IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

A REVIEW ON NATURAL FIBER REINFORCED POLYMER COMPOSITES AND ITS PROPERTIES.

Anushree Sinha* , Dr Pratibha Mishra, Dr Manisha T Sharma***

***B.B.D University ,Lucknow.**

****D.A.V.P.G.College, Kanpur.**

Abstract - Recently, there has been a rapid growth in research and innovation in the natural fibre composite (NFC) area. There are dozens of types of natural fibres with different properties influencing their use, or not, in specific industrial applications. Natural fiber reinforced composites is an emerging area in polymer science. These natural fibers are low cost fibers with low density and high specific properties.The natural origin of these materials causes, in general, a wide range of variations in properties depending mainly on the harvesting location and conditions, making it difficult to select the appropriate fibre for a specific application. In this paper, a comprehensive review about the properties of natural fibres used as composite materials reinforcement is presented, aiming to map where each type of fibre is positioned in several properties.This review paper is intended to provide a brief outline of work that covers in the area of biocomposites, major class of biodegradable polymers, natural fibres, as well as their manufacturing techniques and properties has been highlighted.

Keywords -natural fibre,biocomposites, biodegradable, polymer.

<u>Introduction</u> –

Nowadays in manufacturing industries require some kind of material which is low in cost, high in strength, stiffness, and density with improved sustainability. Composite material plays an important role in improving in a variety of applications. composite materials are become a boon for the manufacturing industry because of their eco friendly nature.[1]To improve the interfacial matrix fiber bonding of composites we will add many chemical modifications which will result improvement in the tensile properties of composites. In the fabrication of the composite materials, it has been revealed the utilization of natural and synthetic fibers in a variety of fields like construction, mechanical, automobile, aerospace, biomedical, and marine. Though composite materials have the high durability property which leads to accumulation of plastic waste in the environment, this problem has been arise. In result many researchers around the world are doing research on environmentally friendly materials associated with cleaner manufacturing process. They are also working on decomposing of waste material processes around the world.

The utilization of natural fibers as alternative materials in many industrial sectors has been of major global interest, for moving towards a greener environment and sustainability. These natural fibers, e.g., kenaf, sugar palm, flax, jute, hemp, etc. have been incorporated with polymeric resins to form new materials, called natural fiber composites (NFCs). These natural fibers can be mixed with bioplastics such as PLA, phenolics, and starch to produce green composites.

Natural fibers in simple definition are “fibers that are not synthetic or manmade. They can be sourced from plants or animals”[2]. In 2010 natural fiber reinforces polymer composite industry sector reached U$2.1 billion worldwide. It is estimated that the growth of NFPCs industry in last 5 years (2011-16) reached 10% worldwide [3].the growth of this industry is very rapid and quickly because of its eco-friendly nature and different structures which can be molded into different patterns. The most common and commercially natural fibers in the world and world production have been shown in Table-1 [4].

Fiber source	World production (ton)
Bamboo	30.000
Sugar cane bagasse	75.000
Jute	2300
Kenaf	970
Flax	830
Grass	700
Sisal	375
Hemp	214
Coir	100
Ramie	100
Abaca	70

Globalization and sustainability has made life not only feasible but challenging too. Materials which are obtained from resources that are renewable tend to be suitable for sustainable development. These materials have a global value since they can act as a counter to the various environmental issues such as waste management problems, increase in global warming, the constant rise in oil prices and the deteriorating fossil resources. Different varieties of renewable materials have been used for many years across the food, furniture, and textile industry such as vegetable oils, starch and cellulosic based polymers, cotton, natural fibers, silk, and wool [5]. On the other hand, it is only recently that these materials have gained interest as a potential alternative to synthetic based polymers for different kinds of industrial applications like automotive, films, construction, paper coating, packaging and biomedical applications. The synthetic polymers pose many drawbacks towards the environment in ways such as the amount of vapors and toxic gases released after incineration and improper disposal, there has been more research work being focused on new green biopolymeric materials and their effective utilization in green composite applications. Over the years, bioproducts have gained commercial importance. Chemical processes such as production of ‘green’ ethylene through dehydration of ethanol 1 and further production of ‘green’ polyethylene, polyvinyl chloride and some other plastics have been reviewed. Certain technological developments have also been used to enhance certain material properties of polymers that are bio-based; an example of which is development of heat resistant polylactic acid, thereby allowing extensive applications. Bio-fibers with stable properties are being produced over time by optimizing plants. There have been numerous applications occurring lately such as packaging, biomedical products, textile, agriculture, construction where these biodegradable biopolymers and biocomposites are an appropriate sustainable replacement [5,6].

Biospecific and biosimulation materials cover the whole field of biofunctional materials. Biofunctional materials are synthesized from the view point of functionality design. The functionality design is based on determination of the polymer structure that realizes the desired functionality and property of materials, and on exploration of the appropriate method of polymer synthesis, polymer reaction, and polymer modification that yields the designed polymer structure.

Concept of composites

A composite is a structural material which includes a combination of different entities that are insoluble in each other and are mixed together at a macroscopic level [5]. One of the constituents is known as the reinforcing phase and the other one into which the reinforcing phase is embedded is called the matrix (Figure 1). The reinforcing phase materials are found to be made of varying textures that can be in the form of flakes, fibers or particles [6]. On the other hand, the matrix phase materials are generally made of continuous phases [7, 8]. One of the most common examples of naturally found composites includes wood (cellulose fibers are reinforced into lignin matrix) and bones (reinforcements of bone-salt plates consisting of phosphate and calcium ions are added to the soft collagen matrix). Each constituent of the composite has different roles giving rise to a strong structural material. The matrix component within composite materials gives a defined shape, protects the reinforcements from environmental damage, transfers loads to reinforcing phase and improves the toughness of material [9]. The reinforcements in composites get strength from the matrix, stiffness and other mechanical properties; contain a high thermal expansion coefficient, high conductivity and good thermal transport [10].

Natural Fiber Reinforced Composite Material

Reinforced phase plays a very important role in determining the overall properties of the composite. Natural fibers can be broadly classified into 3 categories: Plant - based fibers, Animal - based fibers, Mineral - based fibers. One of the commonly used reinforcements is the mineral - based fibers, including carbon, fiberglass and Aramid [11].

Carbon fibers

Carbon fibers are unidirectional reinforcements. Due to this unique structural property of Carbon fibers, they can be structured in a way wherein the composite is stronger in a particular direction making it easier for the composite to bear heavy loads. The physical properties of carbon fiber can be modified by controlling different parameters such as the alignment of fiber, nature of the matrix, fiber-matrix volume fraction and the molding conditions.

Glass fibers

Glass is known to be extensively used as reinforcement in most of the polymeric matrix composites (PMCs). The main advantages observed during usage of glass fibers include low cost of production, good chemical resistance, high tensile strength, and excellent insulating properties.

Kevlar fibers

Kevlar fibers are known to belong to highly crystalline aramid (aromatic amide) fibers. These fibers have a very high ratio of tensile strength to weight and the lowest specific gravity among the currently used reinforcing fibers. Due to their superior mechanical properties, they tend to find major applications in marine and aerospace industries.

Boron fibers

Boron fibers are especially known for having extremely high tensile modulus. Another prominent feature of these fibers is the buckling resistance that results in a high compressive strength for boron fiber reinforced composites (Figures 1and 2).

Figure 1.

Different types of natural fibers used as reinforcement in polymer composites.

Natural Fiber Natural fiber materials have become increasingly popular in the manufacturing industry and have been studied by many researchers. Natural fibers are divided into three categories, namely, cellulose-based, protein-based, and mineral-based, as shown in Table 1. Natural fibers are sustainable materials that are available in nature and have advantages as listed in Table 2. The compositions of natural fibers can be divided into three main components, which are cellulose, hemicellulose, and lignin. Table 3 displays the chemical composition of the natural fibers, in which the chemical composition and cell structures are quite complex and differ between plant parts and origins. Depending on the cellulose crystallinity, the physical, chemical, and mechanical behaviors of the lignocellulosic fibers.

Though the present composite industry majorly depends on synthetic reinforcement fibers, the use of natural fibers have been gaining attention in recent years for academic as well as industrial purposes. In the present time, many different plantbased natural fibers have been explored and researched upon to identify unique properties. Some of these are used in plastics as an reinforcement; some examples of which include hemp, kapok, jute straw, paper mulberry, oil palm empty fruit bunch, wood, wheat, barley, kenaf, rye, rice husk, cane (sugar and bamboo), flax, reeds, oats, sisal, grass, coir, pennywort, water hyacinth, raphia, ramie, pineapple leaf fiber, banana fiber and papyrus [9].

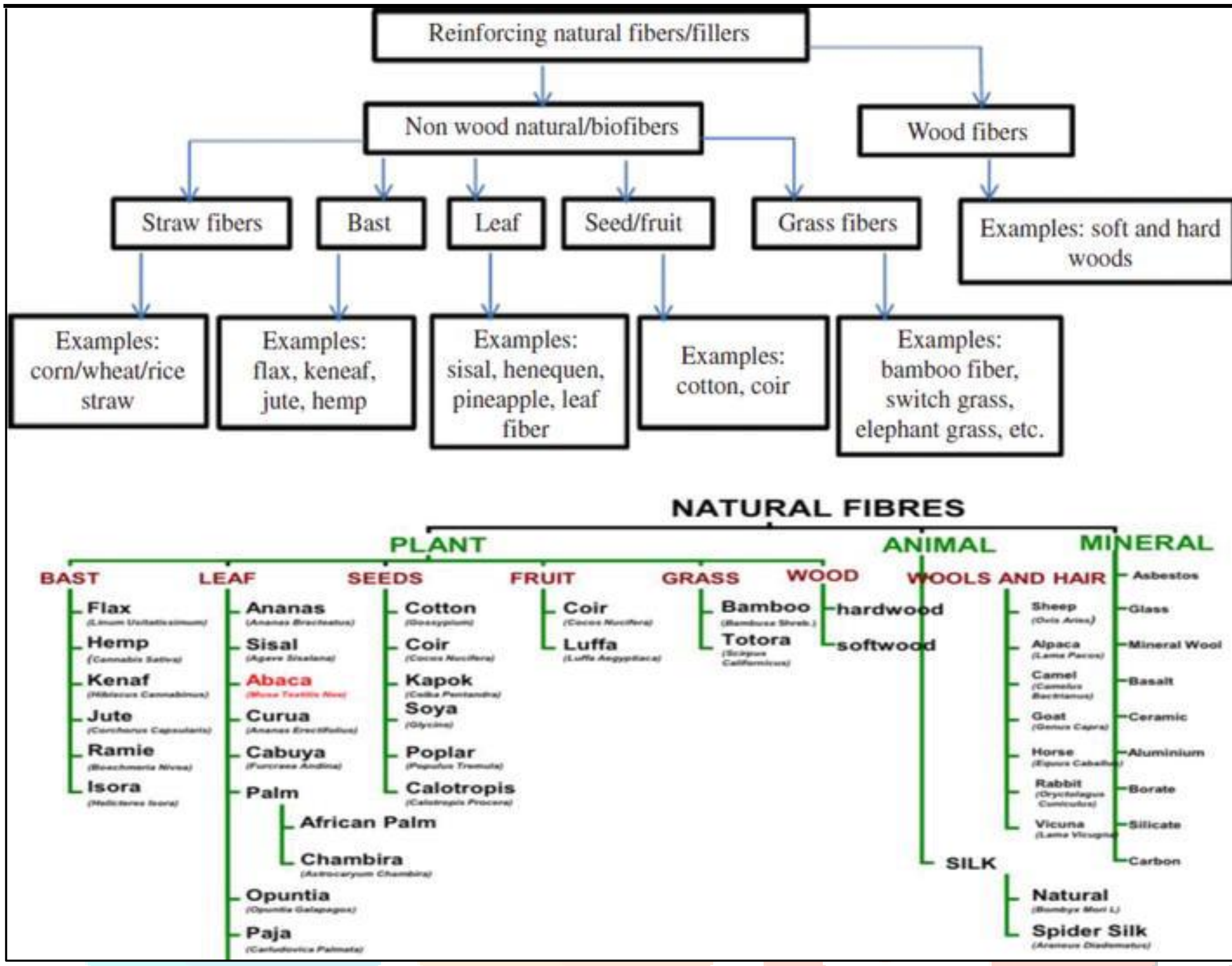

Figure 4. Classification of various fibers of different origin and types with examples [12, 13].

One of the on-demand natural fiber reinforced composite is the thermoplastic matrix containing reinforcements made of special wood fillers due to them being light in weight, possessing reasonable stiffness and strength. Natural fibers have shown immense potential to be used in replacement to non-renewable materials due to their low cost, promising thermoplastic properties, minimal to zero health hazards and can act as a solution for environmental pollution [12, 14]. Some plant proteins have also been used as reinforcements. One such example is the wheat gluten, which when plasticized have a unique ability to form a strong cohesive blend with high viscoelastic properties [15,16,17]. Due to these distinctive properties, wheat gluten has been tremendously used in the making of packaging materials and edible biodegradable films.

Composites based on biologically degradable polyester amide and different plant fibers like flax and cottons, have been investigated thoroughly. These composites generally possess good mechanical properties, such as high biodegradability and good water resistance. Kenaf is a biodegradable and environmentally friendly crop belonging to the hibiscus family (Hibiscus cannabinus L). In a particular research work, Aziz et al. manufactured composite made of a polyester resin reinforced with Kenaf fiber and further studied the mechanical properties of the composite. The properties displayed by the composite were highly satisfactory and fiber could be blownto a height of at least 10 meter. By looking at the present research scenario, natural fiber reinforced polymer composites have the capability to act as a substitute for scarce wood and wood based materials that have many structural applications in the future [18] (Figures 3 and 4).

Plant - based fibers, also called vegetable fibers, are classified into different types based on their origin [19]. The characteristics of plant fibers majorly depend on certain factors such as the type of plant used, the area where it is grown, the plant's botanical age, and the protocol of extraction used. One such example is coir which is known to be a tough and hard fiber with multicellular layers, with the central portion called as "lacuna". Another familiar example is Sisal leaf fibers which are observed to have a high mechanical strength. Pineapple leaf fiber extracts Figure 4. Classification of various fibers of different origin and types with examples [20,21]. 9 Eco-Friendly and Biodegradable Green Composites DOI:

http://dx.doi.org/10.5772/intechopen.98687 are soft and are rich in cellulose. Oil palm fibers, having a similar cellular structure to coir, are hard and tough. Cellulose molecules make the major constituents in most of these plant fibers. The hydroxyls groups present in the basic unit of cellulose have the ability to form intra-molecular hydrogen bonds where the bonding is within the macromolecule, or intermolecular hydrogen bonding between two different cellulose macromolecules and or form hydrogen bonds with hydroxyl groups present in the atmosphere. It can be observed that all plant fibers have a high hydrophilicity, with their amount of retained moisture reaching about 8–13% [22]. Though cellulose is present in a huge quantity inside a plant, they also contain other natural substances such as lignin. The major role of lignin is to act as a cementing or bonding material between the cells of plant fibers. The content of lignin fibers influences a plant's structure, its morphology and its properties.

An important property of vegetable fiber influencing its reinforcement properties is the degree of polymerization (DP). The fibers differ drastically from each other due to the presence of cellulose molecules with differing DPs. Most of these fibers generally consist of a mixture of a base polymer homolog with the configuration $(C_6H_{10}O_5)_n$. The plant fiber known to illustrate the highest DP among other plant fibers is Bast fibers, with values nearing 10,000. In the olden times, these fibers found tremendous applications as packaging materials such as gunny bags and sacks, for making ropes, as a geo-textile material, for making twines and cords, and as carpet-backing [23, 24]. The most common bast fiber found in Cannabis sativa plants is Hemp, which is a lingo cellulosic fiber, repeatedly used as reinforcement in biodegradable composites. It is used in the making of various items such as shoes, toys and clothing, due to its non-toxicity, biodegradability and its ease for recycling [25].

Advantages and Disadvantages of natural Fiber reinforced composite

The advantages of natural fibers are as follows:

1. They are resistant to fire.

2. Natural fibers on burning do not produce poisonous gases.

3. Natural fibers are easily affordable.

4. These fibers absorb sweat and water and hence such clothes are comfortable for summer months.

5. Natural fibers are safe for human skin and are biodegradable.

The disadvantages are as follows:

1. The strength of natural fibers is very less as compared to synthetic fibers.

2. Natural fibers are heavy in weight.

3. Natural fibers can be damaged by moths and other insects.

4. These fibers are not wrinkle-free.

5. These fibers are not long lasting and hence not durable.

Future perspective

Construction and automotive industry are the key markets for biocomposite materials. However, new prospects and applications will arise with certain future innovations and performance enhancement. Due to the accumulation of waste generated by this industry and their harmful effect on the environment which remains a growing concern, a lot of opportunities are going to emerge in this particular sector. Instances such as off-site construction method, for better quality and effortless installation and build, eco-friendly resources are required; although, these prospects could be affected by guidelines based on the present resources. A key target would be in replacing preservative-treated wood which provides a huge market growth. By placing strict limitations on utilization of preservatives such as arsenic containing products, provides immense opportunities for biocomposites to be used in applications especially when there is a threat of microbial attack.

Biocomposites can be incorporated into certain various complex technological applications by enhancing their mechanical functions such as producing new fiber types, processing methods, addition of additives etc. Solvent spinning process when applied to liquid crystalline cellulose creates high strength fibers which has been quite a hopeful research study. Resins can be formed by changing or enhancing the content of particular triglycerides and oils in produces by using biotechnology tools. The resins if altered appropriately would be cost effective and biodegradable compared to existing ones (Figure 3). Studies are being conducted to produce cheap biodegradable resins having decent mechanical characteristics by using novel methods. If successfully produced, the synthetic complexes can be replaced with these biodegradable alternatives.

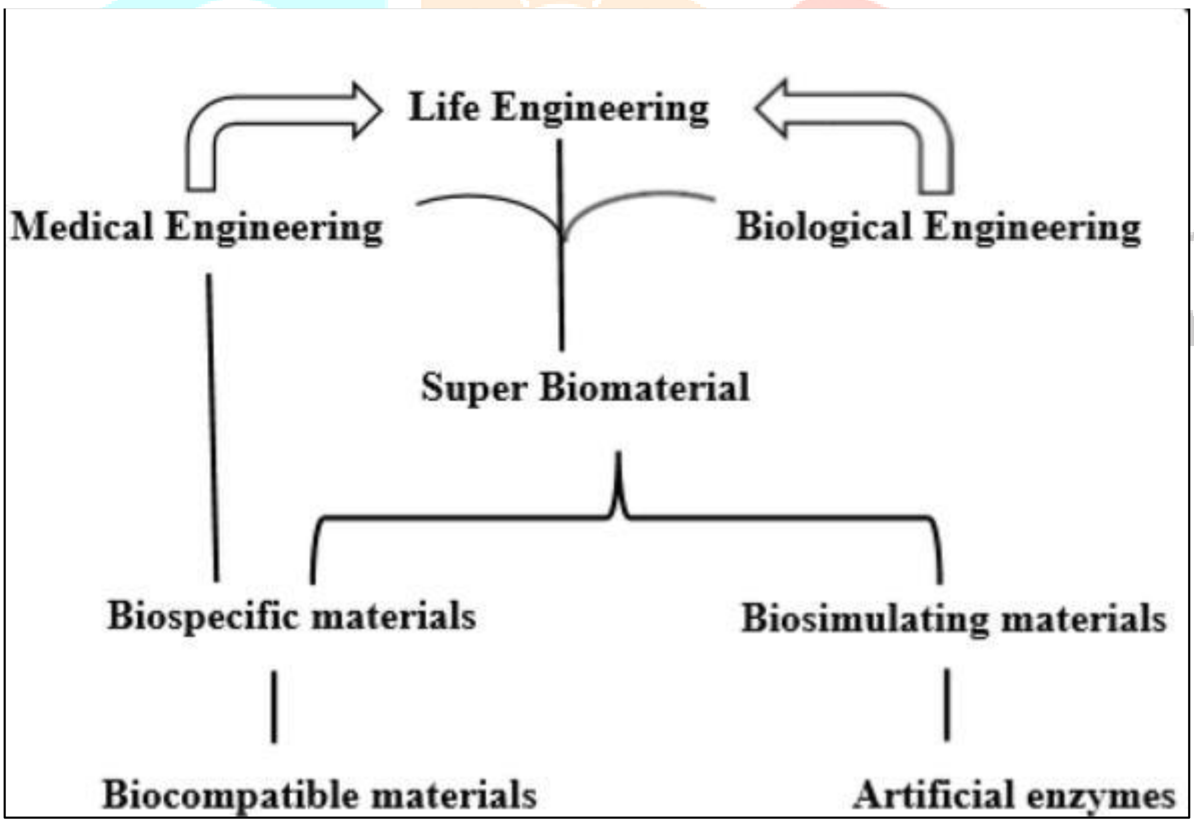

Figure 3.

Scheme for hypothesizing for engineering and biocomposites.

Hybrid materials and products offer scope such as utilization of bio resins and bioplastics adhesives by replacing the existing fossil-based adhesives. Reclaimed fiber provides a decent opportunity to develop various eco-friendly, inexpensive products by utilizing medium density fibreboards or the watercourses of the papermaking industry. Although sufficient prospects are there for these products to be in the market, cost effectiveness is a very important factor for its commercial production and hence the marketing strategy has to be made stronger accordingly. For successful commercialization, the biocomposites should be demonstrated through widespread training and education.

Conclusion

Natural fibers that are renewable and environmentally friendly source of raw materials to create environmental friendly products have played an important role in human civilization. Eco-friendly composites mainly light weight composites and textiles are two of the most popular uses of natural fibers in Indonesia, with ramie and kenaf being the most promising for textile and automotive components. In Malaysia, natural fiber such as kenaf, pineapple also biomass waste from oil palm industry is attractive for further developed for eco-friendly composite. The fascinating properties of natural fibers include lesser density thus lighter weight, more considerable cost, biodegradable, abundantly available, minimal health hazards during processing, reasonably good specific strength and modulus, good thermal, good acoustic insulation characteristics, good physical properties, and ease of availability. To enhance and improve its sustainability, the physical, mechanical, chemical, morphological, and anatomy properties of natural fiber should be considered for appropriate optimal utilization. Chemical properties of natural fiber, such as cellulose in the cell wall, have a strong relationship with tensile properties and density. Natural fibers, despite their advantages, have issues such as low longevity, non-uniform properties, poor adhesion, moisture absorption, and wet ability. In the utilization as composites, the hydrophilicity of natural fibers leads weak adhesion with hydrophobic matrices thus low mechanical properties and poor process ability resulted. As a result, to expand the range of applications for these fibers, the weaknesses should be addressed using suitable technologies.

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