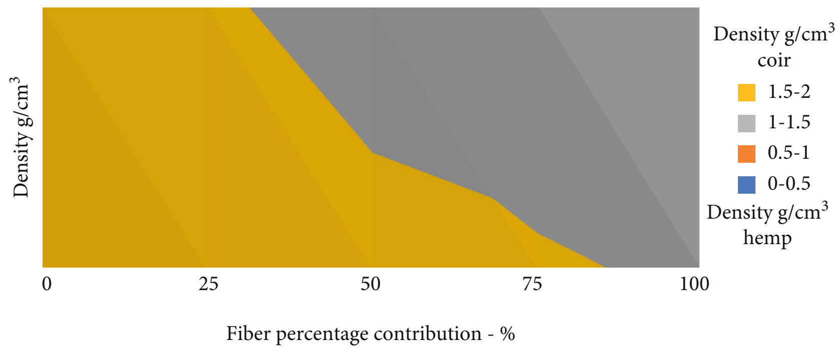


Figure 8: Experimental consequence of density as a contour plot.

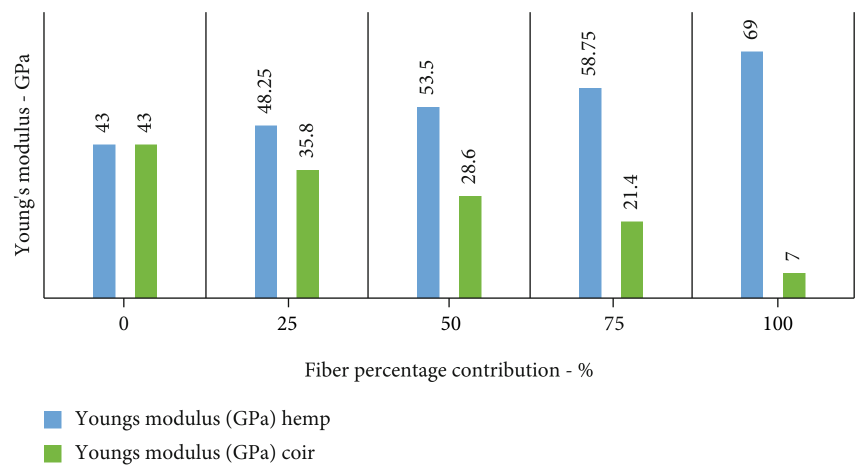


Figure 9: Experimental consequence of Young's modulus as a bar chart.

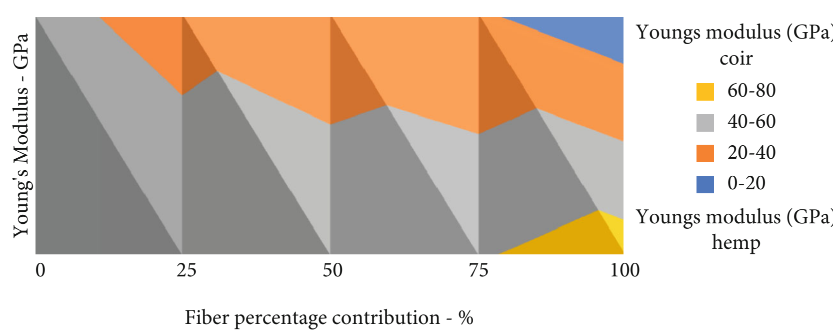


Figure 10: Experimental consequence of Young's modulus as a contour plot.

455 MPa of tensile strength for the composite with 75% of ramie fiber, and the remaining 25% is coir fiber in the total volume of the composite.

Figures 7 and 8 showed the experimentally measured and calculated density values variations of the composites as the graphical representation of bar chart and contour plot, respectively, with the standard deviation of 1.25 [19]. The maximum density is obtained for the individual fiber composite of the ramie fiber composite such as 1.57 g/cm^3. Similarly, minimum density can be reached for the individual fiber specimen of the coir fiber as 1.29 g/cm^3. But the combination-based composite of 75% ramie fiber and 25% hemp fiber reached a higher density of 1.552 g/cm^3 than the composite of the 25% coir and 75% ramie fiber-based density of 1.514 g/cm^3. Contour plots have the two variation regions only such as 1.5 to 2.0 g/cm^3 and 1.0 to 1.5 g/cm^3.

The outcomes of Young's modulus of set 1 and set 2 were mentioned in Figure 9 as a bar chart similar to Figure 10 as a contour plot. The highest Young's modulus (69 GPa) value is reached for 100% of the hemp fiber individual composite. Similarly, a very low Young's modulus value such as 7 GPa is reached for 100% of individual coir fiber composite [20]. But the combination of mixing-based composite has the following results. The 75% of hemp and 25% of ramie fiber composite reached the highest Young's modulus as 58.75 GPa.

Similarly, the 25% of coir fiber and 75% of ramie fiber composite produced 35.8 GPa of Young's modulus value [21]. The individual ramie fiber composite has Young's modulus of 43 GPa. The use of hemp fiber and coir fiber mixed with biodegradable and bioresorbable polypropylene/ramie fiber can produce joints and bone fixtures to alleviate pain for patients.

4. Conclusions

This examination of comparison of properties on ramie fiber with hemp fiber and coir fiber composites gives the following as a comparison results

(i) Both the combination of set 1 and set 2 of the fiber composite can be produced

(ii) From the tensile strength analysis, the set 1 results provided the higher tensile values (704 MPa) compared to set 2 results (399.2 MPa) for the properties such as tensile strength

(iii) In density analysis, set 1was registered as 1.54 g/cm^3, and set 2 was registered as 1.458 g/cm^3 in Young's modulus analysis. Set 1was recorded as 53.5 GPa and set 2 was recorded as 28.6 GPa

(iv) For tensile strength and Young's modulus on 75% of hemp fiber with 25% of ramie fiber composite produced the maximum values (tensile strength: 608 MPa, Young's modulus: 48.25 GPa) among the composite fibers considered for this investigation

(v) From density analysis, 25% of hemp fiber and 75% of ramie fiber reached the maximum density among the composite fibers were observed as 1.516 g/cm^3

(vi) The percentage of elongation of set 2 has greater results than the set 1 fiber composites such as 15.44%

(vii) Here, 25% of the coir fiber with 75% of the ramie fiber produced the maximum % of elongation results

(viii) Hence, the ramie fiber with hemp fiber (set 1) is suitable for the tensile strength, density, and Young's modulus-based biomedical applications. The ramie fiber with coir fiber (set 2) is suitable for elongation-based biomedical applications

(ix) The use of hemp fiber and coir fiber mixed with biodegradable and bioresorbable polypropylene/ramie fiber can produce joints and bone fixtures to alleviate pain for patients

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Disclosure

This study was performed as a part of the Employment of Wolaita Sodo University, Wolaita Sodo, Ethiopia.

Conflicts of Interest

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

Acknowledgments

The authors thank Saveetha School of Engineering, SIMATS—Chennai for the technical assistance to complete this experimental work, and the authors appreciate the supports from Wolaita Sodo University, Ethiopia.

References

[1] H. Mamtaz, M. H. Fouladi, M. Al-Atabi, and S. N. Namasivayam, "Acoustic absorption of natural fiber composites," *Journal of Engineering*, Article ID 5836107, 2016.

[2] D. W. van Krevelen, *Properties of Polymers 3th Edition*, Elsevier, New York, 1997.

[3] A. Shahzad, "A study in physical and mechanical properties of hemp fibres," *Corporation Advances in Materials Science and Engineering*, vol. 2013, article 325085, pp. 1–9, 2013.

[4] D. K. Rajak, D. D. Pagar, P. L. Menezes, and E. Linul, "Fiber-reinforced polymer composites: manufacturing, properties, and applications," *Polymers*, vol. 11, p. 1667, 2019.

[5] A. Shahzad, "Hemp fiber and its composites—a review," *J. Compos. Mater.Vol.*, vol. 46, pp. 973–986, 2011.

[6] Y. S. Munde, R. B. Ingle, and I. Siva, "Investigation to appraise the vibration and damping characteristics of coir fibre reinforced polypropylene composites," *Adv. Mater. Process. Technol.Vol.*, vol. 4, pp. 639–650, 2018.

[7] D. Chen, C. Pi, M. Chen, L. He, F. Xia, and S. Peng, "Amplitude-dependent damping properties of ramie fiber-reinforced thermoplastic composites with varying fiber content," *Polym. Compos.Vol.*, vol. 40, pp. 2681–2689, 2019.

[8] G. Sebe, N. S. Cetin, C. A. S. Hill, and M. Hughes, "RTM hemp fiber reinforced polyester composites," *Appl Compos Mater. Vol.*, vol. 7, pp. 341–349, 2000.

[9] S. H. Aziz and M. P. Ansell, "Optimising the properties of green composites," in *In: Baillie CA (ed.) Green composites*, pp. 154–180, Ch. 8. Cambridge: Woodhead Publishing Limited, 2004.

[10] S. Panthapulakkal and M. Sain, "Studies on water absorption properties of short-hemp glass fiber hybrid polypropylene composites," *Journal of Composite Materials*, vol. 41, pp. 1871–1883, 2007.

[11] S. Yogeshwaran et al., "Experimental investigation on mechanical properties of epoxy/graphene/fish scale and fermented spinach hybrid bio composite by hand lay-up technique," *Materials Today: Proceedings*, vol. 37, no. 2, pp. 1578–1583, 2021.

[12] Z. Djafar, I. Renreng, and M. Jannah, "*Tensile and bending strength analysis of ramie fiber and woven ramie reinforced epoxy composite*," *Journal of Natural Fibers*, 2020.

[13] T. Yu, J. Ren, S. Li, H. Yuan, and Y. Li, "Effect of fiber surface-treatments on the properties of poly(lactic acid)/ramie composites," *Compos Part A Appl Sci Manu.f*, vol. 41, pp. 499–505, 2010.

[14] J. C. Paiva, L. de Carvalho, V. Fonseca, S. Monteiro, and J. R. D.'. Almeida, "Analysis of the tensile strength of polyester/hybrid ramie – cotton fabric composites," *Polymer Testing*, vol. 23, pp. 131–135, 2004.

[15] K. Goda, M. S. Sreekala, A. Gomes, T. Kaji, and J. Ohgi, "Improvement of plant based natural fibers for toughening green composites – effect of load application during mercerization of ramie fibers," *Compos Part A Appl Sci Manu.f*, vol. 37, pp. 2213–2220, 2006.

[16] K. Srinivas, A. Lakshumu Naidu, and M. V. A. Raju Bahubalendruni, "A review on chemical and mechanical properties of natural fiber reinforced polymer composites," *Int. J. Performability Eng.*, vol. 13, no. 2, pp. 189–200, 2017.

[17] A. Lakshumu Naidu, V. Jagadeesh, and M. V. A. RajuBahubalendruni, "A review on chemical and physical properties of natural fiber reinforced composites," *International Journal of Advanced Research in Engineering and Technology (IJARET)*, vol. 8, no. 1, pp. 56–68, 2017.

[18] L. Mwaikambo, "Review of the history, properties and application of plant fibres," *African Journal of Science and Technology*, vol. 7, no. 2, p. 121, 2006.

[19] A. Ticoalu, T. Aravinthan, and F. Cardona, "A review of current development in natural fiber composites for structural and infrastructure applications," *In Proceedings of the Southern Region Engineering Conference(SREC '10)*, pp. 113–117, Toowoomba, Australia, 2010.

[20] T. Sen and H. N. Reddy, "Various industrial applications of hemp, kinaf, flax and ramie natural fibres," *International Journal of Innovation, Management and Technology*, vol. 2, pp. 192–198, 2011.

[21] S. Yogeshwaran et al., "Effect of waste tyre particles reinforcement on mechanical properties of jute and abaca fiber-epoxy hybrid composites with pre-treatment," *Materials Today: Proceedings*, vol. 37, no. 2, pp. 1377–1380, 2021.