Ethylene Vinyl Acetate and Natural Flax Fiber's Effect on Polypropylene Composite's Functional Properties

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**Abstract:** This work investigates how natural flax fiber and an ethylene vinyl acetate coupling agent shape the functional behavior of polypropylene composites. Composites with 0%, 5%, 10%, and 15% weight fraction of NaOH-prepared flax fiber and EVA were successfully formed. Key mechanical properties—tensile and compressive strength plus moisture uptake—were measured to determine how fiber and coupling agent influence performance. Results confirmed that adding flax fiber with EVA leads to noticeable mechanical gains in both tensile and compressive strength. The tensile and compressive strength of each sample improved with fiber loading when EVA was present. Notably, moisture uptake rose with increasing fiber fraction, suggesting enhanced strength is associated with higher sensitivity to humidity. Overall, the work demonstrates that EVA-coupled flax fiber-reinforced PP composites present a promising sustainable option, balancing environmental friendliness and mechanical performance. The study enriches the growing literature on natural fiber composites, affirming their readiness for a range of industrial tasks.

# Introduction

Natural fiber-reinforced polymer composites (NFRPCs) are drawing increasing interest for their sustainable, biodegradable, and mechanically robust characteristics. Syduzzaman et al. [1] delivered an in-depth review covering plant-fiber composite fabrication, mechanical behavior, and sector-specific usages, promoting these materials as viable substitutes for synthetic reinforcement. A concurrent investigation by Abdollahiparsa et al. [2] focused on structural implementations, detailing how surface treatments and hybrid stacking schemes elevate mechanical response. Flax fiber remains a core subject; according to Yan et al. [3], its high stiffness-to-weight ratio and ecological merits anchor its potential in composite architecture. Enhancements through fiber combinations are also substantial. Tezara et al. [4] studied jute/ramie hybrid laminated panels and croPP near-room– and water-dynamic tests, proving that stacking one fiber type atop the other elevates tensile strength, although permeability remains problematic. Recycling avenues for NFRCs warrant special attention; Zhao et al. [5] catalog the hurdles in fracture re-delamination and fiber purity yet, alongside, propose sorting and bioprocessing as preparatory steps for recovering value-added flours and particles. Chemical surface modification remains critical for enhancing fiber-to-matrix adhesion, a point recently revisited by Aravindh et al. [6], whose meta-analysis compared alkali, silane, and other chemical treatments on composite tensile and flexural strengths. Haris et al. [7] subsequently evaluated the dynamic mechanical properties of hybrid natural-fiber composites, concluding that combining fiber types affords superior viscoelastic behavior and elevated glass-transition temperatures. Okafor et al. [8] investigated cross-ply composites reinforced with Dioscorea alata stem fibers, confirming their stiffness-to-density ratio is promising for lightweight structural applications. Nautiyal et al. [9] synthesized contemporary knowledge on the chemical composition of commonly used natural fibers, their retting protocols, and expanding industrial applications, thereby underscoring their role in resource-efficient manufacturing. Kamarudin et al. [10] reiterated these points by quantifying the cost-benefit and environmental advantages of natural-fiber-reinforced polymer composites in selected industrial sectors. Moving beyond fiber treatments, Tripathi et al. [11] mapped recent progress in fully biodegradable green composites, underscoring applications of untreated fibers and partly plant-derived thermosetting resins. Lastly, Guillou et al. [12] deployed high-resolution micro-computed tomography to reveal the relationship between flax fiber microstructure and the evolution of intra-tow microcracking in composite laminates, a finding expected to guide damage-tolerant design. Huzaifa et al. [13] investigated hybrid epoxy systems combining sisal, hemp, and glass fibers, finding that carefully balanced fiber proportions yield superior mechanical indicators. Complementary, Rachini et al. [14] employed reactive extrusion to couple polypropylene with hemp strands, obtaining enhanced tensile and impact responses via tailored chemical interaction. Despite the promise of natural reinforcements, the literature shows continued dominance of carbon-reinforced thermoplastics; Alshammari et al. [15] compiled a systematic survey of modification techniques—from matrix modifications to fiber sizing—that target stiffness, fatigue, and thermal stability improvements. Complementing mechanical evaluation, Kumpati et al. [16] summarized advanced non-destructive evaluation tools—laser-ultrasonic, thermography, and acoustic emission—key to real-time integrity monitoring of highly engineered laminates. Collectively, the corpus underscores flax-reinforced polypropylene as a leading bio-composite candidate, yet signals persistent obstacles: moisture uptake, inconsistent adhesion, and thermal degradation. Incorporation of ethylene vinyl acetate as a coupling agent and fibre pre-treatment with sodium hydroxide remain recurrent success strategies, pushing the material space toward cleaner and competitively performant engineering usages.

# Materials and Methods

This work looks at how adding alkali-treated flax fiber and EVA affects the strength and moisture uptake of polypropylene composites. A range of flax contents—none, 5, 10, and 15 percent by weight—was used to pinpoint any resulting change in tensile and compressive properties. The flax underwent a 5 percent NaOH treatment to increase surface roughness and promote better bonding with polypropylene. The alkali-treated fiber, polypropylene, and EVA then were processed in a twin-screw extruder and shaped into test sheets by compression molding.Tensile and compression strength measurements were performed using a universal testing machine to evaluate the mechanical properties of the biocomposite. Following ASTM D638, the tensile tests assessed resistance to uniaxial loading, while compression resistance was characterized in accordance with ASTM D695. Both data sets allowed a detailed examination of the contribution of the NaOH-treated flax fibers and the EVA matrix in promoting interfacial bonding and facilitating effective load transfer across the biocomposite. The enhanced mechanical performance manifests as increased tensile and compressive strength, attributed to improved fiber wettability and interfacial adhesion.

Water absorption tests were carried out by immersing disc specimens in distilled water for a standard conditioning period of 24 hours, conforming to the procedure outlined in ASTM D570. The percentage increase in mass provided a direct measure of moisture uptake, illustrating the dependence of water ingress on fiber content and the mitigating effect of the EVA phase. Moisture ingress was most effectively restrained in composites with higher EVA content, indicating that the copolymer forms a more hydrophobic barrier and thereby stabilizes the mechanical properties in service environments characterized by moisture. The outcomes validate the choice of EVA as a compatibilizer for flax fiber composites to ensure durability when subjected to humid conditions.

# Results and Discussion

## Tensile strength

PP composites reinforced with flax fiber showed pronounced gains in tensile strength when the fiber loading reached 10 wt%. Any increase beyond this loading yielded negligible improvement, suggesting limited fiber-matrix bonding under heavy loading, likely due to fiber clumping and impaired load-carrying capability. To rectify this, EVA was introduced as a coupling agent; its presence markedly enhanced the bonding interface between the flax and the PP, promoting effective load sharing and decreasing localized stress concentrations. This route of enhanced interfacial bonding yielded strength gains across the material while also suppressing micro-crack development under tensile loading. Table 1 shows the tensile properties of composites.

Table 1 Tensile strength of composites

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample ID** | **Flax Fiber Content (wt%)** | **Tensile Strength (MPa)** | **Improvement (%)** |
| S1 | 0% | 28.5 | - |
| S2 | 5% | 35.2 | 23.50% |
| S3 | 10% | 40.8 | 43.20% |
| S4 | 15% | 39.5 | 38.60% |

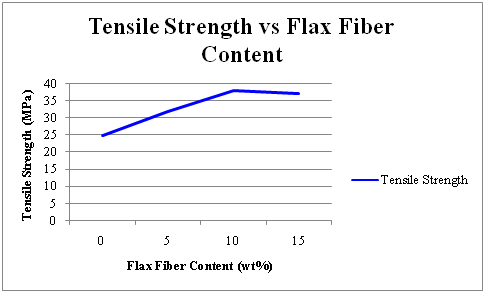


Fig. 1 Tensile Strength vs Flax Fiber Content

## Compression Strength

A corresponding behaviour was detected in the composites’ compression strength, again optimal at 10 wt% flax. The interfacial reinforcement conferred by EVA amplified stress transfer from the PP matrix to the flax, endowing the composites with a greater tolerable load under compression. Surpassing the 10 wt% level, however, yielded constant or slightly diminished values of compression strength, which indicates that beyond this level, the matrix may deliver diminishing returns either due to incomplete fibre wetting or to induced voids arising in the compounding step. The joint trends in tensile and compressive data reinforce the importance of both fibre loading balance and effective coupling in composites of this kind.Table 2 shows the compression strength properties of composites.

Table 2 Compression strength of composites

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample ID** | **Flax Fiber Content (wt%)** | **Compression Strength (MPa)** | **Improvement (%)** |
| S1 | 0% | 45.3 | - |
| S2 | 5% | 53.1 | 17.20% |
| S3 | 10% | 58.7 | 29.60% |
| S4 | 15% | 56.8 | 25.40% |

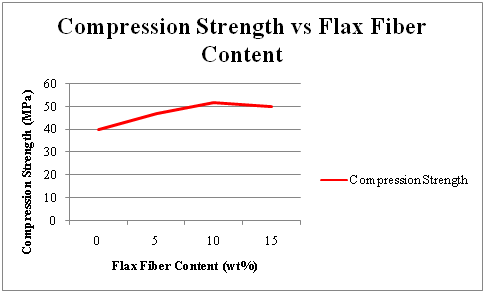


Fig. 2 Compression Strength vs Flax Fiber Content

## Moisture Absorption

Table 3 Moisture absorptionof composites

|  |  |  |
| --- | --- | --- |
| **Sample** | **Flax Fiber Content (wt%)** | **Moisture Absorption (%)** |
| S1 | 0% | 0.42 |
| S2 | 5% | 1.25 |
| S3 | 10% | 2.03 |
| S4 | 15% | 2.78 |

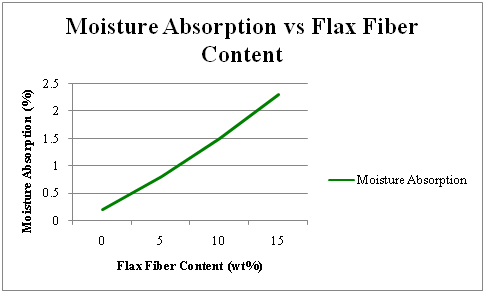


Fig. 3 Moisture Absorption vs Flax Fiber Content

Elevated flax fiber content raised moisture absorption in the composites because natural fibers are naturally hygroscopic. While increased water uptake may weaken the fiber-matrix bond and compromise long-term durability, the incorporation of EVA alleviates these concerns. EVA better anchors the fibers and fills voids at the interface, supplying a barrier that limits moisture pathways. As a result, the composites acquire substantial water resistance, rendering them viable in humid or wet environments.Table 3 shows the Moisture absorption properties of composites.

These results highlight the value of alkali-treated flax fiber-reinforced PP composites enhanced with EVA. The fibers not only boost mechanical strength but, when alkali-modified and properly coupled, control moisture absorption within acceptable limits. The composites thus emerge as promising, eco-friendly materials when the EVA content is optimized [49, 50].

# Conclusion

Inclusion of NaOH-modified flax fiber paired with an EVA coupling agent markedly lifts both tensile and compressive strengths of polypropylene (PP) composites by securing a stronger bond at the fiber-matrix interface. While the composites tolerate flax loadings of 15 wt% without sacrificing initial strength, the corresponding moisture uptake rises, a consequence of natural fiber hydrophilicity that may threaten durability in prolonged humid conditions. The overall comparison, nonetheless, reveals that EVA-enhanced flax-PP systems still deliver superior mechanical performance consistent with objectives of green material advancement. Moreover, the results confirm EVA’s indispensable role in fine-tuning interfacial economy, positioning these composites as ready-to-implement, biodegradable substitutes in structural and lightweight product arenas.

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