STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Issue 6, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc/

Review JoPC

Comparative Analysis of Tensile Properties of Virgin and Rice Husk-Reinforced PLA and ABS Filaments

R. Sudarshan[1*], P.V.R Girish Kumar[2], V. Siva Prasad[3]

Abstract

This study focuses on evaluating the tensile behavior of polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) filaments reinforced with rice husk ash (RHA) particles, in comparison with their respective virgin counterparts. The incorporation of RHA, an abundant agricultural waste by-product, was considered with the objective of developing eco-friendly composites suitable for additive manufacturing applications. Tensile testing was carried out to assess the influence of the reinforcement on the mechanical performance of the materials. The results demonstrated that the addition of rice husk ash generally led to a reduction in tensile strength for both PLA and ABS composites when compared to their neat forms. This decrease can be attributed to the weak interfacial bonding between the polymer matrix and inorganic particles, which often acts as a stress concentrator during loading. However, a notable finding was observed in the case of PLA-based composites, where the elongation at break showed an improvement with RHA reinforcement. This suggests that while the composites may have slightly lower load-bearing capacity, they exhibit enhanced ductility and flexibility, making them more suitable for applications where toughness is prioritized over high strength. The improved elongation also indicates a potential benefit of stress redistribution provided by the ash particles, thereby delaying premature failure. These findings highlight the potential of utilizing rice husk ash as a sustainable filler for thermoplastic filaments in 3D printing, promoting value-added applications of agricultural waste. Overall, the study supports the feasibility of designing greener composite materials that balance mechanical performance with environmental responsibility.

Keywords: Polylactic acid (PLA); Acrylonitrile butadiene styrene (ABS); Rice husk ash (RHA); Tensile properties; Additive manufacturing; 3D printing; Polymer composites; Mechanical behavior; Agricultural waste utilization; Sustainable materials.

***Author for Correspondence**
R. Sudarshan
E-mail: rsudarshan.me@gcet.edu.in

[1]Associate Professor, Department of Mechanical Engineering, Geethanjali College of Engineering and Technology, Cheeryal (V), Keesara (M), Medchal (D), Telangana, India.
[2]Senior Assistant Professor, Department of Mechanical Engineering, Geethanjali College of Engineering and Technology, Cheeryal (V), Keesara (M), Medchal (D), Telangana, India.
[3]Assistant Professor, Department of Mechanical Engineering, PACE Institute of Technology and Sciences, Ongole, Andhra Pradesh, India.

Received Date: September 25, 2025
Accepted Date: October 09, 2025
Published Date: November 11, 2025

Citation: R. Sudarshan, P.V.R Girish Kumar, V. Siva Prasad. Comparative Analysis of Tensile Properties of Virgin and Rice Husk-Reinforced PLA and ABS Filaments. Journal of Polymer & Composites. 2025; 13(6): 224–229p.

INTRODUCTION

The widespread adoption of polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) in fused deposition modeling (FDM) can be attributed to their favorable processing characteristics and mechanical performance. PLA, a biodegradable thermoplastic derived from renewable resources such as corn starch or sugarcane, is valued for its stiffness, ease of printing, and environmentally friendly nature. However, its inherent brittleness and low thermal resistance limit its suitability for demanding applications. ABS, in contrast, is a petroleum-based thermoplastic known for toughness, ductility, and impact resistance, making it widely used in automotive, consumer, and industrial products. Despite its superior toughness, ABS suffer from challenges such as warping during printing and the emission of volatile fumes, which require controlled conditions.

Growing environmental concerns and the need to reduce plastic waste have motivated researchers to explore sustainable alternatives through bio-filling and reinforcement strategies. Rice husk, a by-product of rice milling, represents an abundant and low-cost agricultural waste material with significant potential for use in polymer composites. Rich in cellulose, lignin, and silica, rice husk and its ash offer improved thermal resistance, rigidity, and biodegradability. When incorporated into thermoplastics, rice husk ash not only adds value to agricultural waste but also enhances the sustainability profile of 3D printing materials. Nevertheless, due to its hydrophilic nature, rice husk ash often requires pre-treatment or surface modification to ensure compatibility with hydrophobic polymer matrices such as PLA and ABS [1].

This study focuses on the development and evaluation of rice husk ash-reinforced PLA and ABS filaments. Composite filaments were prepared through the blending of thermoplastic granules with pre-treated rice husk ash powder, followed by extrusion and filament fabrication. The tensile properties of the composites were investigated in comparison with their virgin counterparts using ASTM D638 standard specimens produced by FDM. The findings provide insights into the mechanical behavior of rice husk ash-reinforced composites, highlighting their potential as eco-friendly alternatives in additive manufacturing [4].

BACKGROUND ON MATERIALS

Polylactic acid (PLA) is a biodegradable thermoplastic polymer synthesized from renewable agricultural resources such as corn starch, sugarcane, or other biomass. It has emerged as one of the most widely used materials in fused deposition modeling (FDM) owing to its ease of processing, dimensional stability, and environmentally friendly nature. PLA is valued for its relatively high stiffness and strength, which make it suitable for producing rigid components. Typically, PLA demonstrates a tensile strength in the range of 45–65 MPa, an elongation at break of 1.5–10%, and a Young’s modulus of 2.7–3.6 GPa. Despite these advantages, PLA has limitations such as inherent brittleness, low thermal resistance, and poor impact toughness, which restrict its applications in high-stress, load-bearing, or elevated-temperature environments [2,9].

Acrylonitrile butadiene styrene (ABS), in contrast, is a petroleum-derived thermoplastic known for its superior toughness, ductility, and impact resistance. It is extensively utilized in the automotive, consumer goods, and industrial sectors due to its durability and mechanical reliability. ABS exhibits a tensile strength of 30–50 MPa and an elongation at break in the range of 10–50%, offering greater deformability compared to PLA. However, ABS present challenges during FDM printing, such as warping and shrinkage, which necessitate careful process control, including the use of heated beds and enclosed chambers. Moreover, ABS processing releases volatile fumes, requiring adequate ventilation and safety measures during printing operations [11,12].

Recent studies have focused on developing eco-friendly composites using natural fibers and agricultural waste. Grewia monticola fibers show good strength and bonding properties for bio composites [21], while pineapple fibers improve stiffness and biodegradability in polymers [22]. Microcrystalline cellulose made from orange peel waste has also been found suitable for sustainable composites [23]. Research on drilling and machining shows that process parameters affect the strength of natural fiber composites [24]. In addition, machine learning is being used to predict and optimize composite properties for better performance [25]. Complementing these studies, examined how manufacturing parameters affect the mechanical properties of 3D printed carbon fiber-reinforced PLA parts, showing a clear link between print settings and overall part performance [26-28].

Rice husk, an abundant agricultural by-product of rice milling, has gained attention as a sustainable reinforcement material in polymer composites. Composed primarily of cellulose, lignin, and silica,

Figure 1. (a) PLA Granules and rice husk ash (b) ABS Granules and rice husk ash.

Figure 2. Filament extruder machine.

rice husk is lightweight, biodegradable, and readily available at low cost. The high silica content within rice husk and its ash enhances thermal resistance, rigidity, and dimensional stability when incorporated into thermoplastics. However, due to the hydrophilic nature of rice husk particles, surface modification or chemical treatment is generally required to improve interfacial bonding with hydrophobic polymers such as PLA and ABS [8,13].

In this study, commercially available PLA and ABS filaments were compared with their rice husk ash-reinforced counterparts to investigate the effect of natural filler addition on mechanical properties. The composite filaments were produced by blending thermoplastic granules with pre-treated rice husk ash powder, followed by extrusion and filament fabrication, as illustrated in Figure 1(a) and (b). Standard tensile specimens were prepared using the fused deposition modeling process in accordance with ASTM D638. Mechanical testing was carried out using a universal testing machine (UTM) under controlled environmental conditions of 23 °C and 50% relative humidity. This systematic approach provides insights into the potential of rice husk ash as an eco-friendly reinforcement in thermoplastic composites, promoting sustainability in additive manufacturing [23].

FILAMENT EXTRUSION PROCESS

The filament extrusion process is a critical step in preparing thermoplastic feedstock for Fused Deposition Modeling (FDM), a leading RP technique as shown in Figure 2. The process involves converting raw thermoplastic pellets or recycled plastic materials into filament spools, which are then used in 3D printing.

Material Preparation

Raw material (virgin or recycled thermoplastics such as PLA, ABS, PETG) is first dried to remove moisture, as hydrolytic degradation during melting can deteriorate mechanical and thermal properties [14].

Melting and Homogenization

The dried material is fed into a single screw extruder as shown in, where it is melted at temperatures typically ranging from 160–200°C for PLA. The screw mechanism ensures shear mixing, pressure build-up, and homogenization of the polymer melt [15,16].

Die Extrusion

The molten polymer is pushed through a circular die of desired diameter 1.75mm. The die geometry and cooling system influence dimensional stability, filament roundness, and consistency [17].

Cooling and Calibration

The extruded filament is cooled immediately using air or water baths. Improper cooling can lead to warping, ovality, or surface defects. A laser micrometre is often employed for in-line diameter monitoring [18].

Pulling and Spooling

The filament is pulled at a constant speed using tractor rollers to maintain tension and uniform diameter as shown in Figure 3 before being spooled onto reels. Variations in puller speed can lead to inconsistent filament diameter, affecting print quality [19].

High-quality extruded filament is essential for dimensional accuracy, layer adhesion, and mechanical strength in RP-fabricated parts. Recycled filament requires compounding with additives or virgin polymer to maintain printability and mechanical integrity [20]. Later filament test under UTM as shown in Figure 4(a) and (b).

RESULTS AND DISCUSSION

From Table 1, PLA composite got 31.74 MPa and ABS composite 28.64MPa. Virgin PLA exhibits high tensile strength (45–65 MPa) but low ductility (1.5–10% elongation at break), reflecting its brittle nature (2, 9). In contrast, ABS show lower tensile strength (30–50 MPa) but higher ductility (10–50%), making it more suitable for load-bearing and impact-prone applications [11, 12].

PLA reinforced with rice husk ash demonstrates a decreased tensile strength of 31.71 MPa but significantly improved elongation of 13.74%. The enhancement in ductility can be attributed to the filler-matrix interaction, which introduces energy-dissipating mechanisms such as micro void formation and crack deflection [5,10]. ABS rice husk ash composites also show a reduced tensile strength of 28.64 MPa and moderate elongation (8.74%), suggesting that the filler provides limited flexibility gains and might introduce microstructural stress concentrations [3,6].

Figure 3. Filament extruding through nozzle.

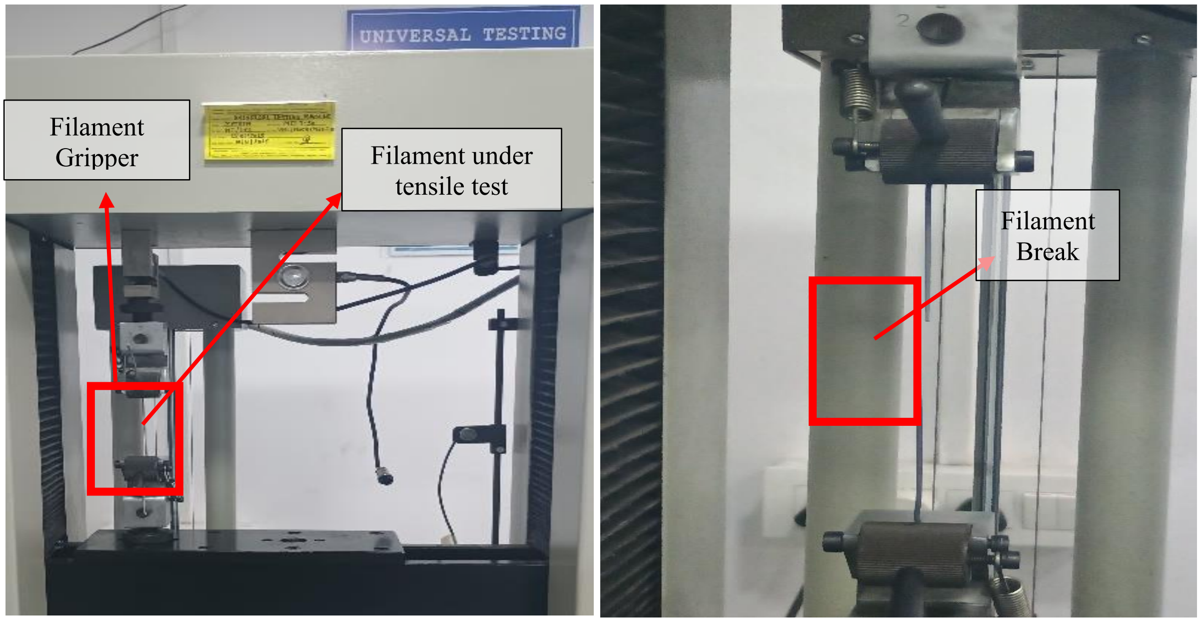

Figure 4. Filament (a) before testing (b) after testing.

Table 1. Tensile strength and elongation at break for neat and rice husk ash-reinforced PLA and ABS filaments.

S.N.	Filament material	Tensile strength (MPa)	Elongation at break (%)
1	PLA Rice Husk ash	31.71	13.74
2	ABS Rice Husk ash	28.64	8.74
3	Virgin PLA	45–65	1.5–10
4	Virgin ABS	30–50	10–50

These results highlight the trade-off between strength and ductility when integrating natural fillers. While virgin polymers offer higher mechanical strength, the bio-filled composites may provide improved flexibility and environmental benefits suitable for specific low-load applications.

CONCLUSION

Rice husk ash reinforcement reduces tensile strength but improves ductility in PLA, while ABS composites show a modest decline in both parameters. These changes suggest the suitability of PLA-rice husk ash composites for non-structural, sustainable 3D printing applications.

FUNDING

This research was funded by the Geethanjali College of Engineering and Technology, Cheeryal (V), Keesara(M), Medchal - Malkajgiri (D), Telangana, India under the Seed Money Grant.

REFERENCES

1. Bhatnagar, A., & Tiwari, N. (2022). Use of agricultural waste in polymer composites: Mechanical and environmental perspectives. Journal of Thermoplastic Composite Materials, 35(7), 865–886.
2. Garlotta, D. (2001). A literature review of poly(lactic acid). Journal of Polymers and the Environment, 9(2), 63–84.
3. Girdis, K., Othman, R., et al. (2022). Characterization of rice husk biocomposites for 3D printing applications. Polymers, 14(3), 567.
4. IEMAI 3D. (2021). PLA Technical Data Sheet. Retrieved from https://www.iemai3d.com
5. Kumar, S., Reddy, T., & Jha, K. K. (2021). Mechanical properties of rice husk filled PLA composite filaments for FDM applications. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2021.01.193

6. Mazzanti, V., Malagutti, L., & Mollica, F. (2019). FDM 3D printing of polymers containing natural fillers: A review of their mechanical properties. Polymers, 11(7), 1094.
7. MatterHackers. (n.d.). ABS Filament Properties. Retrieved from https://www.matterhackers.com
8. Nascimento, D. M. L., Botelho, C., Março, P. H., & others. (2016). Production of cellulose nanocrystals from rice husk. Industrial Crops and Products, 93, 48–57.
9. Prusa Research. (2021). Prusament PLA Technical Data Sheet. Retrieved from https://prusament.com
10. Singh, S., & Ramakrishna, S. (2017). Sustainable composite filaments for fused deposition modelling—A review. RSC Advances, 7, 24795–24803.
11. Torres, J., Cole, M., Owji, A., DeMastry, Z., & Gordon, A. P. (2015). Anisotropic mechanical properties of fused deposition modeling parts: A design of experiments study. Rapid Prototyping Journal, 21(4), 362–376.
12. Ultimaker. (2020). ABS Technical Data Sheet. Retrieved from https://ultimaker.com
13. Yang, T. L., Lee, S. H., Kim, N. H., & others. (2015). Thermal degradation kinetics of rice husk flour and rice husk flour/PLA composites. Thermochimica Acta, 613, 58–65.
14. Anderson I. Polylactides—PLA. In: Plastics Data Handbook. Oxford: Oxford University Press; 2004. p. 325–36.
15. Zander NE, Gillan M, Sweetser D. Recycled polyethylene terephthalate as a new FDM feedstock material. Addit Manuf. 2018;21:174–82.
16. Mohamed OA, Masood SH, Bhowmik JL. Optimization of fused deposition modeling process parameters: a review of current research and future prospects. Adv Manuf. 2015;3(1):42–53.
17. Spoerk M, Holzer C, Gonzalez-Gutierrez J. Material extrusion-based additive manufacturing of polypropylene: a review on process-structure–property relationships. Polymers (Basel). 2020;12(7):1529.
18. LeBlanc J, Wu W, Menon R. Design and characterization of an open-source filament extruder for 3D printing. J Open Hardware. 2020;4(1):2.
19. Torrado Perez AR, Roberson DA, Wicker RB. Fracture surface analysis of 3D-printed tensile specimens of novel ABS-based materials. J Fail Anal Prev. 2014;14(3):343–53.
20. Fafenrot S, Grimmelsmann N, Wortmann M, Ehrmann A. Three-dimensional (3D) printing of polymer–metal hybrid materials by fused deposition modeling. Materials (Basel). 2017;10(10):1199.
21. Almeshaal, M., Palanisamy, S., Murugesan, T. M., Palaniappan, M., & Santulli, C. (2022). Physico-chemical characterization of Grewia Monticola Sond (GMS) fibers for prospective application in biocomposites. Journal of Natural Fibers, 19(17), 15276-15290.
22. Santulli, C., Palanisamy, S., & Kalimuthu, M. (2022). Pineapple fibers, their composites and applications. In Plant Fibers, their Composites, and Applications (pp. 323-346). Woodhead Publishing.
23. Palaniappan, M., Palanisamy, S., Khan, R., H. Alrasheedi, N., Tadepalli, S., Murugesan, T. M., & Santulli, C. (2024). Synthesis and suitability characterization of microcrystalline cellulose from Citrus x sinensis sweet orange peel fruit waste-based biomass for polymer composite applications. Journal of Polymer Research, 31(4), 105.
24. Goutham, E. R. S., Hussain, S. S., Muthukumar, C., Krishnasamy, S., Kumar, T. S. M., Santulli, C., ... & Jesuarockiam, N. (2023). Drilling parameters and post-drilling residual tensile properties of natural-fiber-reinforced composites: A review. Journal of Composites Science, 7(4), 136.
25. Karuppusamy, M., Thirumalaisamy, R., Palanisamy, S., Nagamalai, S., Massoud, E. E. S., & Ayrilmis, N. (2025). A review of machine learning applications in polymer composites: advancements, challenges, and future prospects. Journal of Materials Chemistry A.
26. Pvr, G. K., & Devi, K. D. (2025). Influence of ManufacturIng ParaMeters on the ProPertIes of 3D PrInteD PolylactIc acID carbon fIber coMPonents. Archives of Metallurgy and Materials, 97-104.
27. Kiran A, Kumar PG, Sastry N, Sudarshan R, Babu KS. Investigation on parameters used for fused deposition modeling and inspection of the printed parts. AIP Conf Proc. 2025 Sep;3342(1):020018.
28. Pvr GK, Devi KD. Influence of manufacturing parameters on the properties of 3D printed polylactic acid carbon fiber components. Arch Metall Mater. 2025;97–104.

