

CHAPTER

5

DEVELOPMENT AND APPLICATION OF NATURAL FIBER POLYMER COMPOSITES

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5.1 INTRODUCTION

Materials that are lightweight and possess low density demonstrate highly customizable properties, rendering them essential in a broad spectrum of applications ranging from consumer commodities to engineering, structural, and advanced industrial uses. When compared with metallic and ceramic counterparts, however, these materials often display inferior mechanical performance. To mitigate this limitation, fillers are commonly incorporated into polymeric matrices, acting as load-bearing constituents that enhance mechanical properties such as strength and stiffness, thereby providing comprehensive reinforcement. The resultant material is widely recognized as a polymer composite. The reinforcement of polymers has traditionally relied on high-strength fibers, particularly synthetic varieties such as glass, carbon, and aramid. Fiber-reinforced composites offer considerable advantages in terms of improved strength, stiffness, and durability, making them highly suitable for diverse applications across multiple sectors.

These benefits have been extensively acknowledged and applied within the automotive industry (Paturel & Dhakal, 2020). The growing production and increasing use of such composites have, however, generated major concerns regarding their disposal and long-term sustainability. Despite their desirable properties, synthetic fiber composites are hindered by poor biodegradability and limited recyclability. This issue has become increasingly significant in light of rising environmental awareness and global efforts to combat climate change. Consequently, there has been renewed interest in natural fibers as environmentally sustainable alternatives to synthetic fibers.

Natural fibers are already widely employed in common products such as tea bags, currency notes, and filter papers. Examples include abaca, sugar palm, kenaf, and bamboo, which are typically derived from the lignocellulosic components of plants. These fibers have long been valued for the manufacture of ropes, twines, and textiles owing to their inherent durability and biodegradability (Paglicawan et al., 2021). For instance, abaca fibers are frequently used to produce ropes and binders, exhibiting greater durability than rayon and nylon, attributable to their superior tensile strength and reduced elongation under both wet and dry conditions. The extraction of natural fibers involves several stages, including leaf removal, stem cutting, shelling, shredding, drying, and classification, as illustrated in Figure 5.1.

The process of stripping entails the removal of leaves and the cutting of mature stems to access the fibers. Selected stems are trimmed approximately 10 cm above ground level using a bevel cut angled outward, thereby reducing the risk of stem rot. Structurally, most natural fibers are composed of tubular formations known as lumens, typically with diameters of about 10 μm . These lumens are surrounded by secondary walls comprising nanoscale fibrils, each with a cross-sectional diameter of approximately 10 nm. At the nanoscale, fibrils consist of chains of cellulose molecules bound together predominantly through hydrogen bonding, reinforced by additional Van der Waals interactions (Simbaña et al., 2020). This unique hierarchical arrangement imparts significant mechanical properties to natural fibers. Despite their

advantages, natural fibers possess a strongly hydrophilic nature, resulting in high water absorption.

This hydrophilicity limits wettability with hydrophobic polymer resins, leading to weak interfacial bonding and non-uniform composites (Khoo et al., 2025). To overcome these limitations, fibers are typically subjected to physical or chemical pre-treatments aimed at improving compatibility with polymer matrices. This treatment of fibers can enhance fiber–resin adhesion by modifying surface chemistry and increasing surface roughness, thereby providing more sites for chemical activation and matrix interaction (Rafidah et al., 2023). The outcome is the formation of a stronger fiber matrix network, resulting in improved mechanical performance.

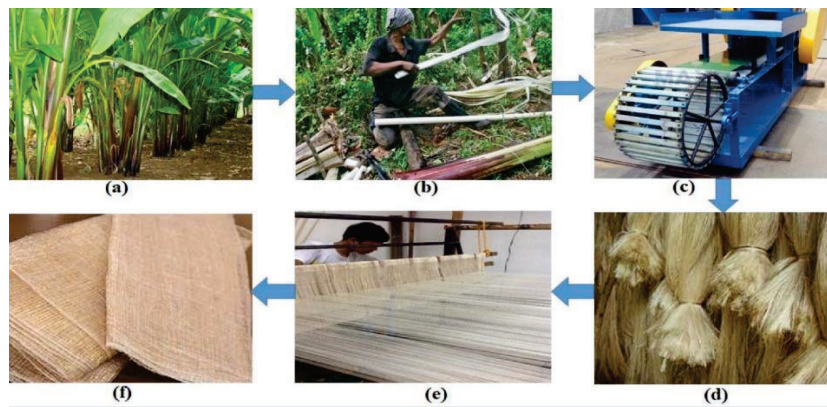


Figure 5.1 Process of cultivating natural fiber: (a) Cultivation of plants as the primary raw material source, (b) Manual extraction of stem layers, (c) Mechanical decortication to separate fibers from the stem; (d) Collection and drying of extracted fibers, (e) Weaving of processed fibers into fabric, and (f) Finished banana fiber-based fabric ready for applications (Source: Simbaña et al., 2020)

The available literature has predominantly explored the use of a wide range of natural fibers as reinforcements in polymer composites. The present chapter extends this discourse by examining the manufacturing and processing of natural fiber-reinforced polymer