

An Overview on Lignocellulosic Fibers Reinforced Polymer Composite Materials

Amamer Redwan, Khairiah Haji Badri and Azizah Baharum

School of Chemical Sciences and Food Technology, Faculty of Science and Technology,
University Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Abstract

In polymer science lignocellulosic fiber-reinforced polymer composite materials have appeared in a wide range area. The composite made from those varieties of materials are low density, low value, comparable certain properties, and most importantly they're environmental friendly. Although a number of the properties linked to composites generated from oil palm fibers and polymers (namely, those that are accessible through commerce) display aspects of commonality when compared to conventional synthetic fiber composites, such properties depend to a significant degree on the extent to which the fibers and matrix phase is compatible with the capacity to absorb moisture. Importantly, this emerges as a key concern and, moreover, disadvantages of Lignocellulosic fibers polymer composites and studies have suggested that it has a considerable impact on the composites' physical and mechanical properties. The central aim of the current paper is to provide an overview of the extant research relating to Lignocellulosic fibers reinforced polymer composites, and particular attention will be directed towards the physical structure and constituent chemical components of Lignocellulosic fibers. [DOI: [10.22401/JNUS.20.1.04](https://doi.org/10.22401/JNUS.20.1.04)]

Introduction

Lignocellulosic materials are a natural, generous and renewable asset critical to how modern social orders work and basic to the advancement of a realistic global economy. As wood and paper products, they have become a significant part in the development of progress. Changes in the quality of the products and assembling ability are often affected by the absence of understanding the overpowering structures and the materials synthetic formations. Cellulose molecules are acquired through many micro-scale elementary extraction stages fiber bundles to nanofibrils from numerous lignocellulosic fibers. The plants cell wall remarkable micro- and macro-structure i.e., lignocellulosic materials, is the main influence for plants survival. Throughout the plant cells' growth, multilayer cell wall is formed around their plasma membrane and the plant cells are protected against mechanical, chemical, and microbial stresses [1]. Lignocellulosic materials are mostly made up of cellulose (35–50%), hemicellulose (15–35%), and lignin (10–35%). The concentration of the components stated is different from plant types. For instance, advanced lignin concentrations are detected in higher plants, whereas lower lignin exists in annual plants [2]. Cellulose, hemicellulose, and lignin interact closely with each other in

the cell wall. This show results in an exclusive three-dimensional cell wall structure. The existence of OH groups in high number on the cellulose chain, polymer of glucose, makes this biopolymer vulnerable for strong hydrogen bonds formation. This finishes with high crystalline cellulose micro-fibrils formation in plant's cell wall. Cellulose micro fibrils are bounded by hemicellulose (a heteropolymer of five and six carbon sugars) and lignin (a complex polymer of phenolic compounds). The high crystallinity of cellulose is critical to exhibit of a plant cell wall's high mechanical strength. Lignin and hemicellulose act as the cellulose's protector against microbial and chemical attacks. Moreover, the lignin's hydrophobic nature safeguards plant cells against moisture loss and death due to drying. The lignocellulosic biomass, the photosynthetic reactions by plants direct product, is the richest renewable material in the world [3]. Adding reinforcement materials better the mechanical properties and decrease polymers cost. Being a small change in the processing parameters that could affect polymers properties, they can be personalized according to the application by controlling the processing parameters. This flexibility allows plastics to be the future's engineering materials.

It is clear that a procedure involving

compounding have a noticeable effect on the composite's final properties. The process of selecting suitable compounding method depends on the final fiber length needed, volume fraction and the fibers' dispersion degree in the matrix. Blending method or processing technique is a benchmark that decides if the blend or mold component has the preferred properties such as high stiffness or good surface finish [4]. Hence, the following requirements have to be met:

- The matrix must wet-out the fibers.
- The fibers must evenly distributed in the matrix without fiber bundles as it may lead to flexible strength.
- The fiber length to diameter must be adequate for active stress transfer from matrix.

Extensive studies based on these lignocellulosic fibers polymer composite materials have been reported in the literature as shown in Table (1) with classification of polymers.

Table (1)
Polymer reinforced with Lignocellulosic fibers with classification [5].

Thermoplastics			Thermosets
Semi-crystalline	Amorphous	Elastomeric	
High-density polyethylene (HDPE)	Acrylonitrile butadiene styrene (ABS)	Ethylene-propylene-diene terpolymer (EPDM)	Diallyl phthalate (DAP)
Low-density polyethylene (LDPE)	Cellulose acetate (CA)	Ethylene-propylene terpolymer (EPT)	Melamine formaldehyde (MF) Phenol
Linear low-density polyethylene (LLDPE)	Cellulose acetate butyrate (CAB)	Nitrile butadiene rubber (NBR)	formaldehyde (PF)
Polyoxymethylene (POM)	Cellulose propionate (CP)	Styrene-butadiene styrene (SBS)	Urea formaldehyde (UF)
Polyporpylene (PP)	Polycarbonate (PC)	Styrene-butadiene styrene (SBS)	Epoxy (EP)
Polya Polybutylene terephthalate (PBT)mid (PA)	Polyether sulfone (PES)	Thermoplastic polyurethane (TPU)	Unsaturated polyester (UP)
Polyether ether ketone (PEEK)	Polyethylene terephthalate (PET)	polyurethane (TPU)	Polyurethane
	Polymethyl methacrylate (PMMA)	Natural rubber SMR L	

Chemical composition of lignocellulosic fiber

Cellulose

Cellulose is a linear homo-polysaccharide that consists of β -D-glucopyranose (glucose) units linked together by β -D-(1-4) links. This polysaccharide is widespread in nature, occurring in both primitive and highly complex plants. The size of a polymer or a macromolecule is defined as the degree of

polymerisation (DP) in a single chain. The DP of cellulose is of 10 000 size and above [6]. However, conformational analysis of cellulose indicated that cellobiose (4-O- β Dglucopyranosyl- β -D-glucopyranose) rather than glucose is its basic repeating unit of the polysaccharide, as shown in Fig.(1).

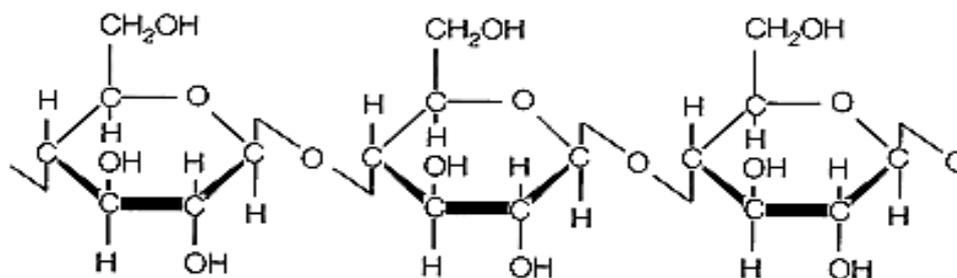


Fig.(1): Structure of Cellulose.

Hemicelluloses

Hemicelluloses are plant heteropolysaccharides whose chemical nature varies from tissue and from species to species and even in different types of cells within the lignocellulosic fibers. These polysaccharides are formed by a wide variety of building blocks including pentoses, hexoses, and uronic acids. Several classes of hemicellulose can be identified; (a) unbranched polymers such as

(1-4) – linked xylans or mannans, (b) helical polymers such as (1-3) – linked xylans, (c) branched polymers such as (1-4) – linked galactoglucomannans, and (d) pectic substances such as polyramnogalacturonans as shown in Fig.(2). Hemicelluloses are structurally more related to celluloses than lignin and are deposited in the cell wall at an earlier stage of biosynthesis [7].

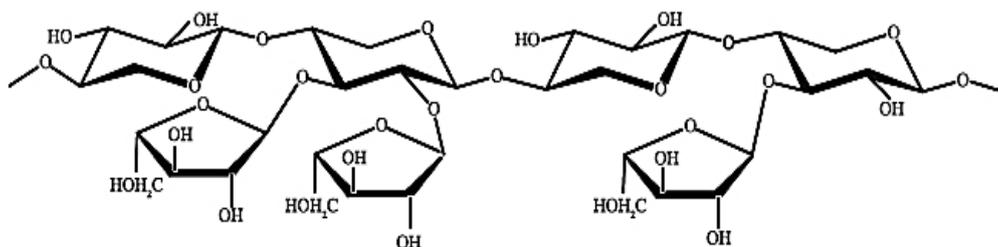


Fig.(2): Structures of Hemicelluloses.

Lignin

Lignin is the natural glue between fiber in wood and annual plants. As a major cell wall component, lignin provides rigidity, internal transport of water and nutrients and protection against attack by microorganisms. Lignin is simplified as an amorphous polymer consisting of phenylpropane units, and their precursors are three aromatic alcohols (monolignols) Fig.(3) Specifically, (1)

p-coumaryl, (2) coniferyl, and (3) sinapyl alcohols. The respective aromatic constituents of these alcohols in the polymer are called p-hydroxyphenyl (H), guaiacyl (G) and syringyl (S) moieties [8]. All types of lignocellulosic fibers lignin are composed of these three phenyl propane units [9].

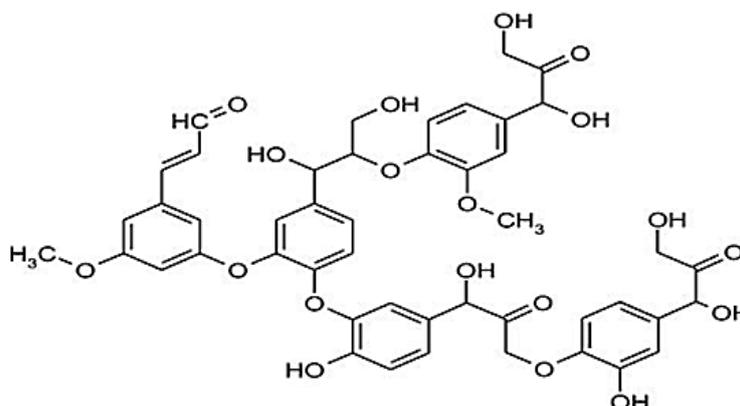


Fig.(3): Structure of Lignin.

Advantages and disadvantages of lignocellulosic fibers filled polymer composite

Advantages and disadvantages of lignocellulosic fibers in general relate to durability, fiber strength and commercial acceptance. Other considerations include cost, the renewable nature of natural fiber compared to synthetics, lack of skin irritations and the biodegradability of lignocellulosic fibers [10]. Disadvantages include supply and demand cycles based on product availability and harvest yields, moisture absorption, and quality variations based on growing sites and seasonal factors. A few advantages and disadvantages of lignocellulosic composite materials over routine ones are as per the following:

Disadvantages of lignocellulosic fibers

Comparing to conventional reinforcing fiber like glass, carbon and Kevlar, lignocellulosic fibers have the following advantages:

- Environmentally friendly
- fully biodegradable
- Non-toxic
- Easy to handle
- Non-abrasive during processing and use
- Low density/light weight
- Compostable
- Source of income for rural/agricultural community
- Good insulation against heat and noise [11].
- Renewable, abundant and continuous supply of raw materials
- Low cost
- Enhanced energy recovery
- Free from health hazard (cause no skin irritations)
- Acceptable specific strength properties
- High toughness
- Good thermal properties
- Reduced tool wear
- Reduced dermal and respiratory irritation
- Ease of separation
- The abrasive nature of natural fiber is much lower compared to that of glass fibers, which offers advantages with respect to processing techniques and recycling [11].

Disadvantages of lignocellulosic fibers

However, natural fiber suffered from the following drawbacks:

- Poor compatibility with hydrophobic polymer matrix
- The fibers degrade after being stored for a long period
- The inherent high moisture absorption
- The relatively high moisture absorption
- The tendency to form aggregates during processing [12]
- The low resistance to moisture.
- Low thermal stability [13].
- Hygroscopicity.

Physical and mechanical properties of lignocellulosic fibers

Many researchers have been carried out to incorporate lignocellulosic to produce composites especially of EFB [14, 15, 16], kenaf [17], banana fiber [18], jute [19], hemp [20] coir [21], flax [22] pineapple leaf [23], ramie [24], sisal and etc. Lignocellulosic materials' tower over synthetic fibers like aramide, carbon or glass fiber with their suitable strength properties, low cost, low density, non-abrasive, improved energy recovery and biodegradable [21]. Moreover, it has good thermal stability provides exceptional insulation against heat, and noise [23] that increases these bio-fibers value. Easiness in processing is also an advantage to bio-fibers over synthetics fibers. Aziz et al [25] reported that coconut coir, sisal, sugarcane bagasse, bamboo, jute and wood bond composites had as of now been examined in more than 40 nations around the world. In Malaysia, where oil palm development has come to an amazing 3 million hectares and creating more than 8 million tons of oil yearly, oil palm businesses has left an immense measure of lignocellulosic materials deposits for the most part as strands that can be promptly transformed into helpful quality included items. Oil palm fiber whether from trunk or vacant organic product cluster is an one of a kind fortifying material as it is non-dangerous, renewable, and promptly accessible at moderately minimal effort because of built up innovation to remove the filaments contrasted with other monetarily accessible strands. To date just a little rate of these deposits are transformed into valuable items

and the rest is either left to spoil or most worst, burnt and polluting the environment. Chen et al [26] associated the two types of experimental kenaf/ramie nonwovens to different binders, looking at their mechanical properties, thermal mechanical property, and thermal conductivity. The study shown that the padding times have considerably affected the acrylic-copolymer bonded composite tensile properties. Ochi [27] inspected the mechanical properties of kenaf fiber reinforced poly lactic acid composites. The study discovered that the flexural properties of composites increased as fiber content increased. The biodegradable study too displayed 38% of weight decreases in four weeks of compositing. The biodegradability of composite was established experimentally.

Garcia et al [28] mentioned that Young's modulus increases intensely with the addition of fibers. However, the addition of fibers may lessen the tensile strength, especially rice husks. This is the addition of more fibers increases the delicateness of composites. With greater fiber contents, the plastic does not implant the fibers properly, hindering the development in mechanical properties, as the matrix content is not sufficient to cover the fiber content to achieve higher mechanical strength. Higher fiber content will avoid the matrix wetting the fibers efficiently. The flexural strength increases with more kenaf applied on the hybrid composite because the rice husk with low aspect ratio acts as fillers rather than as fibers and this contributed to the decrease in the mechanical properties. The impact strength is heightened when the fiber content increased up to 50%. Fiber size and types of the fibers also influenced the impact strength. Eng et al. [29] studied the mechanical properties of empty fruit bunch fiber. Bio-composite were arranged by consolidating polylactic corrosive (PLA) with treated or untreated void organic product pack (EFB) fiber by melt exacerbating technique to watch the impacts of fiber surface medicines on the mechanical properties of the bio-composite. Surface treatment of the fiber was led utilizing salt took after by silane treatment. It was found that treated strands indicated unrivalled mechanical properties of the strengthened bio-composite as contrasted and untreated fiber

fortified biocomposites because of the upgraded grip between the EFB fiber and the PLA lattice. In their work, biocomposites were delivered from treated what's more, untreated EFB filaments. Treated EFB filaments were surface treated with soluble base and silane to build their similarity with the PLA framework. Mechanical tests directed demonstrated enhanced qualities contrasted and untreated filaments. Antacid treatment is successful in uprooting polluting influences creating a rougher fiber surface, which advance fiber grip as demonstrated by SEM pictures. Silane treatment goes about as extension between the PLA network and the fiber. As per the results, mix salt and silane is the best surface treatment to get ideal results. Further study will be concentrated on warm properties of the biocomposite.

Conclusions

Given the similar properties of the lignocellulosic composite when considered in relation to synthetic fiber polymer composites, it can be applied in a broad range of applications. Nonetheless, current applications are not widespread in light of the market competition with synthetic fibers. It is important to acknowledge that fact that researches into the mechanical properties of the lignocellulosic fiber polymer composites have not yielded consistent results; specifically, the outcomes are generally variable and dependent on external circumstances. Consequently, if the lignocellulosic fibers and its composites are to rapidly advance and be acknowledged, the hindrances relating to the fundamental and applied spaces must be surmounted. As such, the complexity with which research into the properties of the lignocellulosic fibers and its composites is characterized requires that a greater body of information is gathered insofar as this will facilitate the establishment of concrete assurances regarding their ultimate application. Foremost is the issue of thermal degradation at low temperatures, which is critical as it serves as an impediment for a range of uses; however, a significant quantity of future research is required in order to account for the current lack of insight into this area, and this is especially the case for

lignocellulosic fibers and its composites at high temperatures.

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