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Renewable Biocomposites: An Overview

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ABSTRACT

This assessment is based on a recent evaluation of the literature on cellulosic fibres and biocomposites in general. Natural fibres, such as flax, hemp, and kenaf, which are available as agricultural resources in many nations, have mechanical qualities equivalent to manmade fibres like glass. They are, however, lighter, biodegradable, and frequently said to be less costly. Natural fibre composites have the potential to be a more appealing alternative to synthetic fibre composites. Natural fibres, on the other hand, have more dispersed characteristics, are less thermally stable, and are more susceptible to moisture absorption. As a result, the matrix used to strengthen these fibres becomes crucial.

In the automotive industry, natural fiber-reinforced polypropylene composites have gained popularity. Because of the petroleum-based feedstock and the nonbiodegradable nature of the polymer matrix, natural fiber-polypropylene or natural fiber-polyester composites are not sufficiently eco-friendly. Many environmental challenges can be handled by combining natural fibres with polymers made from renewable resources. Green bio-composites are constantly being produced by embedding biofibers with renewable resource-based biopolymers such as cellulosic plastics, polylactides, starch plastics, polyhydroxyalkanoates (bacterial polyesters), and soy-based plastics.

1. Introduction

Natural fibres (biofibers) such as wood fibres (hardwood and softwood) or nonwood fibres (e.g., rice straw, kenaf, banana, pineapple, sugar cane, oil palm, jute, sisal, and flax) are combined with polymer matrices derived from both renewable and nonrenewable resources to create biocomposites[1-2]. Low cost, low density, competitive specific mechanical qualities, reduced energy consumption, carbon dioxide sequestration, and biodegradability are all advantages of natural fibres over man-made glass fibre. Natural fibres (Figure 1) give poor countries the opportunity to employ their own natural resources in composite processing[3].

To generate composite materials that are competitive with synthetic composites, bio-fibers such as Kenaf, Hemp, Flax, Jute, Henequen, Pineapple leaf fibre, and Sisal must be combined with polymer matrices from both non-renewable and renewable resources. In the automotive industry, natural fibre reinforced polypropylene (PP) composites have gained popularity. Needle punching techniques for natural fiber-PP composites, as well as extrusion followed by injection moulding, as currently used in the industry, require a "greener" technology - powder impregnation technology[4-6].

Due to the petro-based source and non-biodegradable nature of the polymer matrix, natural fiber-PP or natural fiber-polyester composites are not adequately eco-friendly. Sustainability, industrial ecology, ecoefficiency, and green chemistry are driving the car industry to look for more environmentally acceptable materials for interior uses. Many environmental challenges can be handled by combining natural fibres with polymers (plastics) made from renewable resources. Biopolymers based on renewable resources such as cellulosic plastic, corn-based plastic, starch plastic, and soy-based plastic are constantly being produced by embedding bio-fibers with them.

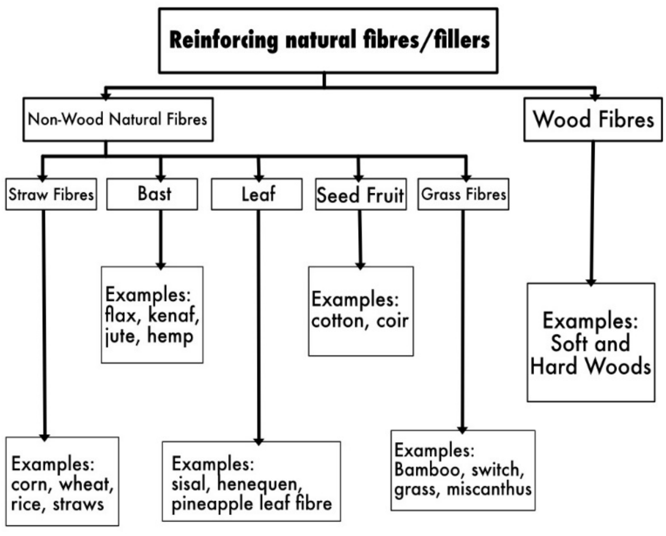

Figure 1: Types of reinforcing natural fibers (Adapted from ref. 1).

Figure 2 depicts the evolution of renewable resource-based bio-composite products. Biocomposites (**Figure 3**) include: (i) petroleum-derived, non-biodegradable polymers such as

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polypropylene (PP), polyethylene (PE), polyester, epoxy, or vinylester reinforced with biofibers; (ii) biopolymers (e.g. PLA, PHA) reinforced with biofibers; and (iii) biopolymers reinforced with synthetic fibres such as glass or carbon. Green composites are biopolymers reinforced with biofibers that are generally believed to be more environmentally friendly[8-9].

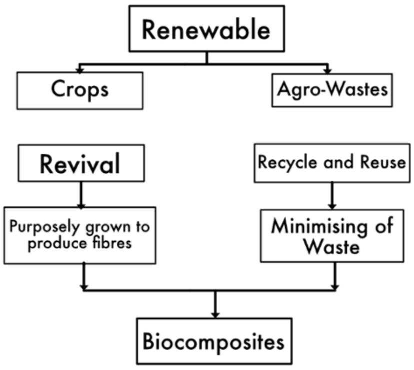

Figure 2: Development of biocomposites from renewable resources. (Adapted from ref 4)

2. Classification of biocomposites

Biocomposites can be divided into two categories based on their applications in the construction industry: structural and nonstructural biocomposites[7]. A structural biocomposite is one that is required to carry a load while in operation. Load bearing walls, staircases, roof systems, and subflooring are examples of structural biocomposites in the construction sector. Structural biocomposites are available in a wide variety of performance levels, from high to poor. A nonstructural biocomposite is one that does not need to carry a load when it is in use. Thermoplastics, wood particles, and textiles are utilised to create biocomposites of this type. Ceiling tiles, furniture, windows, and doors are all made of nonstructural biocomposites.

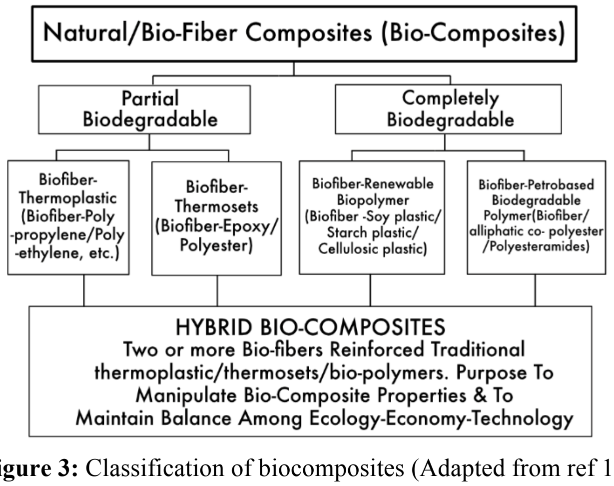

Figure 3: Classification of biocomposites (Adapted from ref 1).

Because of its various advantages, such as lower weight and cheaper manufacturing costs, biocomposites are currently the topic of intensive research, particularly in the construction and building industry. Biocomposites are now being used for a variety of items, including decking and fence, by not only builders but also many homeowners.

3. Matrics for biocomposites

Synthetic non-biodegradable polymers, such as polypropylene, polyester, and others, are currently being investigated as matrix materials for use in industries such as vehicles and construction. Biodegradable polymers can pave the way for bio-composites in the future if they are made available in large quantities and at reasonable rates. Bio-composites become appealing alternatives from an environmental standpoint because both the matrix and the fibres are biodegradable.

Crosslinked or network architectures with covalent linkages between all molecules characterise thermosetting polymers[5]. The application of heat and high pressure, or a chemical reaction, is used to shape them. The application of heat and pressure will not be able to reform it (irreversible process). Epoxies, polyester, and vinyl ester are examples of thermosetting polymers. Thermosetting matrices are more commonly utilised for high-performance advanced composites than thermoplastic matrices (reversible process). Polyethylene (PE), polystyrene (PS), nylons, polycarbonate (C), polyactals, polyamide-imide, polyether-ether kenote (PEEK), polysulphone polyphenylene sulphide, and polyether imide are among the thermoplastic polymers.

The ubiquitous use of petroleum-based polymers and plastics is putting increasing pressure on the environment, prompting a push to develop biodegradable or ecologically acceptable materials. Polysaccharides, starch, cellulose, chitin, proteins[6], collagen/gelatin, casein, polyhydroalkanoates, lignin, lipids, and shellac are examples of natural and biodegradable matrices[5]. These biodegradable biopolymers can be utilised in a variety of applications, but they work best in products with short life cycles or those that are meant for one-time or short-term use before being discarded. As a result, the type of matrices to use is determined by the product applications, and structural components in long-term use (durable condition) are usually taken into account. The mechanical properties of thermosetting polymers are generally substantially higher than thermoplastic polymers in terms of strength and stiffness[3,10].

As a result, thermosetting polymers are more widely used and considered as structural biocomposites for building materials and structures than thermoplastic polymers.

4. Applications of biocomposites

Green materials and constructions are a movement that has gotten a lot of attention in recent years. Green buildings have recently been proposed as ecologically friendly, economically feasible, and healthful places to live and work. Biocomposite is one of the most common materials used in green construction today. Synthetic fibre reinforced composites are being phased out in favour of biocomposites[11].

They are environmentally friendly and aid in the reduction of the rising expense of petroleum-based components. Natural fibres or biofibers (typically sourced from plants or cellulose) are combined with polymer matrices to form biocomposites. Renewable, recyclable, biodegradable, low specific gravity, and high specific strength are just a few of the benefits of biofibers. Furthermore, the use of biofibers helps address the environmental and economic challenges associated with industrial materials. Biocomposites have gotten a lot of attention lately, from academia as well as industry like construction, automotive, and packaging. Building applications, either structural or nonstructural components such as window, door, siding, fencing, roofing, decking, and so on, have a high growth rate among all existing applications[12].

5. The benefits of biocomposites

The advantages of natural fibers have currently attracted the manufacturer's attention. These advantages can be categorised into the following groups:

• Plant fibres are renewable resources. During manufacture, they require little energy. Furthermore, natural fibres are carbon neutral, and composting is an option for their disposal.

• They are organic, natural things. When opposed to glass fibres, they have no cutaneous issues and do not produce a biohazard when discarded.

• Natural fibres are non-abrasive and have a lot of flexibility.

• Natural fibres are light and easy to work with (less than half the density of glass fibers).

• Natural fibres are less expensive than glass fibres.

• In experiments, natural fibres had a safer crash behaviour (i.e., no splintering). Due to their hollow tube construction, they also have good thermal insulating and acoustic qualities.

• Extremely high specific strength

• Excellent sound insulation.

6. Conclusions

Recent advancements in natural fibre development and composite science have opened up new possibilities for greater value-added materials made from renewable resources, as well as increased support for global sustainability. Thus, the primary goal for creating biocomposites has been to create a new generation of fiber-reinforced polymers that are competitive with glass fibre reinforced composites in terms of manufacture, usage, and removal while also being environmentally friendly. Natural fibres are biodegradable, and bioplastics made from renewable resources can be tailored to be biodegradable or not depending on the needs of the application. Bioplastics and biocomposites made from renewable agricultural and biomass feedstocks can be used to build a portfolio of sustainable and environmentally friendly biobased products that can compete and capture markets currently dominated by petroleum-based products.

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