Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-026

Research Article

Open Access

A Comparative Study on Impact Strength Enhancement of Polylactic Acid Composites Reinforced with Jute and Novel Bamboo Fibers

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Received: July 26, 2023
Accepted: September 28, 2023
Published: October 04, 2023

Citation: Mohandas P, Koppiahraj K. 2023. A Comparative Study on Impact Strength Enhancement of Polylactic Acid Composites Reinforced with Jute and Novel Bamboo Fibers. *NanoWorld J* 9(S3): S135-S138.

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Abstract

The aim of this study was to investigate the impact strength enhancement potential of novel bamboo fiber (BF) in jute fiber (JF) reinforced polylactic acid (PLA) composites. Composite materials were prepared using a hand lay-up technique with varying weight ratios of PLA, JF, and novel BF (80/10/10, 70/20/10, 60/30/10, 50/40/10, and 40/50/10 wt.%). The impact strength of the composite materials was tested using a sample size of 20, with 10 samples in group 1 (PLA/JF) and 10 samples in group 2 (PLA/novel BF/JF), a G-power of 0.8, alpha and beta values of 0.05 and 0.2, and a 95% confidence interval (CI). Results showed that the composite materials with higher loading of novel BF had higher impact strength. The impact strength of the PLA/JF/novel BF composite material was 30.32 J/m, while that of PLA/JF was 23.70 J/m. The study concludes that novel BF improves the impact strength of PLA/JF composite materials, which can contribute to their reusability. This finding has implications for the development of sustainable and durable composite materials for various industrial applications.

Keywords

Jute fiber, Impact strength, Novel bamboo fiber, Polylactic acid, Sustainable consumption, Hand lay-up technique

Introduction

Using natural fibers in a biodegradable substrate is especially feasible since the resulting synthetic material has greater tensile and flexural capabilities than a biodegradable substrate. Biodegradable composites are more accessible and less costly than composites reinforced with synthetic fibers [1]. Also, helps in sustainable consumption. The impact strength of each material varies. Foam and plastics, for instance, have lower impact strengths than metals, which have higher impact strengths [2]. Special concrete mixtures can now be made thanks to recent advancements in material technology, including polymer concrete for high durability, fiber-reinforced concrete to prevent fractures, high- and ultra-high strength concrete for applications in tall structures and bridges, lightweight concrete to lower foundation loads, and high-performing concrete for specific performance requirements. Customers are being advised more and more to buy products made of natural fibers since they are among the environmentally friendly materials and might be a decent replacement for synthetic fiber. Natural fibers are used as reinforcing agents more frequently because of their outstanding properties, like being renewable, biodegradable, non-abrasive, affordable, and reuse having a reduced density. Further, natural fibers are inexpensive and offer superior mechanical qualities [3]. The necessary characteristics are also provided by reinforced polymers. In terms of tensile and impact strength, kenaf-aramid hybrid composites surpassed prior hybrid composites [4].

Research has been conducted in recent years to enhance the mechanical characteristics of PLA [2, 3]. Google Scholar found 55 publications, while IEEE Xplore published 105 research papers. According to Han et al. [5] adding more fiber to natural fiber reinforced composites enhances their impact strength to an optimal level, after which adding more fiber causes the composite's impact strength to drop. Biocomposite materials, or renewable resources consisting of biopolymers and natural fibers, were studied by [6]. Sapuan et al. [7] investigated substituting natural fiber for the other synthetic fiber material as a reinforcing component in thermoplastic polymers. Natural fibers like JF and flax fiber are favored over synthetic fibers [8]. When these natural fibers are mixed, the properties are enhanced. Limba et al. [9] assert that fibers that have been alkali-treated will have better fiber-matrix interaction. This is done so since one of the main drawbacks of natural fibers is their high moisture content. These materials' mechanical qualities are much superior to those of the common plastics we use. By substituting biofibers for synthetic and conventional fibers, Alkateb et al. [4] found that the impact strength rose, reducing the impact and perhaps enhancing the crashworthiness of the car that can also be reused. The plain form of kenaf/novel BF hybrid composites showed greater impact strength than the twill variety [10].

By offering a thorough overview of prior studies that are currently available and on pertinent topics, this article addresses the research gap. In this work, PLA is reinforced with JF and novel BF, and composite materials are prepared by following hand lay-up technique. The purpose of this inquiry is to comprehend the differences in strength attributes under diverse process settings. The impact strength of the composite was calculated using the study's correlations. This work contributes to sustainable consumption by recovering value from the waste materials.

Materials and Method

This study was carried out in the mechanical engineering department's Nano lab at the Saveetha College of Engineering (Chennai, Tamil Nadu, India). We bought granulated PLA from Javanthee Enterprises (Chennai, Tamil Nadu, India). Its density was 12.1 g/cm^3, and its melting point was 150 °C. At around 180 °C, it first began to crystallize. The glass transition temperature 55 °C of PLA is about. Reference values for the reinforcement's tensile qualities were selected from the literature after the tensile characteristics of PLA were evaluated in the lab. JF and novel BF were used to make the composite materials for the current study by Javanthee Enterprises (Chennai, Tamil Nadu, India). The investigation calls for the collection of 20 samples and the execution of 20 sample tests. Two sample groups are involved. Group 1 consists of composite materials developed with PLA/JF, whereas group 2 consists of composite materials developed with PLA/JF/novel BF [1]. The computation makes use of a G-power of 0.8, alpha and beta qualities of 0.05 and 0.2, and a 95% confidence level [11].

Lactic acid is the source of PLA, an aliphatic polyester and renewable thermoplastic polymer matrix and reuses. It is one of the most promising biopolymers in the world since it has played a crucial role in the creation of goods that break down organically. Agricultural resources were often fermented to produce lactic acid, which was then used to make PLA. After 12 weeks of exposure to the sun, the JF and novel BF were finally dried. The fibers underwent a 24 h alkaline treatment with NaOH to enhance their adherence to the matrix material during the manufacturing step. The moisture was then entirely removed from the fibers by roasting them for 72 h at 90 °C in an air oven. Thus, the waste JF and novel BF is reused, and it helps in sustainable consumption.

In order to make twenty samples with the proper proportions of each ingredient, independent weight fraction measurements of the PLA, JF and novel BF were obtained using a digital scale. After each sample was weighed, the dry forms of the fiber and polymer were mixed using a mechanical stirrer. By following hand lay-up technique, two groups of samples, group 1 (PLA/JF) and group 2 (PLA/JF/novel BF) were developed. In group 1, 10 samples were prepared with different ratios (50/50, 60/40, 70/30, 80/20, and 90/10). In group 2, the novel BF were added to JF in the following ratio: 80/10/10, 70/20/10, 60/30/10, 50/40/10, and 40/50/10 wt.%. All the composite materials were prepared using hand lay-up technique. The impact strength of these composites has all been studied. Izod impact test was carried out. Each of the unnotched samples underwent an Izod impact test to see if the composite materials met ASTM requirements for impact resistance. The tool had a maximum force of 15 N and a hammer head weight of 150 kg. For each of the specimens under evaluation, the impact strength was calculated in relation to the impact energy received.

Impact strength is the measure of the resistance shown by a material when it hits an object. It is usually expressed as the amount of energy absorbed by the material. There are two methods in which impact strength can be measured namely, Izod and Charpy impact test. In this work, an Izod impact test is carried out. Here, a V-notch is created on the sample for conducting Izod impact test. The V-notch is made at a 45° angle. Then, a hammer with a certain load is made to strike against the workpiece.

Statistical analysis

In this case, IBM SPSS (Statistical Package for the Social Sciences) V26.0 was the software used to measure the statistics. The independent sample t-test analysis was used to determine the mean, standard deviation, and standard error mean. After comparing the two groups using the SPSS program, the mean value and standard deviation values will be utilized with the graph to most precisely identify the significant value. Impact strength is an example of an interdependent variable. Examples of independent variables are the PLA/JF and PLA/JF/novel BF.

Results

A straightforward bar graph comparing the impact strength of PLA/JF and PLA/JF/novel BF is shown in figure 1. The highest impact strength of PLA/JF 23.70 J/m while PLA/JF/novel BF has a highest impact strength of 30.32

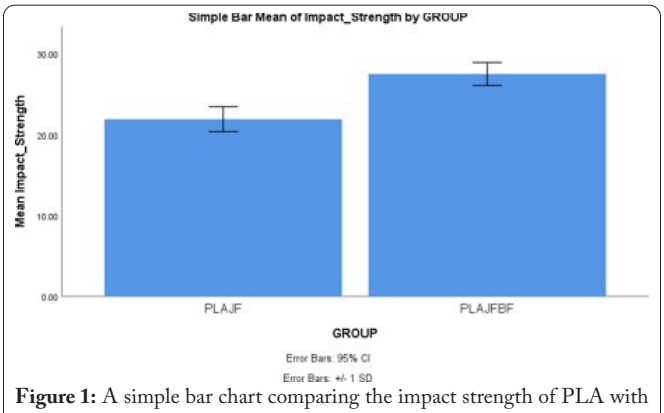


Figure 1: A simple bar chart comparing the impact strength of PLA with JF and PLA with BF has been developed. The impact strength of PLA with JF is 21.91 J/m, while that of PLA with BF is 27.50 J/m. The PLA including JF differs considerably from the PLA containing novel BF (p = 0.05, independent sample test). The impact strength values of PLA with JF and PLA with novel BF are plotted along the X-axis. Y-axis: Mean impact strength for keyword recognition, ±1 standard deviation, with a confidence range of 95%.

J/m. The PLA/JF composite materials are very different from PLA/JF/novel BF (p = 0.05, independent sample test). Along the X-axis are displayed the impact strength values for PLA/JF and PLA/JF/novel BF. For phrase recognition, the Y-axis, 1 standard deviation, 95% CI, mean thermal characteristic and reusability.

The impact strength of PLA/JF and PLA/JF/novel BF are given in table 1. The average impact strength of PLA/JF/novel BF is 27.505 J/m which is more than PLA/JF. PLA/JF/novel BF outperforms PLA/JF in terms of impact strength. The statistical calculations, which include mean, standard deviation, and standard error for PLA/JF/novel BF and PLA/JF, are displayed in table 2. The t-parameter is used to evaluate the impact strength. The mean impact strength of PLA/JF is 21.95 and PLA/JF/novel BF is 27.50. In comparison to PLA/JF, the standard deviation for PLA/JF/novel BF is 1.411.

The statistical results for independent samples contrasting PLA/JF and PLA/JF/novel BF are shown in table 3. Comparing PLA/JF/novel BF and PLA/JF is done using an independent sample t-test with a level of significance of 0.66199 and a 95% CI. 0.001, significance (2-tailed), significance, lower and upper interval difference, mean difference, standard error difference, and significance are the results of this independent sample test.

Table 1: The comparative evaluation metrics for PLA/JF and PLA/JF/novel BF has been presented. The average impact strength of PLA/JF is 21.915 J/m while that of PLA/JF/novel BF is 27.505 J/m. In terms of impact strength, PLA/JF/novel BF performs better than PLA/JF.

Test	Impact strength (J/m)	
	PLA/JF	PLA/JF/Novel BF
Test 1	23.7	30.32
Test 2	20.45	27.52
Test 3	22.25	26.22
Test 4	19.25	27.34
Test 5	22.75	28.65
Test 6	23.55	27.25
Test 7	22.88	25.22
Test 8	20.15	28.36
Test 9	22.95	27.65
Test 10	21.22	26.52
Average test results	21.915	27.505

Table 2: The statistical calculation such as mean, standard deviation and standard error mean for PLA/JF and PLA/JF/novel BF. The impact strength parameter used in the t-test. The mean impact strength of PLA/JF is 21.91 J/m and PLA/JF/novel BF is 27.50 J/m. The standard deviation of PLA/JF is 1.54 and PLA/JF/novel BF is 1.41. The standard error mean of PLA/JF is 0.488 and PLA/JF/novel BF is 0.446.

Group		N	Mean	Std. deviation	Std. error mean
Impact strength (J/m)	PLA/JF	10	21.915	1.54625	0.48897
	PLA/JF/ novel BF	10	27.505	1.41116	0.44625

Discussion

The impact strength of PLA/novel BF/JF and PLA/JF have been compared. The impact strength of the PLA/JF were investigated by adding novel BF (80, 70, 60, 50, and 40 wt.%). In comparison to PLA/JF, PLA/JF/novel BF has superior impact strength. novel BF is stronger and stiffer than regular JF, as evidenced by the PLA/JF/novel BF impact strength (30.32 J/m) as compared to PLA/JF. The high impact strength was found in the reinforced composite at 70/20/10% weight combination of PLA/JF/novel BF. The 40/50/10 wt.% reinforced PLA/JF/novel BF composite had inferior impact strength as a result of insufficient matrix material, which led to improper wetting of the fiber. In a study, Liu et al. [12] the role of resin is very crucial in determining the mechanical properties of the composite materials. Other than resin, studies by Ubeid et al.

Table 3: The statistical calculations for independent samples tested between PLA/JF and PLA/JF/novel BF. The significance value for tensile strength is 0.039. This independent sample test consists of significance as 0.001, significance (2-tailed), mean difference, standard error difference, and lower and upper interval difference.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
									Lower	Upper
Tensile strength	Equal variance assumed	0.770	0.039	-8.444	18	0.001	15.59	0.66199	-6.98078	-4.19922
	Equal variance not assumed			-8.444	17.852	0.001	-5.59	0.66199	-6.98161	-4.19839

[13] and Mohammed and Hama [14] advocated the besides playing an important role in enhancing the mechanical properties of composite materials, overloading of fibers may also lower the mechanical properties. Hence, determining an ideal composition of fiber and resin ratio is critical [15].

In this study, the maximum impact strength was exhibited by the composite material with the composition of 70/20/10% weight. Increasing the novel BF has also resulted in a decrease in the impact strength. Even the addition of lower composition of novel BF such as 60, 50, and 40% has resulted in intermediate impact strength. Hence, the outcome is in agreement with the earlier studies [1, 3] by which states that increase in fiber content may either increase or decrease the mechanical properties.

When reinforced with 50% novel BF, the impact strength of the composites increased as the fiber content increased. However, as the amount of fiber is raised to 80% weight percent, the impact strengths of composites decline. The PLA becomes stiffer but also more delicate with the addition of fibers. The maximum impact strength was obtained with a composition of 80/10/10 i.e., 80% of novel BF reinforced against 10% of JF and 10% PLA.

Conclusion

The conclusion of this study highlights the potential of novel BF as a reinforcement material in JF and PLA composite materials to enhance their impact strength compared to traditionally reinforced JF composites. The PLA/JF/novel BF composite material demonstrated superior impact strength of 30.32 J/m as compared to the PLA/JF composite's impact strength of 23.70 J/m. The study suggests that using novel BF in composite materials can improve their impact resistance, reduce waste, and contribute to the development of eco-friendly composite materials, sustainable consumption practices, making it a promising candidate for various industrial applications.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Koppiahraj K, Bathrinath S, Narayanasamy P, Balasundar P, Parrthipan BK, et al. 2021. A Review on the Factors Influencing Natural Fiber Composite Materials. In Khan A, Rangappa SM, Siengchin S, Jawaid M, Asiri AM (eds) Hybrid Natural Fiber Composites. Woodhead Publishing, pp 185-205.
2. Sachin SR, Kannan TK, Rajasekar R. 2020. Effect of wood particulate size on the mechanical properties of PLA biocomposite. *Pigm Resin Technol* 49(6): 465-472. https://doi.org/10.1108/PRT-12-2019-0117
3. Nur Diyana AF, Khalina A, Sapuan MS, Lee CH, Aisyah HA, et al. 2022. Physical, mechanical, and thermal properties and characterization of natural fiber composites reinforced poly (lactic acid): miswak (*Salvadora persica* L.) fibers. *Int J Polym Sci* 2022: 7253136. https://doi.org/10.1155/2022/7253136
4. Alkateb M, Sapuan SM, Leman Z, Ishak MR, Jawaid M. 2018. Vertex angles effects in the energy absorption of axially crushed kenaf fibre-epoxy reinforced elliptical composite cones. *Def Technol* 14(4): 327-335. https://doi.org/10.1016/j.dt.2018.01.009
5. Han X, Ding L, Tian Z, Song Y, Xiong R, et al. 2023. Potential new material for optical fiber: preparation and characterization of transparent fiber based on natural cellulosic fiber and epoxy. *Int J Biol Macromol* 224: 1236-1243. https://doi.org/10.1016/j.ijbiomac.2022.10.209
6. Campilho RDSG. 2015. Natural Fiber Composites. CRC Press, Boca Raton.
7. Sapuan SM, Razali N, Radzi AM, Ilyas RA. 2021. Roselle: Production, Processing, Products and Biocomposites. Academic Press.
8. Ramnath BV, Elanchezhian C, Nirmal PV, Kumar GP, Kumar VS, et al. 2014. Experimental investigation of mechanical behavior of jute-flax based glass fiber reinforced composite. *Fibers Polym* 15: 1251-1262. https://doi.org/10.1007/s12221-014-1251-3
9. Limba K, Kwembe K, Asumani K, Monde TK, Hassaert G, et al. 2021. Phenotypic and molecular characterization of strains *Lasiododulpodia theobromae* (pat) Griffon & Maulk, pathogen-associated with black rot cocoa pods in the Tshopo province, Kisangani region (DR Congo). *J Adv Microbiol* 21(11): 42-50. https://doi.org/10.9734/jamb/2021/v21i1130400
10. Khoshnava SM, Rostami R, Ismail M, Rahmat AR, Ogunbode BE. 2017. Woven hybrid biocomposite: mechanical properties of woven kenaf bast fibre/oil palm empty fruit bunches hybrid reinforced poly hydroxybutyrate biocomposite as non-structural building materials. *Constr Build Mater* 154: 155-166. https://doi.org/10.1016/j.conbuildmat.2017.07.189
11. Venkatraman V, Sugumar S, Sekar S, Viswanathan S. 2019. Environmental effect of CI engine using microalgae biofuel with nano-additives. *Energy Sources Part A Recovery Util Environ Effects* 41(20): 2429-2438. https://doi.org/10.1080/15567036.2018.1563250
12. Liu N, Wang H, Ma B, Xu B, Qu L, et al. 2022. Enhancing cryogenic mechanical properties of epoxy resins toughened by biscitraconimide resin. *Compos Sci Technol* 220: 109252. https://doi.org/10.1016/j.compscitech.2021.109252
13. Ubeid HS, Hama SM, Mahmoud AS. 2020. Mechanical properties, energy impact capacity and bond resistance of concrete incorporating waste glass powder. *IOP Conf Ser Mater Sci Eng* 745(1): 012111. https://doi.org/10.1088/1757-899X/745/1/012111
14. Mohammed TK, Hama SM. 2022. Mechanical properties, impact resistance and bond strength of green concrete incorporating waste glass powder and waste fine plastic aggregate. *Innov Infrastruct Solut* 7: 1-12. https://doi.org/10.1007/s41062-021-00652-4
15. Vijayan V, Kumar SA, Gautham S, Masthan MM, Piraichudan N. 2021. Design and analysis of prosthetic foot using additive manufacturing technique. *Mater Today Proc* 37: 1665-1671. https://doi.org/10.1016/j.matpr.2020.07.195