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Characterization of Mechanical Properties of Coconut Coir Fibre Reinforced PLA Composites

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Abstract

This study examines the biodegradable and fracture toughness of Polylactic Acid (PLA) composites supplemented with coir fibres at different fibre weight fractions. Sustainable composite materials are made by combining fibres from coconut coir with PLA, a biodegradable polymer sourced from renewable resources. To improve their characteristics, the fibres are treated with sodium hydroxide, and twin-screw extrusion and injection moulding are used to create the composites. According to ASTM standards, tensile, impact, and flexural strength tests show that untreated coir fibre reinforced PLA composites have higher tensile and impact strengths than pure PLA, whereas treated fibres offer marginal increases at particular weight fractions. As fibre content rises, flexural strength often falls; untreated composites outperform treated ones in this regard. These results demonstrate the potential of PLA composites reinforced with coir fibre as greener substitutes for traditional polymers, with prospective uses in structural contexts where mechanical integrity and biodegradability are essential.

Keywords: *Biodegradable, Natural Fiber, PLA*

1.0 Introduction

The development of biodegradable composite materials has drawn a ton of interest recently in the quest for ecologically harmless and maintainable materials[1]. The improvement of biodegradable composite materials has been the focal point of late examination, determined to make biologically amicable arrangements that save primary uprightness. Certain materials, such PLA composites that are loaded with coir fiber, give feasible solutions to ecological issues, especially those pertaining to single-use plastics. These composites offer a manageable substitute in various applications by utilizing normal strands like coconut coir to support PLA produced using sustainable assets like maize flour and sugarcane. Looking at fracture sturdiness is fundamental to decide their fittingness for primary applications and gives understanding into what coir fiber treatment and building up mean for load-bearing limit. Moreover, it is basic to understand how biodegradable these composites are; Concentrates on regarding this matter have zeroed in on how these materials weight diminishes over the long run to evaluate the materials environmental impact and potential for biodegradable applications[2,3]. A concentrate by Harikrishnan *et al*[4]., using the single-edge indented twist (SENB) test, cross breed composites made of jute and glass fiber were researched. The discoveries showed that compo-locales filled exclusively with the glass strands showed the most noteworthy break strength, with those containing a combination of 75% glass and

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25% jute filaments intently approaching the presentation of unadulterated glass fiber composites. These ends were sup-ported by limited component investigation (FEM). Utilizing the hand-layup technique, Nikita Agarwal and partners[5] investigated carbon fiber-supported epoxy composites. They found that composite material with half carbon strands had the best crack sturdiness, alongside exceptional hardness, flexural strength, and effect resistance. They changed the carbon fiber content from 20% to half by weight. In the meanwhile, the 40% carbon fiber composite showed astounding elastic characteristics.

Abdul Hakim Abdulla *et al.* study[6] inspected malleable and crack sturdiness of epoxy composites loaded up with coconut shell fiber. The filaments were treated with a salt saline arrangement, which expanded their rigidity. As per the review, treated fiber-built up composites had the most extreme crack sturdiness when contrasted with untreated ones. AberaBetelie[7] analyzed the way of behaving of the epoxy composites loaded up with sisal in the terms of crack sturdiness. Utilizing a hand-layup procedure and different fiber weight parts, they found that composite with a 30% fiber content had the most extreme crack sturdiness. Hulugappa and partners[8] created glass texture supported epoxy compo-site materials with fillers like silicon carbide and graphite. They identified that composite materials with 10% graphite filler displayed unrivaled flexural and tensile properties. Besides, expanded graphite filler stacking improved the composite's break strength. M. Kullayappa and co-specialists[9] built up groundnut shell and silicon carbide particles with vinylester pitch, making composite plates utilizing the hand-layup technique. This study investigated that the utilization of powdered groundnut shell treated with maleicanhydride essentially impacted the composite's properties. V. Santhnam and others[10] investigated polyester tar composite materials loaded up with banana and glass filaments. They examined that compo-site materials with banana fiber support displayed FT values like those with glass fiber support. This proposes that banana fiber might actually supplant glass fiber in specific applications. In the concentrate by PS Shivakumar Gouda and partners[11], glass-carbon fiber supported half breed polymer composites crack way of behaving was explored, assessing break sturdiness in various fiber directions.

In light of the ecological issues raised by average plastics, the article emphasizes the basic need for funding logical examination and practical alternatives, underlining the meaning of biodegradability testing with regards to composites. Due to their sustainability, and biodegradability, biodegradable materials, particularly biopolymers; are seen as sensible substitutes that can assist with resolving the issue of non-biodegradable waste development[12,13]. It is featured that there are no settled biodegradation testing supportive of cedures for these materials, which makes the making of serious areas of strength for a fundamental for affirming item guarantees and empowering clients to pursue knowledgeable choices[14]. The article additionally resolves the issues with conventional plastics that have been tormenting the climate since the 1950's, particularly in the bundling business, where they have sullied environments and caused contamination and wellbeing risks. The shift is towards exploring eco-accommodating choices like biodegradable and bio-based plastics, which deal benefits like inexhaustibility, diminished harmfulness, and availability. Despite the fact that endeavors have been made to address plastic waste through choices like burning and reusing, these strategies have restrictions[15].

The primary target of this study is to portrayal of crack sturdiness and biodegradable properties of coir filled PLA composites with variable filler weight division.

2.0 Materials and Methods

2.1 PLA Granules

Polylactic acid, similarly implied as polyactide (PLA), is biodegradable and bioactive polyester created utilizing the design blocks of lactic destructive. Various composing has written about Polylacticacid (PLA), maybe of the most ideal biodegradable polymer all through late years.

2.2 Coconut Coir Fiber

Coconut is a huge regular fiber that is for the most part open in India and Sri Lanka. This fills in as a sustaining subject matter expert. Coir is a tacky substance that can be gotten in the outside and hard within coconuts. *Cocos nucifera* is the intelligent name for *Aceraceae* coconut fiber, and it has a spot with the (*Palm*) plant family. There are two distinct natural hued collections of coconut fiber.

2.3 Sodium Hydroxide

Typical fiber is artificially treated using sodium hydroxide. Sodium hydroxide's compound name is NaOH. It is a large part of the time implied as consuming pop. The sodium hydroxide drops used to misleadingly treat the fiber. It is Na and benevolent containing areas of strength for white compound.

2.4 Production of Composites

A mindful course of action of strategy ought to be kept on making PLA compo-regions upheld with coconut coir. The isolated strands are first totally cleaned to wipe out any buildup and plant stores, and a short time later they are sun-dried to cut down their suddenness content. The fibers are then artificially treated with a sodium hydroxide reply for work on their characteristics. Then, using a twin screw extruder machine, the coconut coir strands are gotten together with Polylactic (PLA) to retry the design of the composite materials. Using an implantation framing machine (JIT 80) under oversaw conditions composite plates are fabricated[16].

2.4 Composite Material's Composition

Using the mixture shaping cycle, composite material models with changed weight paces of treated and untreated customary are made. The conformation the composite materials produced are shown in the Table 1 underneath.

3.0 Materials Characterization

3.1 Tensile Test

The test is conducted at room temperature using a measure length of 60 mm and a cross head speed of 1

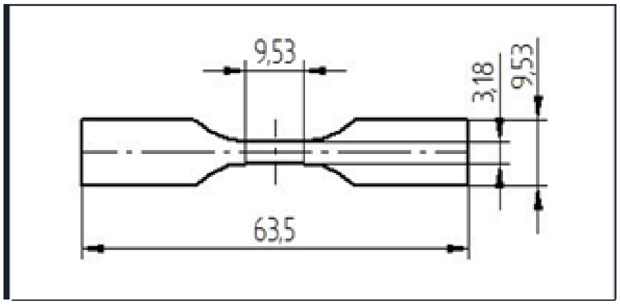

Figure 1. Tensile test specimen dimensions as per ASTM standards.

Figure 2. Tensile test set up.

Table 1. Composition of composite materials

Composite name	PLA weight %	Coir Fibre weight %	Total weight %
Pure PLA	100	00	100
U-10-C	90	10	100
U-20-C	80	20	100
U-30-C	70	30	100
T-10-C	90	10	100
T-20-C	80	20	100
T-30-C	70	30	100

mm/min. Figure 1 shows the tensile test example aspects in accordance with ASTM D-638. The example in Figure 2 shows the exploratory test setup for the elastic trial of composites.

3.2 Flexural Strength Test

To find the force required to bend under three-point loading conditions, flexural tests are carried out. The flexural test results are used to determine the project's material selection. portions or sections capable of bearing weights without bending. In compliance with ASTM D-790 standard, flexural strength tests are carried out by the UTM-Kalpak Universal Testing Machine. The test is conducted at room temperature with a span length of 75 mm and a crosshead speed of 2 mm/min. A load was applied to the test specimen at its middle using a loading nose after it had been positioned on the two parallel roller supports. In compliance with ASTM D-790, the dimensions of the flexural test specimen are displayed in Figure 3.

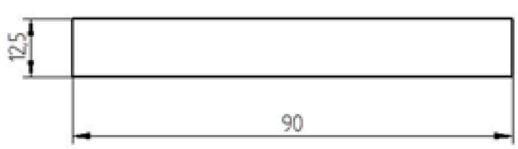

Figure 3. Flexural strength specimen.

3.3 Impact Test

A notched specimen (with the notch facing away from the point of contact) is placed within a sizable apparatus that has a known-weight pendulum in order to conduct the charpy impact test procedure. After being elevated to a predetermined height, the pendulum is let to fall. The specimen is struck and broken by the pendulum's swing as it rises to a predetermined height. The procedure is depicted in the Figure 4.

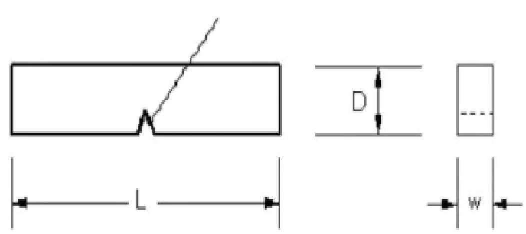

Figure 4. Impact strength specimen.

4.0 Result and Discussions

4.1 Tensile Test

The Figure 4 shows the tensile strength values for pure PLA and coir fiber reinforced PLA composites. The above graph, it is observed that for untreated 10 wt%, 20 wt% and 30 wt% fiber reinforced PLA composites the tensile strength values are higher as compared to that of pure PLA composites. Similarly, the above graph, it is observed that for treated 10 wt%, 20 wt% and 30 wt% coir fiber reinforced PLA composites also shows incremental values of tensile strength as compared to that of pure PLA.

By Figure 4 we can also derive that as compared to treated fiber specimen untreated one shows better values of tensile strength with slight increments in treated 20 wt% composites hence good load bearing capacity. By comparing untreated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows ascending pattern of tensile strength parallel to increasing weight fraction. Similarly, by comparing treated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows descending pattern for tensile strength parallel to increasing weight fraction with slight increments in 20 wt% composites.

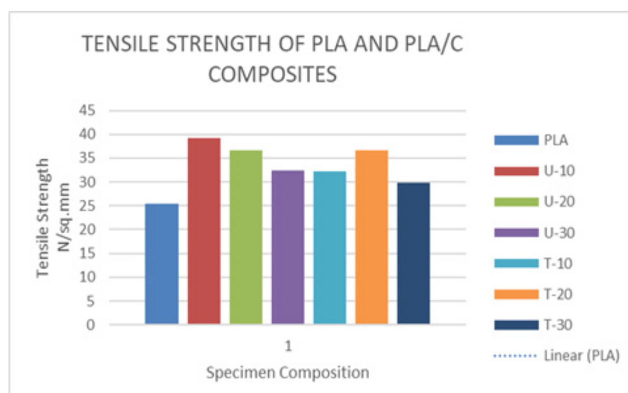

Figure 5. Tensile strength of PLA and PLA/C composites.

4.2 Impact Strength

The Figure 5 shows the impact strength values for pure PLA and coir fiber reinforced PLA composites. The above graph, it is observed that for untreated 10 wt% and 20

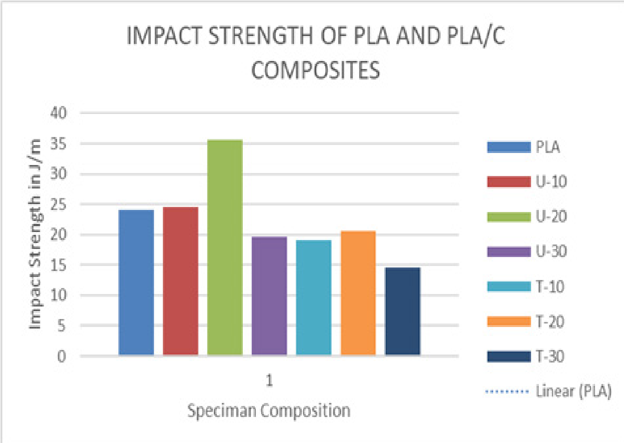

Figure 5. Impact strength of PLA and PLA/C composites..

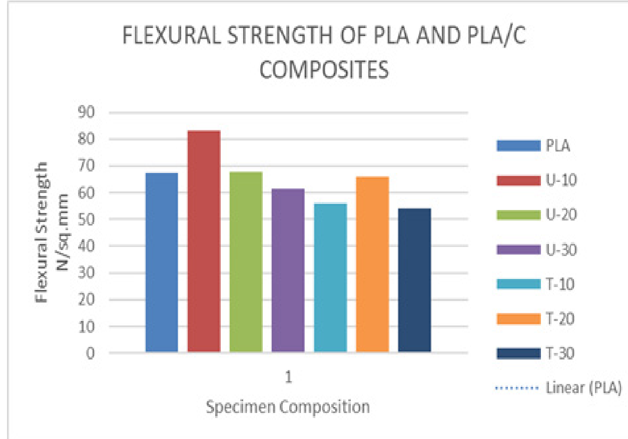

Figure 6. Flexural strength of PLA and PLA/C composites.

wt% fiber reinforced PLA composites the impact strength values are higher as compared to that of pure PLA composites. But, untreated 30 wt% coir fiber reinforced PLA composites demonstrates lesser value of impact strength as compared to that of pure PLA. Similarly, the above graph, it is observed that for treated 10 wt%, 20 wt% and 30 wt% rice straw fiber reinforced PLA composites shows decremented values of impact strength than that of pure PLA.

By Figure 5 we can also derive that as compared to treated fiber specimen untreated one shows better values of impact strength hence good load bearing capacity. By comparing untreated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows ascending pattern of impact strength parallel to increasing weight fraction with slight decrements in 30 wt% composites. Similarly, by comparing treated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows descending pattern for impact strength parallel to increasing weight fraction with slight increments in 20 wt% composites.

4.3 Flexural Strength

Figure 6 shows flexural strength for pure PLA and coir fiber reinforced PLA composites. The above graph, it is observed that flexural strength of untreated 10, 20 and 30 wt% fiber reinforced PLA composites drops as increase in weight fraction as compared to that of pure PLA. Similarly, the above graph, it is observed that for treated 10 wt%, 20 wt% and 30 wt% coir fiber reinforced PLA composites shows decrement values of flexural strength than that of pure PLA with slight increment in 20 wt% composites.

By Figure 6 we can also derive that as compared to treated fiber specimen untreated one shows better values of flexural strength hence good load bearing capacity. But, comparing untreated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows descending pattern of flexural strength parallel to increasing weight fraction. Similarly, by comparing treated 10, 20 and 30 wt% fiber reinforced PLA composites among themselves they shows descending pattern for flexural strength parallel to increasing weight fraction with slight increment in 20 wt% composites.

4.4 Discussion on Environment Impact and Biodegradable Properties of the Composite

By providing an ecologically safe substitute for synthetic fibres, the fibres from rice straw can make a substantial contribution to the sustainability of the environment when used in composite materials. An agricultural residue known as rice straw is frequently seen as waste and is normally burned, which releases greenhouse gases into the atmosphere and pollutes the air. We may minimise our dependency on non-renewable, petroleum-based products and lessen the environmental impact of waste disposal by integrating rice straw fibres into biodegradable polymers like Polylactic Acid (PLA). Because rice straw fibres come from a natural source and PLA is biodegradable, the resulting composites can break down naturally, minimising landfill waste and promoting a circular economy.

Moreover, the manufacturing of PLA composites supplemented with rice straw fibre encourages resource efficiency and gives agricultural waste a new use. These composites have better mechanical qualities, like increased impact and tensile strength, which can improve the functionality and durability of goods produced of them. We can significantly lessen our influence on the environment by substituting these sustainable composites for conventional, non-biodegradable polymers in a variety of applications, including construction materials, automobile parts, and packaging. This change lowers the carbon footprint connected to the material lifetime and promotes sustainable farming methods in addition to the conservation of natural resources.

The research highlights the potential of Polylactic Acid (PLA) composites reinforced with coir fibres as sustainable materials by exploring their biodegradable characteristics. Because PLA is made from renewable resources, it degrades naturally through microbial activity and hydrolysis into lactic acid. The natural and biodegradable coir fibres add to PLA's environmentally beneficial qualities. These fibres are added to the composites at different weight fractions, which improves some mechanical qualities while preserving the composites biodegradability. The goal of treating fibres with sodium hydroxide is to increase the adhesion between the fibre and the matrix, which may have an impact on the rate of biodegradation and mechanical performance. These composites sustainable qualities are especially encouraging for applications where the influence on the environment is a major factor. According to the experimental results, untreated PLA composites supplemented with coir fibres show greater tensile and impact strengths than pure PLA, suggesting that the addition of coir fibres improves mechanical integrity without impeding biodegradation. Nevertheless, as the amount of fibre increases, the flexural strength tends to decrease; Untreated composites perform better than treated ones. This nuanced performance suggests that although adding fibre can slightly enhance certain features, the overall mechanical profile of the composites may not always benefit from it. However, the fact that both treated and untreated fibre composites are biodegradable highlights their potential as more environmentally friendly substitutes for traditional polymers, making them appropriate for structural uses where environmental sustainability and mechanical strength are essential.

5.0 Conclusions

- Tensile strength improvement: The tensile strength of PLA composites reinforced with untreated coir fiber was found to be higher than that of pure PLA, and the strength increased as the fiber weight percentage increased. The treated fiber composites showed only modest improvements; among the treated samples, the 20 weight percent composites had the best tensile strength.
- Trends in impact strength: Untreated PLA composites with coir fiber reinforcement at 10 and 20 weight percent showed greater impact strength than pure PLA, however untreated PLA composites at 30 weight percent showed lower strength. The impact strength of treated fibre composites was consistently less than that of pure PLA.
- Flexural strength observations: As the fibre weight fraction rose, the flexural strength of untreated fiber-reinforced PLA composites decreased. In a similar vein, treated fiber.
- Composites flexural strength decreased, with a minor improvement shown in the 20 weight percent composites.
- Comparing treated and untreated fibres: In all tests, untreated fibre composites performed better than treated fibre composites in terms of tensile, impact, and flexural strength, suggesting that untreated fibres have a higher capacity to support loads.
- Ideal fibre weight fraction: In tensile and flexural strength tests, treated fibre composites with a 20weight percent fibre content consistently performed better, indicating the ideal compromise between fibre content and composite strength. Biodegradability consideration: The study underlined the necessity of standardized biodegradation testing procedures and stressed the significance of creating biodegradable composites to address environmental issues related to conventional plastics.

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