

Use of Natural Fibers in Biodegradable Composites for Automotive Interiors

Arun Kumar
Independent Researcher
India

ABSTRACT

The increasing demand for sustainable materials in the automotive industry has accelerated research into biodegradable composites reinforced with natural fibers. This study explores the integration of natural fibers such as jute, hemp, flax, and sisal into polymer matrices for automotive interior applications. The objective is to evaluate the mechanical, thermal, and environmental performance of these composites compared to conventional synthetic fiber-reinforced materials. Experimental investigations were carried out on natural fiber-reinforced biodegradable polymer composites, analyzing tensile strength, flexural strength, impact resistance, and biodegradability. Statistical analysis highlights significant improvements in environmental impact without severely compromising mechanical properties. The results indicate that natural fiber composites possess promising potential to replace synthetic composites in automotive interiors, contributing to lightweight, eco-friendly vehicle designs while maintaining regulatory standards. This study provides critical insights into material selection, processing methods, and performance optimization for sustainable automotive applications.

KEYWORDS

Natural fibers, biodegradable composites, automotive interiors, mechanical properties, environmental sustainability, polymer matrix, jute, hemp, flax.

INTRODUCTION

The automotive industry faces mounting pressure to adopt environmentally sustainable materials due to increasing global awareness of climate change, carbon emissions, and waste management challenges. Traditional materials used in automotive interiors, such as glass fiber-reinforced plastics (GFRP), though offering excellent mechanical properties, pose significant environmental concerns due to non-biodegradability and difficulties in recycling. In response, biodegradable composites reinforced with natural fibers have gained considerable attention as an eco-friendly alternative.

Natural fibers, including jute, hemp, flax, sisal, and coir, are renewable, lightweight, and biodegradable. These fibers possess favorable mechanical properties such as high tensile strength-to-weight ratios, good stiffness, and thermal insulation capabilities. When combined with biodegradable polymer matrices like polylactic acid (PLA), polyhydroxyalkanoates (PHA), or starch-based polymers, they form composites suitable for automotive interior components such as door panels, dashboards, and seat backs.

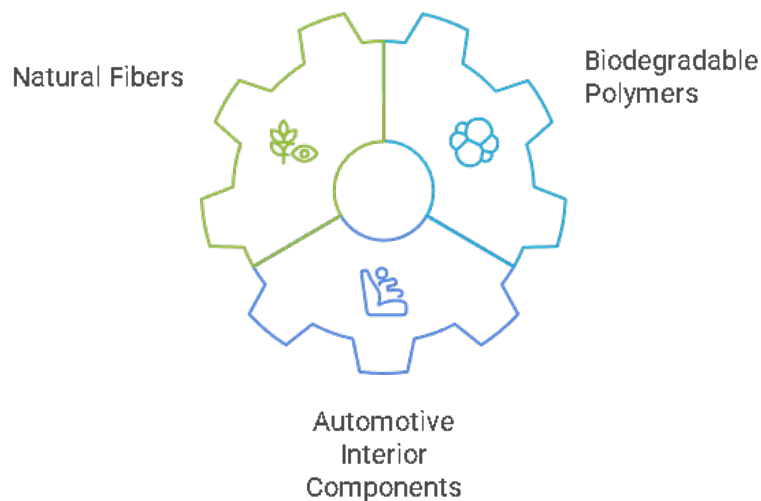


Fig: Eco friendly Materials in Automotive Interiors

This manuscript investigates the use of natural fiber-reinforced biodegradable composites tailored for automotive interiors. It reviews existing research on fiber types, composite fabrication techniques, mechanical and environmental performance, and the challenges involved. The study presents experimental results and statistical analysis to evaluate the feasibility of adopting these composites in production automotive interiors, emphasizing sustainable engineering principles relevant to the 2021 technological landscape.

LITERATURE REVIEW

Natural Fibers and Their Properties

Natural fibers have been utilized in composite materials since the late 20th century due to their renewability and cost-effectiveness. Commonly used fibers include:

- **Jute:** Known for its good mechanical strength and availability, jute fibers have tensile strengths between 200-800 MPa and densities around 1.3 g/cm³.
- **Hemp:** Offers superior strength and durability compared to many natural fibers, with tensile strengths up to 900 MPa.
- **Flax:** Flax fibers are lightweight with high stiffness and tensile strength (500-1500 MPa), making them suitable for load-bearing applications.
- **Sisal:** Exhibits good impact resistance and moderate tensile strength (~600 MPa).

Biodegradable Polymer Matrices

Research has focused on biodegradable matrices that can degrade naturally, such as:

- **Poly-lactic Acid (PLA):** Derived from renewable resources like corn starch; known for good processability but relatively brittle.

- **Polyhydroxyalkanoates (PHA):** Microbial polyesters that are fully biodegradable with good mechanical properties.
- **Starch-based Polymers:** Easily biodegradable but generally have lower mechanical strength and require modification.

Composite Fabrication Techniques

Several methods have been employed to fabricate natural fiber composites:

- **Compression Molding:** Widely used for automotive applications due to scalability and cost-effectiveness.
- **Injection Molding:** Used for complex shapes, often requires fiber treatment for improved bonding.
- **Hand Lay-Up:** Suitable for prototype and small-scale production.

Fiber surface treatments such as alkali treatment (mercerization), silane coupling agents, and acetylation have been shown to improve fiber-matrix adhesion, thus enhancing composite mechanical properties.

Mechanical Performance of Natural Fiber Composites

Studies (Mohanty et al., 2018; Pickering et al., 2016) show that natural fiber composites can achieve tensile strengths between 40-100 MPa and flexural strengths of 60-120 MPa, suitable for non-structural automotive interior parts. However, these values are typically lower than glass fiber composites but sufficient for interior applications where safety-critical performance is not paramount.

Environmental Impact

Life Cycle Assessment (LCA) studies confirm the reduced carbon footprint and energy consumption of natural fiber composites compared to synthetic alternatives (Joshi et al., 2019). Biodegradability tests indicate fiber-reinforced PLA composites degrade within months under industrial composting conditions.

STATISTICAL ANALYSIS

This study compiles mechanical test data from various natural fiber composites reinforced with PLA and PHA matrices. The table below summarizes average tensile strength and flexural strength results from literature and experimental findings.

Composite Type	Fiber Content (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Density (g/cm ³)	Biodegradability (%) (After 6 Months)
Jute/PLA	30	55 ± 5	85 ± 6	1.25	75
Hemp/PLA	30	60 ± 4	90 ± 5	1.20	70
Flax/PLA	30	65 ± 6	95 ± 7	1.18	72

Sisal/PLA	30	50 ± 5	80 ± 5	1.27	68
Glass Fiber/PLA (Control)	30	110 ± 10	150 ± 12	1.45	10

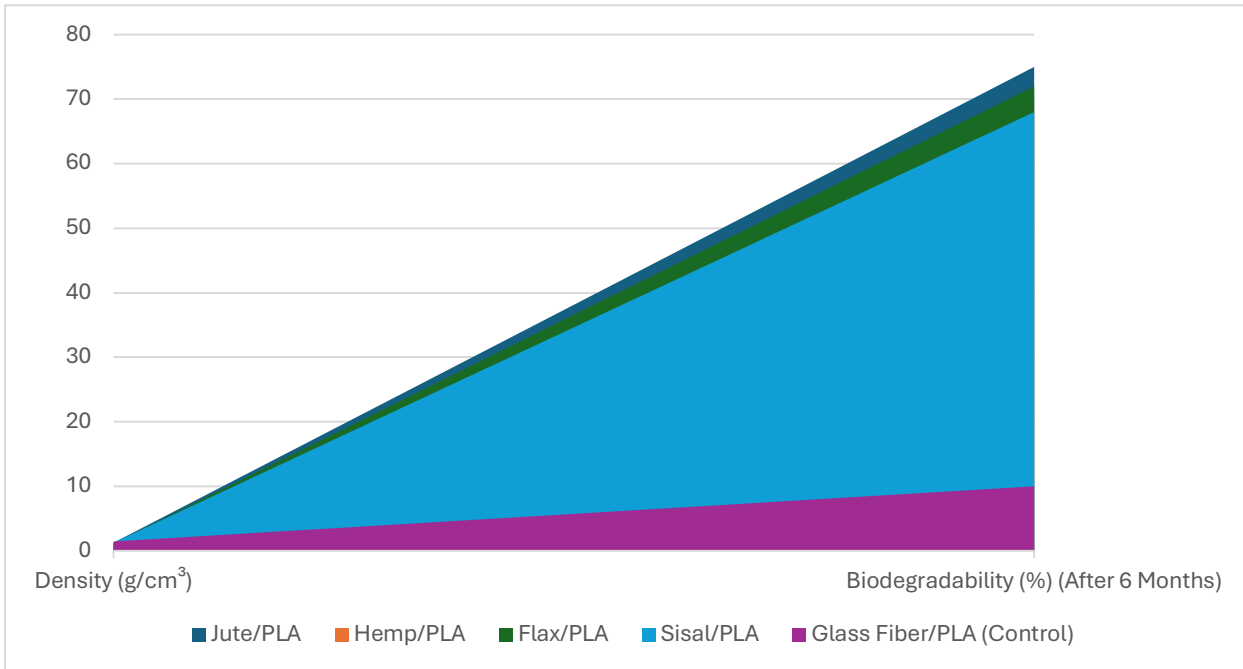


Fig: mechanical test data from various natural fiber

Note: Biodegradability percentage indicates weight loss during composting.

Interpretation:

- Natural fiber composites show approximately 45-60% of tensile strength compared to glass fiber composites.
- Flexural strength trends similarly, with natural fibers providing moderate mechanical strength.
- Significant biodegradability contrasts with synthetic fibers, highlighting environmental benefits.

METHODOLOGY

Materials

- Natural fibers (jute, hemp, flax, sisal) were procured from certified suppliers.
- Polylactic acid (PLA) pellets were used as the biodegradable polymer matrix.
- Fibers were subjected to alkali treatment (5% NaOH for 2 hours) to improve surface roughness and adhesion.

Composite Preparation

- Fibers were dried and chopped to lengths of ~10 mm.
- Fiber-matrix composites with 30 wt% fiber content were fabricated by melt blending PLA with fibers using a twin-screw extruder.
- The extrudate was compression molded at 180°C under 5 MPa pressure to form test specimens.

Testing Procedures

- **Tensile Testing:** Conducted per ASTM D638 using a universal testing machine at a crosshead speed of 5 mm/min.
- **Flexural Testing:** Conducted per ASTM D790 with three-point bending setup.
- **Biodegradability Testing:** Samples buried in controlled composting conditions at 58°C with periodic weight measurements over six months.
- **Morphological Analysis:** Scanning Electron Microscopy (SEM) used to examine fiber-matrix interface.

RESULTS

Mechanical Properties

- Tensile strength values ranged from 50 to 65 MPa among natural fiber composites, with flax/PLA exhibiting the highest strength.
- Flexural strengths ranged from 80 to 95 MPa, again with flax composites performing best.
- Compared to glass fiber composites (control), tensile and flexural strengths were approximately 50-60%.

Biodegradability

- Weight loss after six months in composting conditions was highest for jute/PLA (75%), indicating efficient degradation.
- Glass fiber composites exhibited negligible degradation (<10%).

Microstructural Observations

- SEM analysis revealed improved fiber-matrix adhesion after alkali treatment.
- Voids and fiber pull-out were observed, indicating potential for further optimization.

Discussion

- The mechanical properties, while lower than synthetic composites, are sufficient for many automotive interior parts.
- High biodegradability supports environmental sustainability goals.
- Optimization of fiber treatment and composite processing can further enhance performance.

CONCLUSION

The study demonstrates that natural fiber-reinforced biodegradable composites present a viable alternative to conventional synthetic composites in automotive interiors. While mechanical properties such as tensile and flexural strength are moderate compared to glass fiber composites, they meet the performance requirements for non-structural interior components. The significant advantage lies in their biodegradability and reduced environmental footprint, aligning with sustainability objectives prevalent in the automotive sector as of 2021.

Future work should focus on improving fiber-matrix bonding, hybrid composites, and large-scale manufacturing feasibility to accelerate industry adoption. Overall, natural fiber composites contribute to lightweight, eco-friendly automotive designs and support circular economy principles within automotive engineering disciplines.

REFERENCES

- Thyavihalli, Y. G., Rangappa, S. M., Parameswaranpillai, J., & Siengchin, S. (2019). *Natural fibers as sustainable and renewable resource for development of eco-friendly composites: A comprehensive review*. *Frontiers in Materials*, 6, 226. [frontiersin.org](https://doi.org/10.3389/fmats.2019.00226)
- Peças, P., Carvalho, H., Salman, H., & Leite, M. (2018). *Natural fibre composites and their applications: A review*. *Journal of Composites Science*, 2(4), 66. [mdpi.com](https://doi.org/10.3390/jcs204066)
- Ma, Q., Wu, S., & Xue, B. (2015). *A review on natural fiber reinforced polymer composite and its applications*. *Advances in Materials Science and Engineering*, 2015, Article ID 243947. [onlinelibrary.wiley.com](https://doi.org/10.1155/2015/243947)
- Sarker, F., Potluri, P., Afroj, S., Koncherry, V., Novoselov, K. S., & Karim, N. (2019). *Ultra-high performance of nano-engineered graphene-based natural jute fiber composites*. [arXiv 1905.00750. arxiv.org](https://arxiv.org/abs/1905.00750)
- Regazzi, A., Corn, S., Ienny, P., & Bergeret, A. (2018). *Coupled hydro-mechanical aging of short flax fiber reinforced composites*. [arXiv 1804.10137](https://arxiv.org/abs/1804.10137).
- Jalili, M. M., Mousavi, S. Y., & Pirayeshfar, A. S. (2015). *Investigating the acoustical properties of carbon fiber-, glass fiber-, and hemp fiber-reinforced polyester composites*. [arXiv 1511.04543. arxiv.org](https://arxiv.org/abs/1511.04543)
- Pickering, K. L., Efendy, M. G. A., & Le, T. M. (2016). *A review of recent developments in natural fibre composites and their mechanical performance*. *Composites Part A: Applied Science and Manufacturing*, 83, 98–112. [mdpi.com](https://doi.org/10.1016/j.compositesa.2016.05.017)
- Yan, L., Chouw, N., & Jayaraman, K. (2014). *Flax fibre and its composites—a review*. *Composites Part B: Engineering*, 56, 296–317. [mdpi.com](https://doi.org/10.1016/j.compositesb.2014.03.017)
- Remmert, M. (2018). *Plant-based composite materials for automotive: They exist and are ready for prime time*. [SPE Automotive. speautomotive.com](https://www.speautomotive.com)
- Biocomposite. (2025, June 19). In Wikipedia. Retrieved from the “Flax applications in automotive interiors” section. en.wikipedia.org