Examining the Performance of Eco-Friendly Flax Fiber Composites: Mechanical, Thermal and Durability Properties – Review

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Abstract

Flax fibers are suitable for lightweight applications and offer cost-effective solutions that do not compromise mechanical performance. Amongst natural fibers, flax fibers are the strongest and currently used in various mechanical and thermal-based applications. Chemical and structural compositions determine its behavior. Besides, many studies explore flax fiber surface treatments and various fabrication techniques to improve their performance. For instance, this compendious review explored the thermal behavior, water absorption, and durability of flax fiber-reinforced composites, including their hybridization and chemical treatments. Using such natural fibers helps improve the mechanical, thermal and durability performances and enhances the environmental sustainability benefits. Thus, the natural fibers and their composites are easily attracted by various industries seeking to develop eco-friendly materials. In conclusion, this review concisely discusses flax fiber's usefulness as a sustainable and cost-effective reinforcing element for polymer matrix composites.

Highlights

- Flax fibers are considered one of the strongest fibers from the natural fiber family.
- Flax fibers' mechanical and thermal behaviours are significantly influenced by their structural and chemical compositions.
- Flax fiber gives dual benefits, such as improved mechanical and thermal performance, and it offers environmentally friendly materials.
- Flax fibers are a suitable choice for producing lightweight materials.
- Careful handling of flax fibers is essential in their use as reinforcement in composites.

Keywords: Flax fiber, eco-friendly materials, sustainability, durability, mechanical and thermal characteristics.

1. Introduction

The enormous increase in academic and industrial research and developments over the past 10 to 20 years is evidence of the need for reinforced plant-fiber composites. The market is expected to continue expanding over the next few decades. This growth has been prompted by environmental regulations and increased awareness among people, due to the effects of global warming[1]. Modern professionals have agreed that natural flax fibers are comparable with synthetic fibers, due to their distinct physical and mechanical characteristics, which have been obtained for decades. It is reported that the cultivation area of flax fibers has increased by

+133% from 2010 to 2020 (refer to Fig 1). According to reference [2], 145,000 hectares of flax fibers were cultivated in Europe by 2022.

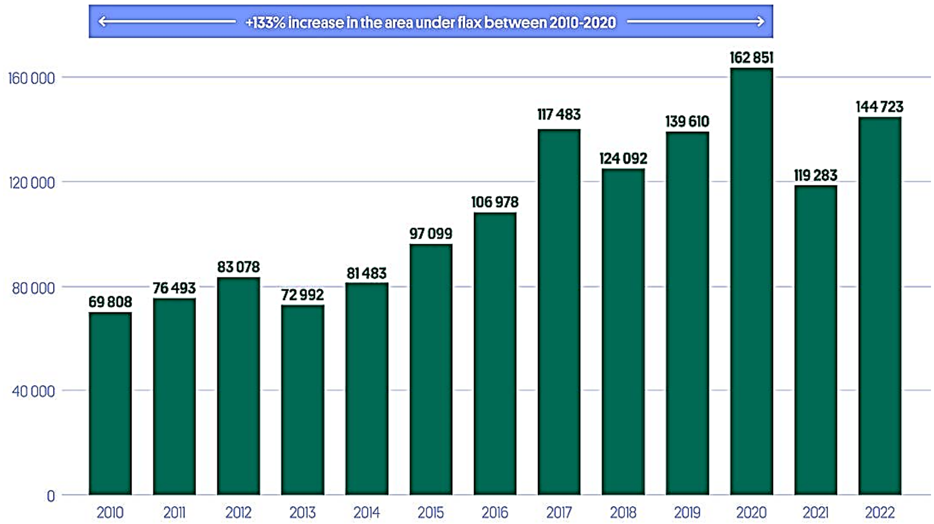

Fig. 1. Increase in the area of flax between year 2010 to 2020

Flax is a naturally occurring, widely available fiber with superior mechanical properties than many other natural fibers. Flax fiber appears to be a suitable feedstock for the support of an eco-friendly bio-based society. Their environmental performance as reinforcements in composite materials was examined in earlier life cycle assessments (LCAs)[3]. Yelin Deng et al investigated the flax fiber composite for the life cycle assessment (LCA). The results revealed varied patterns. The flax mat-PP composite achieves optimal volume fractions of 28-32% v/v while minimizing life cycle CO2 emissions. Short flax fiber-PP, on the other hand, consistently reduces CO2 emissions. The LCA analysis should be expanded to assess the environmental impact of various chemical treatment options. Bensadoun F et al. (2016) and Deng Y et al. (2016) that talk about how well flax fiber composites resist water and weathering. These experiments demonstrate the effectiveness of surface treatments and proper matrix selection in improving durability[4], [5][6]. For instance, one study demonstrates that the environmental impact of using flax fibers as reinforcing elements is lower than that of using glass fibers. A comparison of the environmental and cost impacts of synthetic and natural fibers in actual manufacturing scenarios is also feasible. According to more LCA research on biocomposites, substituting some or all of the synthetic fibers with natural fibers shows a reduced environmental impact on that component [7]–[9]. Reinforcing fibers manufactured from flax are frequently used in polymer composites. Raw flax fiber mostly comprises the hydrophilic components: cellulose, hemicellulose and lignin. The polymer matrix used for

for eco-conscious materials. This study examined the mechanical, thermal, retention of water, extraction, chemical and other characteristics of FFRPCs, as well as potential methods for enhancing the efficiency of the composites. The properties support suitable structural applications where lightweight yet strong materials are desired. The renewable and biodegradable nature of flax fibers further enhances their sustainability profile.

Moreover, water absorption increases with flax fiber volume percentage in the composites, demonstrating a correlation between fiber volume fraction and composite performance. Additionally, it has been demonstrated that chemical modification and hybridizing synthetic fibers can increase their water absorption and durability. Warm and humid conditions have no noticeable impact, other than a moderate decrease in mechanical performance. While the review highlights the advantages of flax fibers as reinforcement, it also acknowledges certain limitations. In conceptual terms, FFRPCs might benefit from chemical treatment for improved mechanical qualities, water resistance and durability. Several studies recorded alkaline (sodium hydroxide) chemical treatment as the preferred choice compared to others. Most investigations used polyester to replace epoxy because of its inexpensive cost and reasonable strength. However, bio-epoxy is becoming more popular as a thermoset matrix. Flax fiber has been used as reinforcement for thermoset polymer composites, demonstrating the ability to manufacture intricate geometries, including tanks, tubes, pipelines and turbine blades. The inherent characteristics of flax fibers enhance their appeals for uses, such as automotive components and many products.

This review concludes that flax fibers offer a promising and cost-effective solution for improved mechanical properties of polymer-based composites and support sustainability goals. Notwithstanding, further research towards developing and optimising fiber treatment methods to enhance the fiber-matrix interfacial adhesion, composite manufacturing techniques to reduce the percentage of voids and understanding long-term durability is required to increase various applications of flax fiber-reinforced polymer composite structures in diverse industries.

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Conflicts of interest

The authors declare no conflicts of interest.

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