Research Article

Journal of Environmental Nanotechnology

Investigation of Snake Grass/Casuarina/Cork Filler Reinforced Bio Polymer Hybrid Composite

C. Parthasarathy[1*], K. Mayandi[1], S. Karthikeyan[1] and S. Senthilrajan[2]
[1]Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Krishnankoil, TN, India
[2]Department of Robotics and Automation Engineering, Rajalakshmi Engineering College, Chennai, TN, India
Received: 25.06.2024 Accepted: 15.08.2024 Published: 30.09.2024
*visitcps@gmail.com

ABSTRACT

The environment is continuously affected for various reasons, prompting researchers to seek solutions from different angles. This study explores the potential of mixing polymers with and without agricultural/bio fillers such as Snake Grass / Casuarina / Cork in various volume proportions, analyzing their mechanical properties. The hybrid materials are made with the polymers and bio fillers without any change in the quality of existing polymer products, the quality of hybrid materials is assured by the results of impact, flexural, and tensile tests. Finally, the biodegradability tests revealed weight loss in a soil burial test when bio-filler was added to the polymer composite.

Keywords: Snake grass; Cork; Casuarina; Bio fillers; Alternative materials.

1. INTRODUCTION

Bio-based plastic goods and biodegradable polymers, crafted from renewable resources, hold promise for creating environmentally friendly and sustainable alternatives that can effectively compete in today's market (Mohanty *et al.* 2002; Satyanarayana *et al.* 2009; Fernandes *et al.* 2013). In this study, specimens were created using the hand lay-up method, epoxy with varying proportions of Casuarina flora. Mechanical testing, including impact, flexural, and tensile tests, was performed to epoxy-based Casuarina composite material. This composite material was then used to manufacture an environmentally friendly gear. It's maybe used for small and medium applications (Parthasarathy *et al.* 2022). The mechanical properties of composites made from natural fibers are affected by parameters such as fiber type, orientation, maturity, chemical treatment, fiber volume / weight percentage, alignment, distribution, processing procedures, and additives utilized (Arrakhiz *et al.* 2013; Pickering *et al.* 2016; Dixit *et al.* 2017). This research examines the mechanical properties of epoxy composites reinforced with Snake/Mudar Grass fibers. The composite is further enhanced with the addition of nano-silica filler. It highlights the enhanced performance resulting from the addition of nano-silica, making it suitable for structural applications. (Jenish et. al. 2022). The composite containing 20-25% natural filler had the best mechanical properties, demonstrating an optimal balance between filler concentration and composite performance (Chandramohan *et al.* 2023; Parthasarathy *et al.* 2024). Recent research into biodegradable and environmentally friendly fillers of composites from polymers has gained traction due to globally environmental movements and recycling challenges (Jagadeesh *et al.* 2013; Shah *et al.* 2014; Prabhakar *et al.* 2015). A major concern with using natural fibers in composites has their tendency to absorb moisture, which can negatively impact their physical and mechanical qualities. The type of fiber and matrix, production method, and relative humidity all influence the amount of moisture absorbed (Dhakal *et al.* 2007). This study developed polyester composites reinforced with Cyperus pangorei fiber (CPF) using compression molding, examining the impact of fiber content and length on mechanical properties. The optimal composite, with 40 mm fiber length and 40 wt% fiber content, showed significant increases in tensile, flexural, and impact strengths, making it a viable alternative for structural applications in construction and automotive industries (Kalimuthu *et al.* 2019). In this study, specimens were fabricated using the hand lay-up method, incorporating epoxy with varying proportions of cork powder. Mechanical testing, including impact, flexural, and tensile tests, was conducted on the epoxy-based Casuarina composite material. The optimum values for these properties were determined (Parthasarathy *et al.* 2024). This study examined the impact of carbon/silica hybrid nanofillers on the wear resistance and hardness of glass fiber reinforced epoxy composites. Results showed significant improvements in both properties, with time being the most influential parameter on wear, followed by nanoparticle content (Megahed *et al.* 2017). This research evaluated the effect of fiber length and loading on the flexural and dynamic mechanical properties of jute/polyester composites. The 5 mm length, 25 wt% fiber composites showed the highest flexural strength, while the 15 mm length, 25 wt% fiber composite demonstrated better fiber-matrix adhesion and higher storage modulus (Senthilrajan *et al.* 2022). This study evaluated Al-Hybrid fiber metal laminates (HFMLs) reinforced with basalt, hemp, and bamboo fibers, with the BBbAlBbB configuration showing superior mechanical properties. The findings highlight their potential for eco-friendly, high-performance applications in micro-mobility vehicle panels (Padmanabhan *et al.* 2024).

This research examines the effects of incorporating bio fillers into a matrix made from epoxy as a fiber material, with the goal of determining how it influence the mechanical properties and biodegradability of epoxy composites. While previous studies frequently utilized both bio and non-bio fibers/fillers in the epoxy composites, this research stands out by focusing on optimizing the formulation of composites using epoxy and bio fillers at different volume percentages. Bio composites provide an eco-friendly alternative to traditional plastics by utilizing renewable resources such as plant fibers. These materials lead to a more environmentally friendly future by reducing emission of carbon and reliance on fossil fuels. Furthermore, bio composites typically biodegrade more readily than conventional plastics, helping to mitigate environmental pollution.

Table 1. Bio-filler and epoxy percentages in the specimen

Sample ID	Materials			
	Epoxy (%)	Casuarina (%)	Cork (%)	Snake Grass (%)
Type-1	80	0	10	10
Type-2	80	10	0	10
Type-3	80	5	5	10

2. EXPERIMENTAL PROCEDURE

2.1 Materials

To achieve uniform dispersion, a mechanical mixer was used to continually swirl both the natural and synthetic resins for 45 minutes. The compression molding method was used to create cork filler with epoxy hybrid polymer material laminates (Ganesamoorthy *et al.* 2021). The laminates had been sliced for various testing in conformity with the criteria of the ASTM standards after they had cured. Table 1 shows the ratios of bio fillers and epoxy used in specimen production.

3.TESTING METHODS

3.1 Mechanical Properties

The instron universal testing machine was used to perform tensile and flexural testing. The ASTM D-3039 was followed in the performance of the tensile test. To determine flexural vigor, a three-point bending experiment has been executed by ensuing the guidelines of ASTMD-790 (Altaee *et al.* 2023) In compliance with ASTM D-4812, the impact strength was determined using the Izod method. Five samples were used in each test, and the median value has been calculated. Table 2 gives details about the Specifications and dimensions for the test specimens.

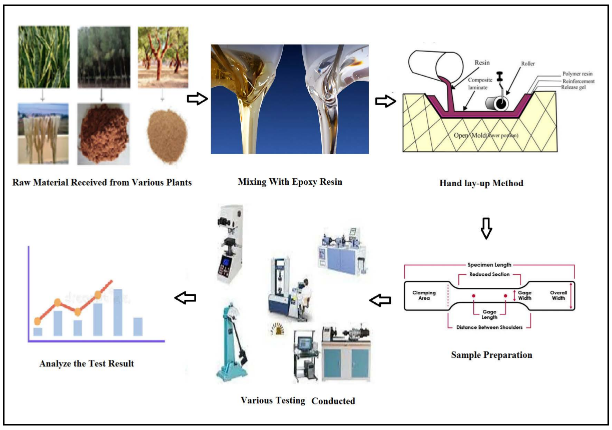

Fig. 1: Work flow of Bio filler epoxy composite study

Table 2. Test Specimens Standards

Testing Methodology	Specification	Dimension (mm)
Tensile Testing	ASTM D 3039	250 x 25 x 2.5
Impact Testing (Izod)	ASTM D 4812	64 x 12.7 x 3.2
Flexural Testing	ASTM D 790	154 x 13 x 3

3.2 Biodegradability Test

The most traditional and widely used technique for evaluating deterioration is soil burial, which takes advantage of the rich microbial community in soil that arises from actual waste disposal circumstances (Guo *et al.* 2013). By tracking weight loss in soil over time, the biodegradability of the samples was evaluated. Samples were first weighed, buried in soil, excavated after intervals of 30, 60, 90, and 120 days, rinsed, and then reweighed.

3.3 RESULT AND DISCUSSION

The hybrid bio composite was made using different fiber and filler material compositions in accordance with ASTM standards, and a mechanical evaluation was performed on it. Pure epoxy results compared with type 1, 2 and 3 epoxy composite. In type 1 epoxy composite samples were prepared with snake grass fiber (10%) and cork filler (10%). In type 2 epoxy composite samples were prepared with snake grass fiber (10%) and casuarina filler (10%). In type 3 epoxy composite samples were prepared with snake grass fiber (10%), cork filler (5%) and casuarina filler (5%). The results are depicted in Fig. 2 to 4. Fig. 2 presents tensile performance results for diverse compositions, showing total tensile strength and modulus. The preparation of tensile specimens was carried out in compliance with ASTM D3039 [ASTM D3039, 2014]. Epoxy composite type 1, 2 and 3 tensile result was better than the pure epoxy. Type-3 composition (5% Casuarina/ 5% cork/ 10% snake grass fiber/ 80% epoxy resin) exhibited optimal outcomes, with overall tensile strength at 37 MPa and tensile modulus at 1398 MPa. These findings demonstrate how significantly the fiber ratio of volume affects the composite's tensile characteristics.

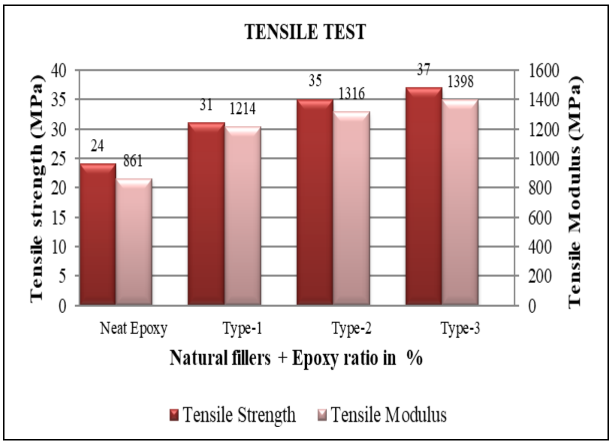

Fig. 2: Hybrid composite material - Tensile properties

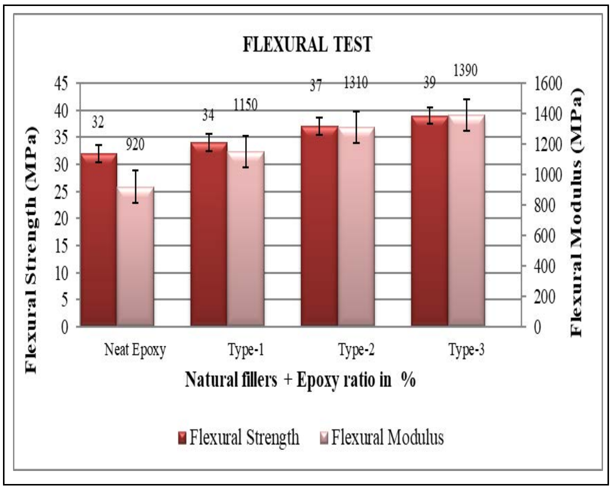

Fig. 3: Hybrid composite material - Flexural properties

Fig. 3 illustrates the changes in flexural vigor and flexural modulus in different mixtures. The preparation of tensile specimens was carried out in compliance with ASTM D790 [ASTM D790, 2014] The flexural test results for epoxy composites types 1, 2, and 3 were better than those for pure epoxy. Type-3 composition (5% Casuarina / 5% cork / 10% snake grass fiber/ 80% epoxy resin) demonstrated superior performance, with overall flexural strength is measuring 39Mpa and modulus measuring 1390 MPa. This pattern will be further explained in terms of how the fiber content affects the composite's flexural qualities. Fig.4 illustrates the changes of impact strength in different mixture. The preparation of impact specimens was carried out in compliance with ASTM D4812 [ASTM D4812, 2019]. The Type-3 composition (5% Casuarina / 5% Cork / 10% Snake grass fiber / 80% epoxy resin) exhibits the maximum impact strength, measuring 1.73 J, as shown in Fig. 4. The impact test results for epoxy composites types 1, 2, and 3 outperformed those of pure epoxy. Impact strength measures a material capacity to endure abrupt, heavy load for the brief period of time (Venkateshwaran *et al.* 2011). Impact tests are designed to produce large strain in a short amount of time, hence no discernible variation in impact strength results should be expected across all compositions tested.

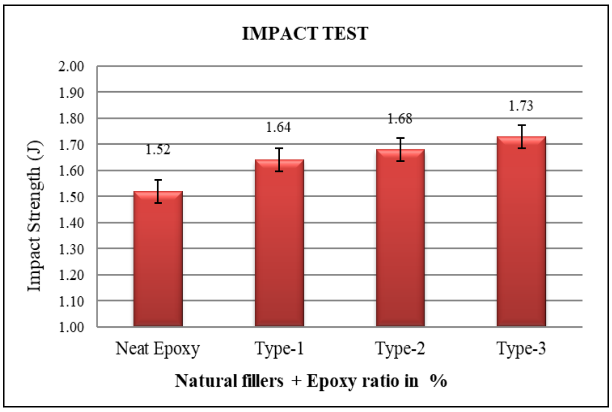

Fig. 4 Hybrid composite Material - Impact properties

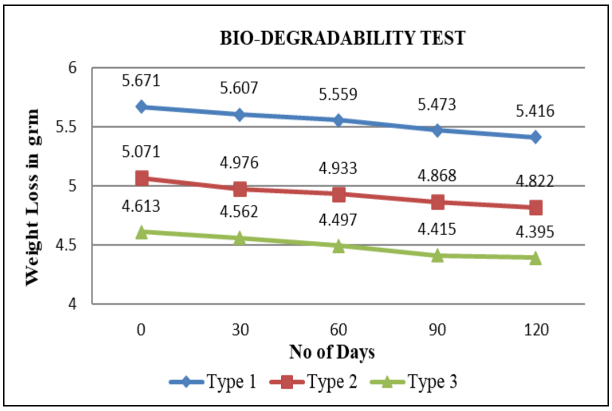

Fig. 5 Bio Degradability analysis

Biodegradability testing involved burying a material sample in damp soil, as illustrated in Fig. 5, to assess the impact on cork-blended epoxy polymer materials. Before burial, the sample's initial weight was recorded, and further measurements were collected at regular intervals to track any changes. After 120 days, the samples exhibited a loss of approximately 4 to 5 percent of their total weight. The interaction with micro and macro-organisms was attributed for the weight loss observed in the composite sample over time. A comparative evaluation of the substance with other bio fiber and fillers - reinforced polymer composites showed that its biodegradability was higher. The incorporation of bio filler in the epoxy hybrid material contributes to the production of a more environmentally friendly polymer.

4.CONCLUSION:

This study investigated the development of bio-composites hybrid polymer material by incorporating snake grass, Casuarina, and cork fillers into epoxy resin. The research comprehensively analyzed the consequence of these fillers upon mechanical qualities of the epoxy.

- A thorough examination of mechanical qualities revealed that the composite containing Type 3 (10% snake grass, 5% Casuarina, 5% cork, and 80% epoxy) exhibited superior values for impact, flexural and tensile strengths.
- This optimization was greatly aided by the remarkable fit between the bio fillers and resin, which was especially noticeable at an amount ratio of 5% Casuarina, 5% cork, 10% snake grass, and 80% epoxy.
- In the biodegradability test, a notable weight loss ranging between 4 to 5 percent was observed over a span of 120 days, signifying the most substantial degradation.
- Incorporating agricultural products as fillers not only meets the quality expectations for polymer products but also enhances their performance compared to pure polymers.
- The increased rigidity of the composite material presents significant opportunities for industries emphasizing mechanical robustness, particularly aerospace and automotive sectors. Stiffer epoxy composites facilitate weight reduction and enhance structural performance in aircraft components, thereby improving fuel efficiency.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

COPYRIGHT

REFERENCES

Altaee, M. A. and Mostafa, N. H., Mechanical properties of interply and intraply hybrid laminates based on jute-glass/epoxy composites, *J. Eng. Appl. Sci*., 70, 121 (2023). https://doi.org/10.1186/s44147-023-00293-7

ASTM D3039 (2014) In: Stand. Test Method Tensile Prop. Polym. Matrix Compos. Mater. ASTM Stand.

ASTM D790 (2014) In: Stand. Test Methods Flexural Prop. Unreinforced Reinf. Plast. Electr. Insul. Mater. ASTM Stand.

ASTM D4812 (2019) In: Stand. Test Methods Flexural Prop. Unreinforced Reinf. Plast. Electr. Insul. Mater. ASTM Stand.

Arrakhiz, F. Z., Achaby, M. El, Malha, M., Bensalah, M. O., Fassi-Fehri, O., Bouhfid, R., Benmoussa, K. and Qaiss, A., Mechanical and thermal properties of natural fibers reinforced polymer composites: Doum/low density polyethylene, *Mater. Des.* 43, 200–205 (2013). https://doi.org/10.1016/j.matdes.2012.06.056

Chandramohan, P., Kalimuthu, M., Subramanian, K., Nagarajan, R., Muhammed, F. F., Al-Lohedan, H. A. and Krishnan, K., Mechanical and thermo-mechanical behaviors of snake grass fiber-reinforced epoxy composite, *BioResources* 19(1), 1119–1135 (2023). https://doi.org/10.15376/biores.19.1.1119-1135

Dhakal, H., Zhang, Z. and Richardson, M., Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites, *Compos. Sci. Technol.*, 67(7–8), 1674–1683 (2007). https://doi.org/10.1016/j.compscitech.2006.06.019

Dixit, S., Goel, R., Dubey, A., Shivhare, P. R. and Bhalavi, T., Natural Fibre Reinforced Polymer Composite Materials - A Review, *Polym. from Renew. Resour.*, 8(2), 71–78 (2017). https://doi.org/10.1177/204124791700800203

Fernandes, E. M., Pires, R. A., Mano, J. F. and Reis, R. L., Bionanocomposites from lignocellulosic resources: Properties, applications and future trends for their use in the biomedical field, *Prog. Polym. Sci.*, 38(10–11), 1415–1441 (2013). https://doi.org/10.1016/j.progpolymsci.2013.05.013

Ganesamoorthy, R., Meenakshi Reddy, R., Raja, T., Panda, P. K., H. Dhoria, S., Nasif, O., Alfarraj, S., Manikandan, V. and Jenish, I., Studies on Mechanical Properties of Kevlar/Napier Grass Fibers Reinforced with Polymer Matrix Hybrid Composite, *Adv. Mater. Sci. Eng.*, 2021, 1–9 (2021). https://doi.org/10.1155/2021/6907631

Guo, W., Bao, F. and Wang, Z., Biodegradability of wood fiber/poly(lactic acid) composites, *J. Compos. Mater.*, 47(28), 3573–3580 (2013). https://doi.org/10.1177/0021998312467387

Jagadeesh, D., Sudhakara, P., Lee, D. W., Kim, H. S., Kim, B. S., Song, J. I., Mechanical Properties of Corn Husk Flour/PP Bio-composites, *Compos. Res.*, 26(4), 213–217 (2013). https://doi.org/10.7234/composres.2013.26.4.213

Kalimuthu, M., Nagarajan, R., Batcha, A. A., Suchart, S., Varada, R. A. and Nadir, A., Mechanical Property and Morphological Analysis of Polyester Composites Reinforced with Cyperus pangorei Fibers, *J. Bionic. Eng*., 16, 164–174 (2019). https://doi.org/10.1007/s42235-019-0015-6

Mohanty, A. K., Misra, M. and Drzal, L. T., Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World, *J. Polym. Environ.*, 10, 19–26 (2002). https://doi.org/10.1023/A:1021013921916

Megahed, A. A., Agwa, M. A. and Megahed, M., Improvement of hardness and wear resistance of glass fiber-reinforced epoxy composites by the incorporation of silica / carbon hybrid nanofillers, *Polym. Plast. Technol. Eng.*, 57(4), 251-259, (2017). https://doi.org/10.1080/03602559.2017.1320724

Padmanabhan, R. G., Rajesh, S., Karthikeyan, S., Sivasubramanian, P., Ilyas, R. A., Nadir, A., ElSayed, M. T. and Mohamed, K., Evaluation of mechanical properties and Fick's diffusion behaviour of aluminum-DMEM reinforced with hemp/bamboo/basalt woven fiber metal laminates (WFML) under different stacking sequences, *Ain Shams Eng. J.*, 15(7), 102759 (2024). https://doi.org/10.1016/j.asej.2024.102759

Parthasarathy, C., Mayandi, K., Karthikeyan, S. and Kulothungan, K., Experimental investigation of cork filler reinforced polymer composite, *Mater. Today Proc.*, (2024). https://doi.org/10.1016/j.matpr.2024.05.085

Parthasarathy , C., Karthikeyan, S., Padmanabhan, R. G. and Kulothungan, K., Experimental Investigation of Casuarina Filler Reinforced Polymer Composite, Recent Advances in Mechanical Engineering, Lecture Notes in Mechanical Engineering (2022). https://doi.org/10.1007/978-981-99-2349-6_50

Pickering, K. L., Efendy, M. G. A. and Le, T. M., A review of recent developments in natural fibre composites and their mechanical performance, *Compos. Part A Appl. Sci. Manuf.*, 83, 98–112 (2016). https://doi.org/10.1016/j.compositesa.2015.08.038

Prabhakar, M. N., Shah, A., ur rehman, Song, J. I., Thermal and Mechanical Properties of Waste Ground Nut-shell Reinforced Polyester Composites, *Compos. Res.*, 28(3), 118–123 (2015). https://doi.org/10.7234/composres.2015.28.3.118

Satyanarayana, K. G., Arizaga, G. G. C., Wypych, F., Biodegradable composites based on lignocellulosic fibers—An overview, *Prog. Polym. Sci.*, 34(9), 982–1021 (2009). https://doi.org/10.1016/j.progpolymsci.2008.12.002

Senthilrajan, S., Venkateshwaran, N., Naresh, K., Velmurugan, R. and Gupta, N. K. Effects of jute fiber length and weight percentage on quasi-static flexural and dynamic mechanical properties of jute/polyester composites for thin-walled structure applications, Thin-Walled Structures, 179, 109719 (2022). https://doi.org/10.1016/j.tws.2022.109719

Shah, A., ur R., Prabhakar, M. N., Lee, D. W., Kim, B. S. and Song, J. I., Development and Characterization of Oyster Shell Powder Filled Polypropylene Composite, *Compos. Res.*, 27(5), 201–206 (2014). https://doi.org/10.7234/composres.2014.27.5.201

Venkateshwaran, N., ElayaPerumal, A. and Jagatheeshwaran, M. S., Effect of fiber length and fiber content on mechanical properties of banana fiber/epoxy composite, *J. Reinf. Plast. Compos.*, 30(19), 1621–1627 (2011). https://doi.org/10.1177/0731684411426810