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HYBRID KENAF/GLASS COMPOSITES: PROPERTIES, DESIGN AND APPLICATIONS

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ABSTRACT

Biocomposites have gained increasing attention as sustainable engineering materials, especially those reinforced with natural fibres such as kenaf. Kenaf offers fast growth, high fibre yield and favourable mechanical properties, making it suitable for replacing or hybridising synthetic fibres like glass in polymer composites. This review highlights the potential of kenaf as reinforcement, the fundamentals of polymer-based biocomposites and the main challenges related to moisture absorption, weak fibre–matrix bonding and durability issues. Hybridisation with glass fibre is highlighted as an effective strategy to improve strength, stiffness and overall performance, although limitations such as fibre loading and recyclability remain. The paper also discusses design considerations for biocomposite products, including environmental impact, manufacturability and life cycle aspects. Current applications in automotive and consumer products demonstrate the practical value of kenaf-based composites.

KEYWORD

Kenaf, Biocomposites, Properties and Design

INTRODUCTION

Biocomposites have emerged as a promising class of engineering materials that align with current global demands for sustainability, lightweight structures, and cost-effective manufacturing. Driven by increasing environmental concerns and the shift towards biodegradable and renewable resources, kenaf (*Hibiscus cannabinus L.*) have gained significant research and industrial interest (Balakrishnan et al., 2024). Kenaf exhibits rapid growth, high fibre yield and favourable mechanical properties, making it a potential candidate for replacing or hybridising traditional synthetic reinforcements such as glass fibres in polymer composite systems. Kenaf composed of kenaf pith, bast and core that can be cultivated as fibre reinforcement.

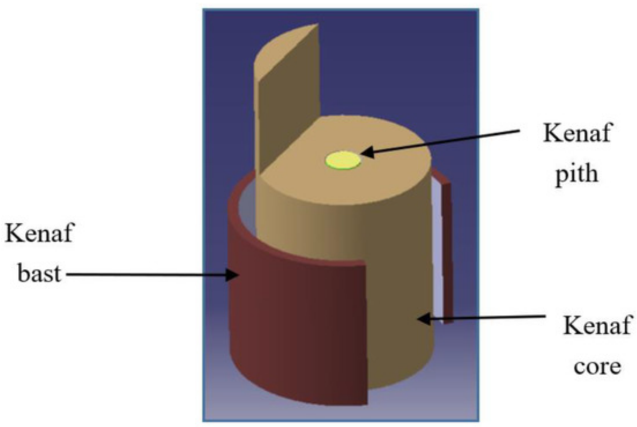

Figure 1: Bast and core parts of kenaf stem (Sim & Nyam, 2021).

This article provided highlight essential aspects of kenaf fibre development, polymer-based biocomposites, challenges associated with natural fibre reinforcement, hybridisation strategies, and the design and application of biocomposite products. This article consolidates these elements into a structured narrative to provide a comprehensive understanding of hybrid kenaf/glass polymer composites and their relevance in modern engineering applications.

KENAF FIBRE AS POTENTIAL REINFORCEMENT IN POLYMER COMPOSITES

Kenaf fibre originates from the bast and core regions of the plant stem, each possessing different mechanical characteristics and structural functions. The bast fibre, typically longer and stronger, is commonly exploited for reinforcement in polymer composites. Kenaf fibre has demonstrated significant capability as reinforcement in biodegradable and thermoplastic matrices, particularly due to its lightweight nature, renewability, cellulose-rich composition and reasonable tensile properties. Lyu et al. (2021) have shown that natural lignocellulosic fibres offer competitive strength-to-weight ratios while contributing to environmental sustainability through biodegradability and lower embodied energy.

Polymer matrix composites consist of a continuous polymer phase that binds reinforcing fibres, transfers loads, and defines the composite’s overall mechanical performance. Biodegradable polymers can break down naturally through microorganism activity, making them ideal partners for natural fibres such as kenaf. Biocomposites is a category in composites in which at least one phase is derived from renewable sources. The employment of biocomposites in various sectors represent a growing field supported by strong global interest in green engineering. Their environmental advantages include low carbon footprints, reduced dependency on petroleum-based materials, and enhanced end-of-life disposal options.

ISSUES ASSOCIATED WITH KENAF FIBRE COMPOSITES

Despite its advantages, kenaf fibre faces several challenges when integrated into polymer matrices. One of the major issues is moisture absorption, which leads to fibre swelling, micro-cracking and fibre–matrix debonding. Figure 2 presents a detailed mechanism of water uptake, showing how moisture penetrates fibre cells, forms micro-cracks, leaches water-soluble compounds and weakens the interfacial bonding.

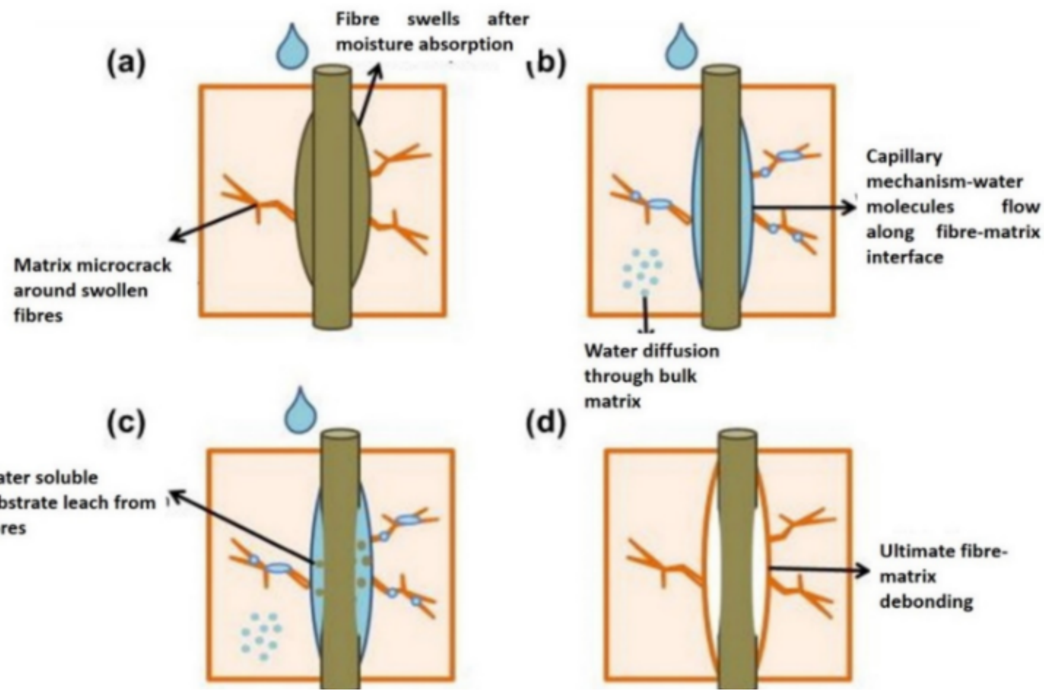

Figure 2: Detailed failure mechanism of kenaf composites (Mochane et al., 2019).

Moreover, the failure mechanisms of kenaf composites often include matrix cracking, fibre pull-out, interfacial shear failure and delamination, all of which affect their mechanical performance and durability. Mochane et al. (2019) indicate that achieving stable performance under varying humidity and load conditions remains a significant challenge in structural applications. These limitations motivate the hybridisation of kenaf with stronger, moisture-resistant synthetic fibres such as glass fibres.

HYBRID KENAF COMPOSITES

Hybrid composite systems combine natural and synthetic fibres to achieve synergistic improvements in mechanical performance. The hybridisation can produce a balance between cost reduction, improved strength, high stiffness and sufficient durability for engineering applications. However, hybrid kenaf fibre composites generally cannot exceed 50% natural fibre loading due to interfacial and structural constraints (Supian et al., 2024). Glass fibre is the most common co-reinforcement because of its high tensile strength, chemical stability and excellent electrical insulation properties. Previous works on hybrid kenaf/glass fibre composites, indicate significant improvements in tensile, flexural and impact properties when compared to pure kenaf composites (Dhar Malingam et al., 2018). Furthermore, tailoring fibre orientation, stacking sequence or incorporating fillers can enhance strength, stiffness and energy absorption, making hybrid composites suitable for semi-structural and structural applications.

DESIGN IN KENAF BIOCOMPOSITE PRODUCTS

Designing biocomposite products requires a structured conceptual framework that integrates material characteristics, functional requirements, manufacturing capabilities and sustainability criteria. The design methodology for biocomposites is still poorly established, as most existing guides pertain to conventional composites rather than fibre-reinforced biopolymers (Sapuan, 2015). Kenaf-based composites already see commercial use in automotive components such as package trays, door panels and window regulators, as illustrated in Figure 3.

Figure 3: Applications of kenaf-based composite products.

Mayer (1993) conceptual design framework outlines several essential considerations that guide the development of biocomposite products. These include ensuring compliance with relevant codes and standards, which is fundamental for safety and performance validation. The framework also emphasises environmental impact and sustainability, encouraging designers to prioritise materials and processes that minimise ecological footprint. Life cycle considerations play a central role, requiring evaluation of a product's impact from raw material sourcing to end-of-life disposal.

In addition, designers must account for manufacturability and cost, ensuring that proposed solutions are economically feasible and compatible with available fabrication techniques. Finally, the framework highlights the importance of ease of refurbishment, recycling or reuse, supporting circular-economy principles and enhancing the long-term sustainability of biocomposite products.

The life cycle of biocomposites typically progresses through several key stages, beginning with raw material cultivation, where renewable plant-based fibres are grown and harvested. This is followed by fibre extraction and treatment (Lee et al., 2021; Mansor et al., 2014), involving processes such as retting, chemical treatments, or mechanical decortication to enhance fibre quality and compatibility with polymer matrices. The next stage is composite fabrication, in which fibres are combined with polymer matrices through mixing, moulding and curing to produce finished composite components. During product use, these biocomposite parts generally provide sufficient mechanical performance for semi-structural and load-bearing applications (Zakaria et al., 2023). Finally, at the end-of-life stage, the components may undergo reuse, recycling, biodegradation or energy recovery, depending on the type of polymer matrix used and the degree of hybridisation with synthetic fibres.

CONCLUSION

Kenaf fibre presents strong potential as a reinforcement in polymer-based biocomposites due to its environmental benefits, lightweight properties, and competitive strength-to-weight ratio. However, issues such as moisture absorption and interfacial bonding weaknesses limit its performance in demanding applications. Hybridisation with glass fibres effectively overcomes many of these limitations by improving strength, stiffness and durability. To fully exploit hybrid kenaf/glass composites, designers must apply structured conceptual design methods that integrate environmental considerations, manufacturing techniques, fibre orientation and performance requirements. Current applications in automotive components, consumer products and potential structural uses demonstrate the growing industrial relevance of biocomposites. With ongoing research into fibre treatments, hybrid structures and design methodologies, hybrid kenaf-based composites are poised to contribute significantly to future sustainable engineering solutions.

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