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UTILIZATION OF SAWDUST FIBRES IN HIGH-DENSITY POLYETHYLENE COMPOSITES: A SUSTAINABLE APPROACH TO PLASTIC WASTE RECYCLING

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Abstract

Environmental issues related to plastic waste and sawdust disposal have generated interest in developing composites using natural fibers. This study examines how to make sawdust-reinforced high-density polyethylene (HDPE) composites from recycled food plastic takeaway containers and disposable water cups. The sawdust underwent alkaline treatment with sodium hydroxide to improve the bond between the fiber and matrix. Composites were created using a two-roll mill and compression molding with different fiber loadings (0–50 wt%). We evaluated mechanical properties like tensile strength, flexural strength, modulus, and impact resistance according to ASTM standards. The results indicate that a 30 wt% fiber loading achieved the best mechanical performance. The alkaline-treated fibers showed better mechanical properties than untreated fibers because of improved bonding at the interface. This research highlights the potential of sawdust as a reinforcing agent in polymer composites and offers an eco-friendly option for reusing plastic and wood waste.

Keyword: high-density polyethylene, sawdust fibers, alkaline treatment

Introduction

Composite materials combine two or more different phases, including a matrix (continuous phase) and a filler (dispersed phase). The performance of a composite mainly relies on the type of matrix, filler, and their interface. There is growing interest in replacing synthetic fibers like glass with natural plant fibers because they are better for the environment and cost-effective.

Wood fibers are especially appealing due to their high strength and stiffness, recyclability, biodegradability, and visual charm. Adding them to thermoplastics has shown to improve mechanical performance. Wood-Plastic Composites (WPCs), or Wood Fiber Polymer Composites (WFPCs), are commonly found in construction materials, car panels, and furniture. This study looks at how to use sawdust along with recycled HDPE to improve mechanical properties and support sustainable waste management.

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Material and Methods

Table 1: Materials, Equipment, Chemicals and Additives

Category	Description
Materials	Sawdust (collected from Panteka Market, Kaduna)
	Recycled food plastic takeaway (RPFT)
	Recycled water disposable cups (RWD Cup)
Chemicals/ Additives	Sodium hydroxide (NaOH)
	Universal indicator paper
Equipment	Hand sieve (2 mm)
	Weighing balance (Model AD01)
	Griffen Grund hot oven
	Two-roll mill (Reliable 5189, New Jersey)
	Impact testing machine (Charpy, Cat Nr Model 412)
	Flexural testing machine (Monsanto Flexural Mode)
	Tensile testing machine (Monsanto Type W, S/No 9875)
	Hydraulic compression moulding machine (Model 1190)

METHODS

Fibre Preparation

Sawdust (2–5 mm) was sun-dried for 24 hours. It soaked in 5 wt% NaOH for 30 minutes at room temperature to remove surface impurities. Then, it was washed to neutral pH (pH 7) and dried at 100°C for 24 hours.

Composite Formulation

Four sets of composites were prepared:

Treated/untreated sawdust + RPFT

Treated/untreated sawdust + RWD Cup

Each set was made with 0%, 10%, 30%, and 50% fibre loading (by weight).

Composite Fabrication

Mixing occurred on a two-roll mill preheated to 150°C. Composites were compression moulded into sheets of 100 × 100 × 3 mm under 0.5–0.75 metric tons of pressure for 5 minutes, then cooled.

Mechanical Testing

Tensile Strength (ASTM D638)

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Specimens were tested using a Monsanto Tensile Machine. The parameters measured included UTS, strain, % elongation, and modulus of elasticity.

Flexural Strength (ASTM D662)

Flexural tests were performed using a Monsanto Flexural Mode machine. The team calculated flexural strength and modulus.

Impact Strength (Charpy Method)

Impact strength was measured with the Charpy impact tester. Specimens were prepared according to standard geometries.

RESULTS AND DISCUSSION

Tensile Strength

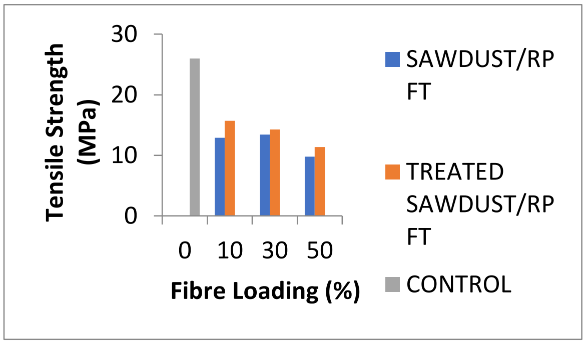

Figure 4.1 Tensile strength as a function of fibre loading of treated and untreated sawdust/Recycle food plastic takeaway

Figure 4.1 shows the tensile strength behavior of both treated and untreated sawdust/recycled plastic food takeaway (SD/RPFT) composites. As the fibre content increased from 10 wt% to 30 wt%, the tensile strength decreased. A further reduction was noted at 50 wt%. This decline mainly stems from poor interfacial bonding between sawdust fibres and the recycled plastic matrix. This is a common problem in short-fibre composites. When there is too much fibre loading, it causes fibre crowding and weakens the connection between the matrix and fibres (Pan, 2025; Nwosu et al., 2021).

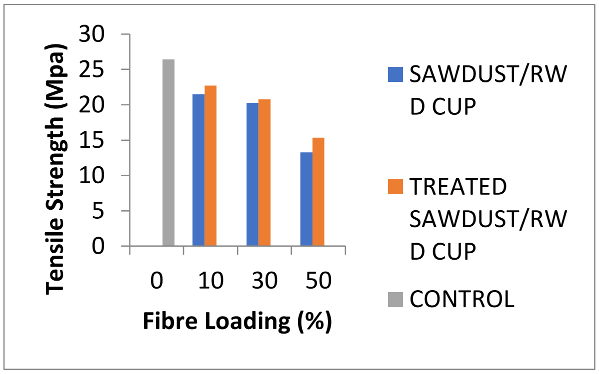

Figure 4.2 Effect of fibre loading on the tensile strength of treated and untreated sawdust/recycled water disposable cup

Figure 4.2 shows how the tensile strength of treated and untreated sawdust/recycled water disposable cup (SD/RWD Cup) composites changes with fibre loading. We observed a steady decrease in tensile strength as the fibre content increased from 10 wt% to 50 wt%. This drop mainly results from weak bonding between the sawdust fibres and the recycled water disposable cup matrix, which affects how stress moves through the composite.

Similar patterns of reduced tensile strength with higher natural fibre loadings have been seen in wood–plastic composites. In these cases, more filler material leads to fibre clumping and a weak matrix interface, which lowers overall mechanical performance (Kiryakova et al., 2024; Kuo et al., 2025).

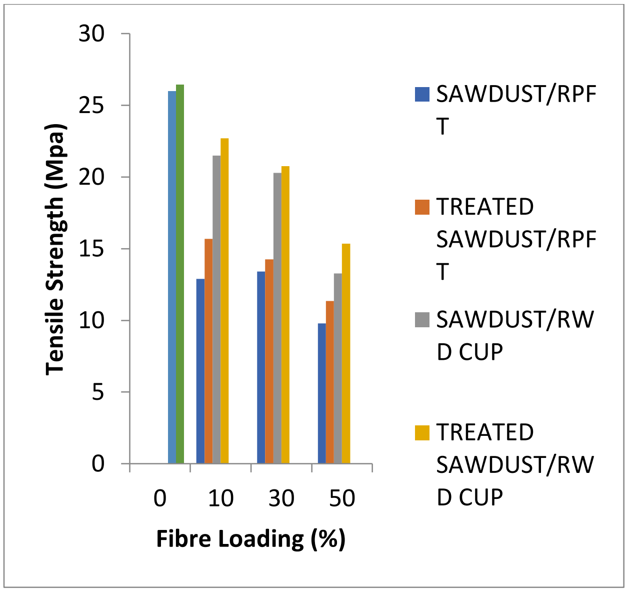

Figure 4.3: Effect of tensile strength on fibre loading of treated and untreated sawdust/recycled water disposable cup and recycled plastic food takeaway

Figure 4.3 shows the tensile strength profiles of treated and untreated sawdust/recycled plastic food takeaway (SD/RPFT) and sawdust/recycled water disposable cup (SD/RWD Cup) composites. For treated SD/RPFT composites, tensile strength consistently decreased as fibre loading increased from 10 wt% to 50 wt%. Composites reinforced with alkali-treated fibres had noticeably higher tensile strength than untreated ones. This improvement is due to better fibre-matrix bonding, which allows for more effective stress transfer and increased composite stiffness. Similar results from alkali treatment have been seen in sawdust-reinforced recycled HDPE composites, where treated samples showed better tensile properties compared to untreated ones (Ferede et al., 2020).

Tensile Modulus

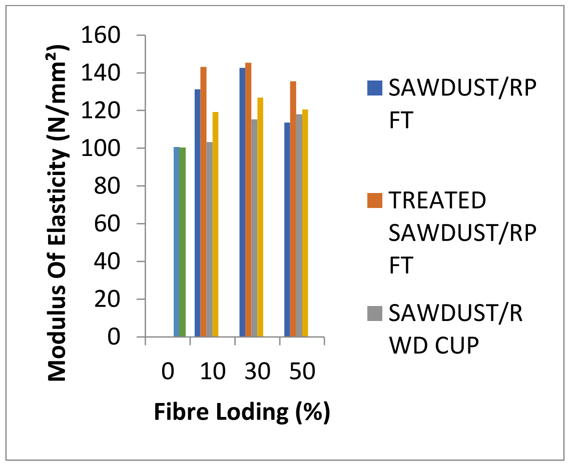

Figure 4.4 Effect of tensile modulus changes for both treated and untreated SD/RPFT and SD/RWD

Figure 4.4 shows how the tensile modulus changes for both treated and untreated SD/RPFT and SD/RWD Cup composites as the fibre load increases. For treated SD/RPFT composites, the tensile modulus goes up from 10 wt% to 30 wt% but then drops at 50 wt%. It reaches a high of 143.1 N/mm² and a low of 113.5 N/mm². This pattern indicates that

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the interaction between the fibre and matrix improves up to 30 wt%. After that, fibre clumping and poor spreading lower the mechanical performance (Fibre Loading, 2025; Natural Fibre Composites, 2023). On the other hand, SD/RWD Cup composites consistently increase in tensile modulus as fibre loading rises from 10 wt% to 50 wt%. This steady stiffening probably results from more fibre blockage and the removal of impurities during processing. This improves fibre stiffness and the efficiency of stress transfer (Composite Review, 2023; Bamboo NR Review, 2013).

Flexural Strength

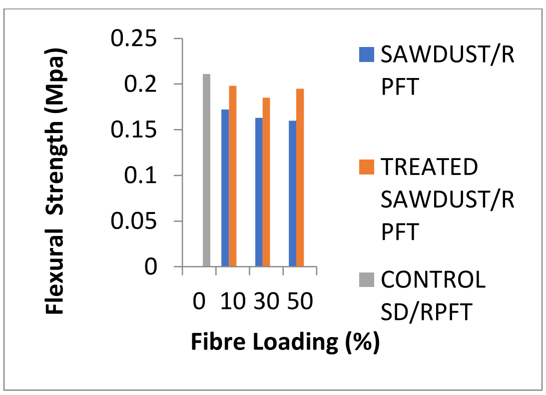

Figure 4.5 Effect of flexural strength on fibre loading for treated and untreated SD/RPFT

Figure 4.5 shows the change in flexural strength of treated and untreated sawdust/recycled food plastic takeaway (SD/RPFT) composites based on fibre loading. In the treated composites, flexural strength rose with fibre content from 10 wt% to 30 wt%, then dropped at 50 wt%. This pattern suggests that the interaction between fibre and matrix improved stiffness up to the 30 wt% level. After that point, fibre clumping and poor mixing likely weakened the structure. On the other hand, the untreated SD/RPFT composites showed a consistent increase in flexural strength across all fibre loadings. These results match findings by Ferede (2020), who reported that alkaline-treated sawdust–PP composites reached their highest flexural strength between 30 and 40 wt% fibre loading before dropping.

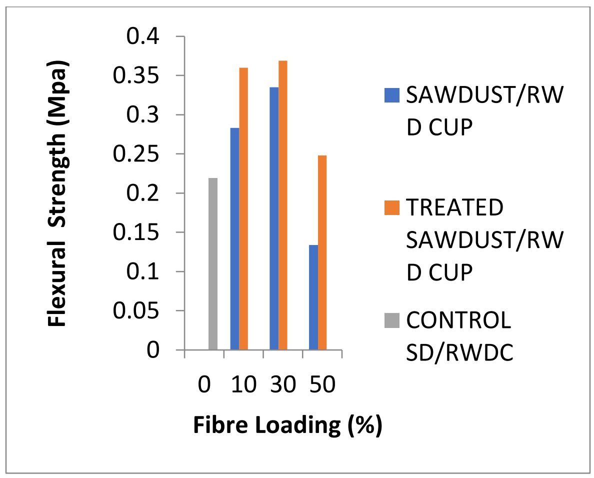

Figure 4.6 Effect of flexural strength on fibre loading of treated and ubtreated SD/RWD cup

Figure 4.6 shows how the flexural strength of treated and untreated sawdust/recycled water disposable cup (SD/RWD Cup) composites varies with different fibre loadings. Flexural strength increased from 10 wt% to 30 wt% but dropped at 50 wt%. This decrease at higher fibre content is due to weak bonding between sawdust fibres and the RWD Cup

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matrix, which negatively impacts stress transfer and composite stiffness. A similar pattern appears in wood–plastic composites. The flexural strength improves with more filler added up to a certain point, after which it falls because of fibre clumping and weak interfaces between the matrix and fibres (Arapoglou et al., 2022).

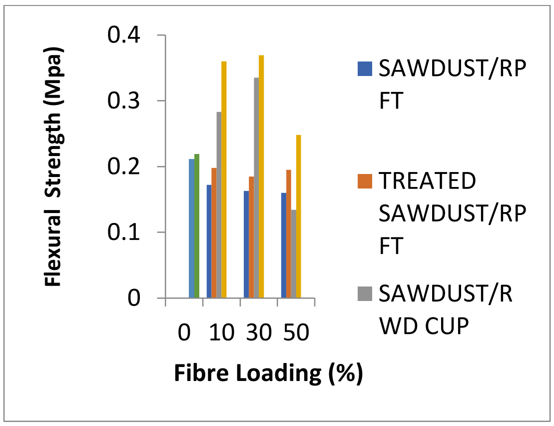

Figure 4.7 Effect of flexural strength on fibre loading for treated and untreated SD/RPFT and SD/RWD cup

Figure 4.7 shows the flexural strength profiles of treated and untreated SD/RPFT and SD/RWD Cup composites at different fibre loadings. Both treated and untreated SD/RPFT composites showed non-linear flexural strength trends. Their strength increased and then decreased as fibre loading rose from 10 wt% to 50 wt%. For the treated SD/RWD Cup composites, the highest flexural strength, 0.369 N/mm², was at 30 wt%. This strength decreased to 0.248 N/mm² at 50 wt%. These trends highlight how much fibre content affects composite rigidity and structural integrity. A similar pattern has been seen in natural fiber reinforced composites, where the best flexural strength occurs around 30 wt% fibre loading. More fibre typically leads to agglomeration and weak interfacial bonding, which harms mechanical performance (Mertens et al., 2020).

Flexural Modulus

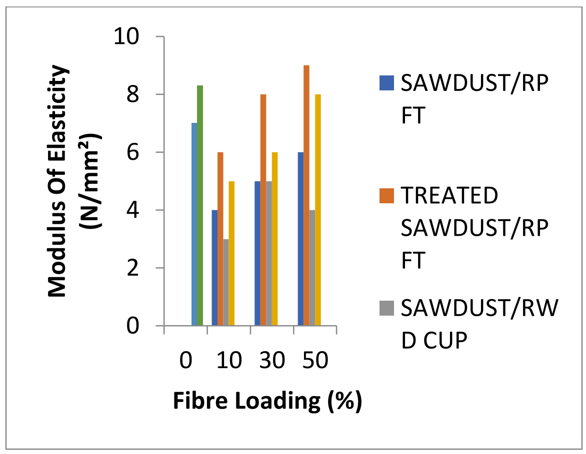

Figure 4.8 Effect of flexural modulus changes on fibre loading for treated and untreated SD/RPFT and SD/RWD cup

Figure 4.8 shows how the flexural modulus varies in treated SD/RPFT and both treated and untreated SD/RWD Cup composites at different fibre loadings. For treated SD/RPFT, the flexural modulus steadily increased with fibre content from 10 wt% to 50 wt%. In contrast, SD/RWD Cup composites, both treated and untreated, showed an increase in modulus from 10 wt%

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to 30 wt%, followed by a drop at 50 wt%. This decrease at higher fibre content mainly results from weak interfacial adhesion between the sawdust fibres and the recycled matrix. This weak bond limits effective stress transfer and reduces the stiffness of the composite. These trends match results in treated sawdust PP composites, where the flexural modulus increases with filler loading but eventually levels off or drops due to agglomeration and poor dispersion (Rahman et al., 2011; Idrus et al., 2011).

Impact Strength

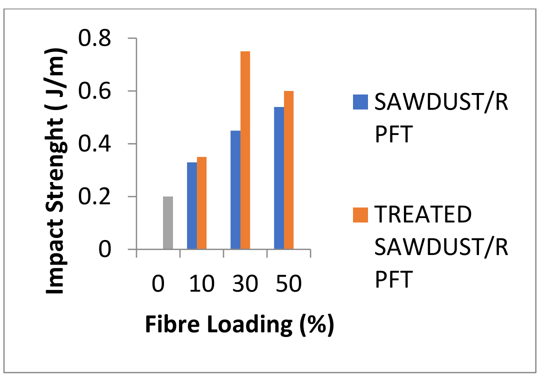

Figure 4.9 Effect of Impact strength on fibre loading for treated and untreated SD/RPFT

Figure 4.9 shows how impact strength varies for treated and untreated SD/RPFT composites based on fibre loading. Treated composites had higher impact strength, reaching a peak of 0.75 J at 30 wt% and dropping to 0.35 J at 10 wt%. On the other hand, untreated composites showed a steady increase in impact strength from 10 wt% to 50 wt%. This trend matches the results from chemically treated sawdust-polypropylene composites. Treated samples displayed rising impact strength with more fibre content due to better fibre-matrix bonding. Untreated samples improved continuously because the reduced interfacial area at higher fibre loadings allowed for better matrix mobility and energy absorption (Ferede et al., 2020).

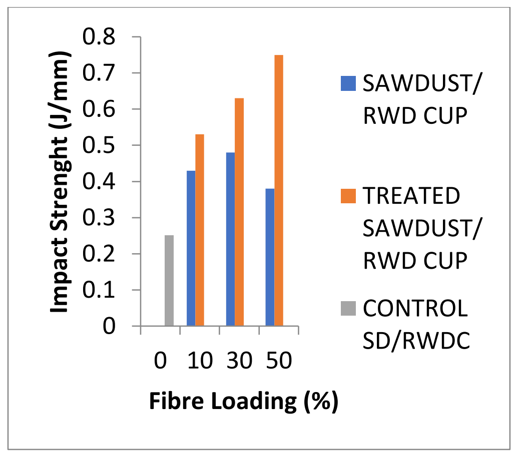

Figure 4.10 Effect of Impact strength on fibre loading for treated and untreated SD/RPFT and SD/RWD cup

Figure 4.10 shows how the impact strength of treated sawdust/recycled water disposable cup (SD/RWD Cup) composites changes with different fibre loadings. As the fibre content increases from 10 wt% to 50 wt%, the impact strength rises, reaching a maximum value of 0.75 J at 50 wt% fibre loading. This pattern indicates better energy absorption at higher fibre levels, probably because of stronger fibre reinforcement in the matrix (Rathna et al., 2020).

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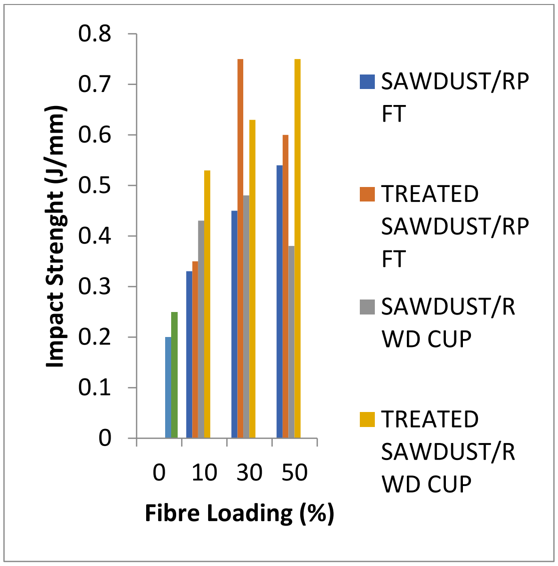

Figure 4.11Effect of Impact strength on fibre loading for treated and untreated SD/RPFT and SD/RWD cup

Figure 4.11 shows the impact strength of treated and untreated SD/RPFT and SD/RWD Cup composites. Both treated and untreated SD/RPFT showed better mechanical performance as the fibre loading increased from 10 wt% to 30 wt%. For the untreated SD/RWD Cup, the impact strength peaked at 0.48 J with 30 wt% fibre loading but dropped to 0.38 J at 50 wt%. This decrease is due to weak bonding between the sawdust filler and the recycled water disposable cup matrix.

Conclusion

Adding sawdust fibers to recycled HDPE matrices improved mechanical properties and offered a sustainable way to handle wood and plastic waste. Treating the fibers with NaOH greatly boosted interfacial bonding, tensile strength, flexural strength, and impact resistance. The best results came at a fiber loading of 30 wt%. These findings show that wood-based natural fillers can work well in polymer composites for industrial use.

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