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Natural Fibre based Biocomposites and Their Applications (Brief Review)

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ABSTRACT

The rising environmental and ecological awareness has motivated hard work in support of growth of new pioneering resources for a variety of end-use application. Polymeric composites prepared from natural resources, occupied substantial research awareness from the last upcoming years. In this paper a summarized effort that includes the vicinity of biocomposites, majority of the category of eco-friendly polymers, natural fibres, highlighted with production techniques and properties of these composites are discussed. A variety of interface alteration methods were included to advance the fibre-matrix bond resultant in the improvement of different characteristics of the bio based composites. This paper conclude that the bio based composites constitute a promising field in polymeric composites that increase awareness for applications in various fields ranges from vehicle to the construction industries.

Keyword: Natural fibre, Polymer, Material.

INTRODUCTION

Fibre-built up plastic (FRP) composites have been utilized widely from a long time because of their high cohesion to weight proportion, low thickness, high wearing away resistance, and minimal expense. These FRP composites are most appropriate for various applications like aerospace applications, automotive parts, toy making, building construction and in marine industries. Rising requests for recyclable and sustainable materials due to natural concerns and government policies are encouraging the researchers to use the composites that are beneficial to the environment and thus scientist are using the composites that are prepared by using agrarian and bio-based materials in. Uma Devi et al.,[1] reported viscoelastic properties of the palm leaf and glass fibre based polyester mixture composites.

Tran *et al.,*[2] reported the consequence of the fibre loading and alkali treatment on the mechanical property of short coir/poly butylene succinate eco-friendly composites and found that the chemical behavior of coir fibres enhanced the interfacial bond among the fibre and the resin. Improved tensile and flexural properties be obtained for alkali treat bio fibre loading of 20% properties of short coir based poly-butylene-succinatebio-based composites and found that the substance treatment of coir strands expanded the interfacial bond between the fibre and the network. Better ductile and flexural properties were obtained in case of the alkali treat bio fibre loading. Investigative assessments on the mechanical properties of the hybrid bio based matrix were reported which was made by utilizing the bio fibres. Rice husk, coir pitch and groundnut shell powder were used as particulate bio fillers in the epoxy composites. The outcomes have shown that the hybridization of the bio fillers brought about upgraded mechanical properties and diminished swelling nature of the composite material. It has been analysed to decide the impact of soaking of 5% NaOH on the jute fibres. It was shown that the elastic moduli of the treated jute fibres were increased because of alkali treatment. It was likewise announced that the most extreme flexural strength and laminar shear strength was achieved for the jute/vinyl ester composite with 35% jute fibres. The impact of maleic anhydride (MA) on the properties of banana, hemp and sisal fibres has been explored[3-5]. Composites were prepared by utilizing MA treated bio fibres as filler in novolac resin. Test outcomes had shown that the composites with MA treated fibres were having better mechanical properties. Higher assimilation of steam and water was additionally noticed for the composites with untreated fibres. *Rong et al.,*[6] completed various sorts of surface treatments like warming, silane, alkalization, acetylation, and cyanoethylation on the sisal fibre. The research showed that the fibre treatment brought about halfway evacuation of lignin and hemicellulose of the bio reinforcement. Composites were developed by adding treated sisal fibre in the epoxy matrix and it was shown that the mechanical strength had been improved because of changes in the surface and inward construction of the fibre. Yang *et al.,*[7] reported tests by utilizing lignocellulosic material (like rice husk flour) as space filler in polypropylene (PP) based matrix. Test outcomes showed that the mechanical properties of the composite have diminished by rise in the filler's concentration while Li *et al.,*[8] studied the impact of surface alteration in various bio fibres utilizing different fillers and inferred that synthetic treatment of the fibre brought about better surface attachment and furthermore worked on the elasticity of the fibre.

In view of all such interesting variety of natural polymers and their tremendous application serving the purpose of environment protection, ease of availability and cheap cost made us to compile the details of these polymers in one review paper. This paper will be helpful to study the various properties of the natural fibres and natural fibre based bio-composites.

Natural fibres

Division of natural fibres can be done on the basis of their origins, viz. vegetation, animals, or source from which they are derived. Plant based fibres including bast fibre, leaf fibre of the plant, seed of the plant, fruit, wood, cereal straw and other grass fibres. All plant fibres are having cellulose, whereas animal fibres consist of proteins and their examples are hair, silk and wool.

From the last many years, major focus of the research has been engaged in studying the utilization of natural fibre as composite resources[1-5]. Lignocelluloses based fibres (or Natural fibres) contains main chemical constituent, namely cellulose, hemicelluloses and lignin. Apart from this, these fibres also contain slight quantity of pectin, waxes, and other water soluble substances. Lignocellulosic fibres composition and structure differ very much, depending on plant type, age, type of weather, and soil environment. It is important to know the chemical structure of lignocellulosic fillers and fibres because it determine their property and therefore their uses can be explored. An important part of all lignocellulosic based fibres is cellulose.

Plant fibres or natural fibres can be divided according to their bast, leaf, fruits, seeds and stalk. Examples of Bast fibres are flax, jute, hemp, kenaf examples of Leaf fibres are sisal, pineapple, abaca etc. shown in Figure 1.

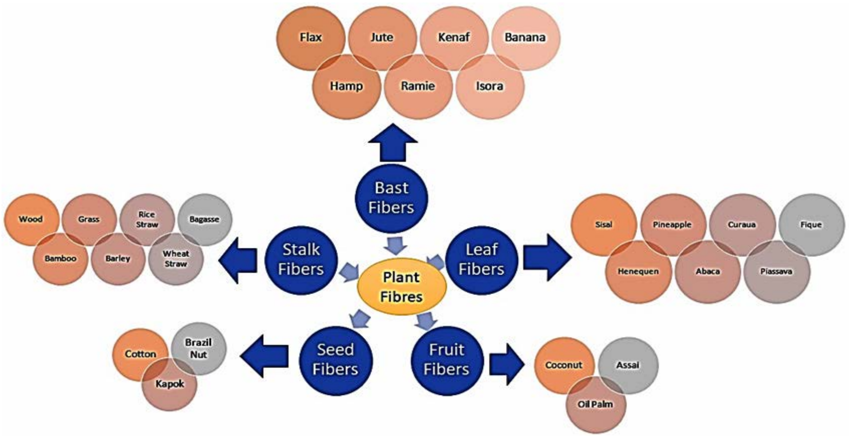

Fig. 1. Plant Fibres and their Classifications

Advantages of Natural Fibres are as follows:-

- It gives good protection against warmth and noise.
- It provides renewable, plentiful and persistent flow of raw materials.
- It is cheaper.
- Small thickness.
- It provides biodegradable nature.
- Provides improved energy revival.
- Without health vulnerability (no skin disorder)
- Suitable explicit strength characteristics.
- Elevated durability.
- High-quality warm properties.
- Reduce device wear.
- Ease of detachment.

Because of the brilliant mechanical properties, natural fibres are widely employed to strengthen biopolymers to manufacture biodegradable composites. A comprehensive perceptive of the properties of these materials is essential to assess their applications to a variety of commodities. The present paper discusses some useful properties linked to various relevance in order to discover the possible uses of natural fibre for commercial applications.

Natural fibres are having major limitation of water absorption capacity which degrades the mechanical properties of the developed composites. Natural fibres are polar in nature and have low interfacial bonding which can be avoided by various chemical treatments like alkali treatment, benzoylation, sodium bicarbonate and thus improved properties of the composites can be achieved after these treatments.

Kenaf- fibre

Kenaf fibre belongs to a rubbery plant family which is also known as deccan hemp. kenaf fibres be one of the significant fibres which belong to hathor fibres and it is mostly worn for paper and cord fabrication. Kenaf plants are rigid, sturdy, and tough and are having high confrontation to pesticides. They are grown 3,000 years back in Asia. The kenaf fibre can be taken out from its flowers, external fibre, and internal core. Kenaf fibres have the ability to be transformed into fine woven fabric. They are recyclable because they are totally biodegradable. From the ancient times, Kenaf fibres were employed for making fabrics fibre ropes and storage space bags. These days Kenaf fibres are used in making composites which are mainly used in automotive, building, wrapping, furnishings, textile, mats and for making paper pulp.[9-11]

Hemp-fibre

The Hemp fibre is a kind of plant life variety grown-up mostly in parts of Europe and Asia. The internal belt is bounded by center and the external coating is stacked to the internal coating by a matter which is just like glue or pectin. Hemp fibres are worn in rope, fabrics and in the variety of construction matter. In current development, it is used to manufacture diverse composites.[12-14]

Jute-fibre

Jute is a noteworthy naturally occurring fibre cultivated in the most parts of world in addition to India, China, and Myanmar Jute fibre usually has length up to 20 cm in a very short span and its fibres can be extracted. Its processing can be done by the chemicals or geographically In organic processing, the stalk is harvested can be put in bundle and then immersed in water for nearly 15 days. This process eliminates the pectin sandwiched between the hathor and the woodland core which aid the division of the fibres. After that fibres are kept to dry.

Jute fibre could be capable strengthening to be employed in composites because of its low thickness, high specific strength and modulus, no wellbeing vulnerability, all around efficiently accessible, sustainability and much lower energy necessity for preparing.[14-15]

Sisal-fibre

The sisal fibre is amongst the mainstream utilized natural fibres and is mostly found in Brazil. The sisal plant can give about 250-300 commercially functional leaf in the time extent of 6-8 years. These fibres shows superior mechanical properties and are generally employed in locomotive manufacturing, transport manufacturing, constructions and in agricultural twine etc Ecological impact on degradation behavior, effect of coupling agent, abrasive wear qualities, and the ageing effect on mechanical characteristics have been reported in case of sisal plastic composites. The prepared sisal/ plasticized wood flour composites were established to be completely recyclable from the degradation test. The procedure of decomposition was enhanced by taking into consideration its lignin and cellulose content in the developed composites.[16]

Flax-fibre

The flax fibres are generally being grown as of the primitive era. Flax fibres can be extracted from the stem of the plant. It is a cellulosic plant and crystalline in nature. A flax fibre is having 90 cm distance end to end and width of nearly 15 µm. Countries like Netherlands, Belgium, and France are the most important manufacturer of flax fibres. Flax fibres are worn in furnishings, fabrics, linen, interior ornamentation accessories, etc. The fibre removal includes the retting, and boiling which will make a few alterations in the properties of the fibres.[17-18]

Coconut fibre (Cocos nucifera)

The coconut fibre can be extracted from the shell of the coconut. Amongst distinctive natural fibres, coconut fibre is the thickset fibre. Coconut trees are mostly found in all region of Asia coir fibre, specifically, is having less weight and solid fibre that has been drawn in logical, business significance because of their particular qualities and accessibility. Contrasted with further natural fibres, coconut fibre has superior lignin and lesser cellulose and hemicelluloses, and elevated microfibrillar point, offer different important property, like versatility, power, and damping, wear, protection from enduring, and elevated prolongation at break. The coir fibre has applications in mats, beddings, brushes, in the upholstery business, horticulture, development, and so on[19].

Bamboo (Bambusoideae) fibre

Bamboo fibre is a natural glass fibre because of the arrangement of fibres in the lengthwise orders. Bamboo fibre is one of the widely accessible vegetation in the thick timberlands chiefly in China. It is utilized as filler in polymer materials because of its less weight, minimal expense, elevated strength, and firmness. Bamboo fibre has been usually utilized for making house, spans, customary boat and so on. The strands removed from bamboo are utilized in the development of new type of superior composites in different enterprises.[20]

Silk (Bombyx mori) fibre

Silk fibres are obtained from silkworms due to its uses in clothes purpose since very old era. Silk is fashioned mainly in China, South Asia, and Europe. Silk fibres can be taken out from the cocoons it is a kind of larva of the insect that undergo full transformation. Silk fibres have excellent mechanical properties like high strength, extensibility, and compressibility.[18]

The mechanical properties of silk fibre based composites was reported, the ultimate strength, elongation at break, and Young's modulus were done by using uniaxial tensile test on a single fiber. Silk fiber-reinforced composites are becoming a future biomaterial having various industrial as well as in medical applications.[19]

Natural fibre composites are made by combining different plant-derived fibres with a polymeric matrix. The natural fibre component may be wood, sisal, hemp, coconut, cotton, kenaf, flax, jute, abaca, banana leaf fibres, bamboo, wheat straw or other fibrous material, and the matrix can be a polymeric material.

Fig. 2. Images of different fibres (Source:Wikipedia)

Different types of polymers when reinforced with the natural fibres then the resultant material is polymeric composites they can be called as bio-composites. Bio based composites are the composites that can be processed by using natural resources. Bio-composites are durable, having low cost and has better performance in the developed these composites are eco friendly renewable in nature, light weight and are having higher strength as compared to the man made fibre based polymeric composites.

Natural fibers taken out from the natural sources are being used from many years as fillers in the polymeric composites as they provide immense strength and ductility. After choosing a proper ratio of the polyer material and a filler ratio a new developed composite can be utilized for a specific application. Polymer matrix: Plant based fibres such as hemp, flax, jute, kenaf and sisal are being used in making green composites which are an alternative to the synthetic fibre based polymeric composites.

The use of renewable and recycled energy declined the use of petrochemicals and minerals and thus reduced the deformation of natural energy. Bio based polymeric composites are useful for both the academicians as well as for the researchers Polymeric composites can be prepared by various methods like polymerization techniques, melt mixing methods, extrusion process, powder mixing solution mixing techniques etc.

A major role of bonding exist between the fibre and the polymeric matrix and therefore in order to get excellent reinforcement the superior quality of fibre must be taken. An impotant requirement to have better fibre matrix adhesion should be optimized.

For instance coir fibre and jute fibre reinforced bio composites are used in concrete panels which are highly durable as they are not affected by the acid or any other chemicals having high concentration of sulphates. Therefore coir reinforced panels and jute reinforced panels are used in making concrete slabs which provides light weight loading structures.

Factors affecting the processing of composites

Fibre dispersion

Fibre dispersion is the major factor which influence the property of short fibre composites it is specially a confront for natural fibre based composites, which usually have hydrophilic fibres and hydrophobic nature. while large fibres can additional amplify the inclination to agglomeration. Fibre dispersal in a good manner results in high-quality interfacial bonding, dipping void by ensuring that fibres are completely bounded by the mold. Fibre dispersal can be inclined by manufacturing factors like high temperature and strain, fillers like stearic acid have been used in polymers to alter dispersal and to enhance interfacial bonding like MAPP which support fibre matrix interaction. Likewise, fibre alteration during graft can also be in use, although it is more costly[20-25]. though utilization of extra concentrated incorporation methods like twin-screw extruder as compared to existing methods lead to improved fibre dispersal, this is usually on the price of fibre smash up and fibre length originate to decrease noticeably throughout the process depends on temperature and screw pattern.[21-26]

Fibre orientation

When the fibres in a composite are leaning similar to the way of the applied force, mechanical properties are often the best. Natural fibres, on the other hand, are more difficult to align than continuous synthetic strands. Depending on the viscosity of the matrix and the geometry of the mould, some alignment is accomplished during injection moulding. However, in order to get higher levels of fibre, on the other hand, standard textile processing of fibres, such as spinning, can be used to make a continuous yarn. However, as the name implies, there is some twisting of the fibres involved. Wrap spinning, a technology employed in the textile industry since the 1970s, may also produce aligned fibre yarns; at this point, small fibre could be transformed into a constant form by the utilization of a loom.[26-31]

The continuous fibre can be made of the short fibre, or it could be made of thermoplastic and used to make the medium material during compression moulding (CM). For making the composites thermoplastic polymers can also be used as a support for the natural fibre if it is oriented in the yarn direction. Continuous fibre tape has recently been created by means of the fibres natural resin as a glue and stretching the tape while it is still wet. Natural fibre composites can be processed a lot in the similar way as continuous synthetic fibre such as filament winding etc. to achieve high-quality of fibre configuration inside the matrix, though it must be remembered that continuous material cannot be processed in the similar manner as invariable artificial fibres[32-38].

Development of composites

Extrusion method, injection molding method and compression molding method, Resin Transfer molding are the majority of widespread methods which are employed for making natural fibre based composites which is used with thermo set composites and pultrusion method have been effectively in use for joint flax based polymeric composites.

Variables deciding properties incorporate temperature, pressing factor and speed of preparing. It can be feasible meant for fibre debasement to happen if it is at high temperature, consequently restricts the polymer networks worn to softening focuses lower than the temperature at which corruption can happen.[39]

In expulsion, thermoplastic, normally as dabs or pellets, is mellowed and blended in with the fibre moved through a solitary or two pivoting screws, compacted and constrained elsewhere in the cavity at a consistent speed through a bite the dust. High screw pace could bring about air ensnarement, extreme liquefy temperature and fibre breakage. Short paces, be that as it may, lead to helpless blending and inadequate wetting of the fibres. This strategy can be utilized all alone or for creating pre-cursor for injection moulding. Twin screw frameworks are preferable mechanical performance over single screw extruders.[40,45-46]

Injection molding can be done with both types of polymers either thermoplastic or thermo sets lattices, despite the fact that is considerably more regularly utilized for thermoplastic grids. Variety of fibre direction happens across the form segment with shear stream along the dividers because of grating bringing about fibre adjusted along the shape divider while a advanced stretch rate at the middle produce fibre that is all the additional dynamically adjusted to the stream course, a design alluded to as casing center construction arrangement is extra critical with higher fibre substance. Lingering pressure in thermoplastic framework composites because of pressing factor gradient, un even temperature profile, polymeric chain arrangement and contrasts in the fibre can lessen composite strength[39]. Because of the thickness necessities, Injection molding of these composites is by and large restricted to composite of fewer than 50 m% fibre content. Fibre whittling down in injection molding with respect to extrusion diminishes the span of the fibre throughout its preparation.

The most utilized technique is compression molding which is employed for the mostly thermoplastic frameworks by free cleaved fibre either arbitrarily situated or adjusted, however can likewise be utilized by thermo set lattices. In this case fibres are typically stacked on the other hand with thermoplastic grid sheet before pressing factor and temperature is applied. The consistency of the network throughout squeezing and warming should be painstakingly controlled, specifically for broad examples to ensure that the lattice is impregnate completely into the gap between the strands. Advanced composite could be delivered by taking in control the viscosity, pressure, time, temperature assessing the sort of fibre and the medium[40]. Film stack have been suggested as it confines normal fibre debasement because of contribution of only one temperature region. Temperature actually should be thoroughly controlled at which a specific composite can be prepared at a temperature in which fibre corruption will happen.

Resin transfer moulding

Resin transfer molding or vacuum injection are dirt free, clogged methods. Arid fibres are kept in the mould, then, at that point its shape is lock via one more form or through a sacking film and then polymer is infused. Whichever with over-tension on the infusion surface or vacuum at the opposite surface the fibres is impregnated. Lay up techniques and high fibre volume substances are conceivable. In this manner, the procedure empowers the assembling of extremely huge items with high mechanical properties. To empower appropriate fibre situation and large fibre quantity substance, a performing pace might be needed. Performing is squeezing the mat with a limited quantity of water into an additional minimal shape. Thick mat of flax fibre are hard to permeate. Enhanced resin stream would after that be able to be gotten by utilizing the thicker sheet fibres like sisal fibre.[41]

Sheet moulding compound

A significant contrast with glass sheet moulding compound is the creation of the molds. Typically pre impregnated are made by slashing the glass fibres and putting them on a film of resin and filler composites. This planning is not suitable for regular fibres as the chopping of fibres is extremely challenging. Different strategies are being created. A fitting strategy to keep a layer of fibres in a particular direction that is adequately free to flow throughout the molding procedure and it is dependent on the kind of fibre and raw material which is being supplied.

This process is similar to the vacuum injection, yet speedier and fewer refined. Following fibre position a container filled with a resin is pour in the item, an unbending top shape is kept and at the border of the arrangement of molds vacuum is applied.[41-42]

Sandwich technique

Nowadays, composite overlays in glass fibre based polymers are developed with boundless distance end to end. Fortified on different side of a froth block they assemble solid pack in boards that are utilized in automobiles, trailer and building development. They give warm protection and can satisfy an essential underlying capacity. Limited scope prototyping has demonstrated that replacement of glass by regular strands is plausible. A lesser insulating yet at the same time very well reasonable for divider and rooftop development are sandwich made of regular fibre composite skin and bamboo fibre columns as the sandwich core. An ideal mix of these unique mechanical masterpiece finished essentially. This idea is currently being worked on.[41-42]

Applications of the bio based polymeric composites

Natural fibre based polymeric resources are actively employed in automotive and aircraft industries and are helpful in manufacturing various types of natural fibres based materials for their internal parts. Polymeric materials are also prepared by using natural fibres for diverse application areas, insulation, impact sound insulation equipment and ceiling panels for thermal insulation applications, and acoustic soundproofing uses. Natural fibres demonstrate a practical prospect in design, by means of an immense assortment of building materials, shapes, and surprisingly working on present generally utilized materials. The utilization of engineered fibres in the area of design can be subbed through regular fibres. They are utilized as material for sunscreen creams, protective clothing, ceiling, and floor covering. The regular fibres like flax, hemp, sisal, and fleece are presently utilized as automotive and electrical parts[43-44]. The coir/polyester built up composite was utilized in the paperweights, projector cover, head protector, rooftop etc. The flax fibres were utilized in new designed cars. Natural fibres are utilized in applications like structure materials, furniture, fabrics, fish nets, pressing resources and also in pulp make. Bunches of endeavors have been made to expand the utilization of regular fibre composites in the car business, especially in vehicle insides. Other than the utilization for vehicle inside parts, it can be additionally utilized for assembling exterior automobile body segments.[45-46]

CONCLUSION

Improved ecological consciousness has led an increase demand for exploitation of bio based fibre to be an efficient strengthening matter in polymeric matrix composites. Bio based fibres are dexterous resources which can substitute the accessible synthetic fibres. The fibres can be typically taken out from plants and animals often suggest deprived resistance to dampness and mismatched quality of fibres turn out to be the main drawback. Consequently, alteration of material property can be done through chemical treatment of natural fibres thereby improving the bond connecting the fibres and the polymer used. Improved functional properties of the composites can be achieved through various chemical treatments. In the coming prospect, the bio based fibre will turn out to be one of the sustainable and renewable wealth which will substitute manmade fibres in a lot of suitable products. At present, reasonable homes and power conservation are the important issues in civil constructions so bio-based materials are given importance because bio-based composites are feasible and can reduce material maintenance cost as well as heat relocation in building. It was reported that fibre based mud bricks were lighter as compared to the conventional mud bricks as the compressive strength of the fibre based mud bricks was higher as compared to mud bricks.[47]

In an another study, Binici *et al.,*[48] investigated that straw fibre enhanced the thermal insulation capabilityof mud bricks and thus helped in conservation of energy in construction of buildings.

Khedari *et al.,*[49] depicted that coir fibre based soil-cement composite blocks were lighter in mass, with compact thermal conductivity.

Fibre based composites have many applications like construction of green houses, fabrics, fabric based boards and they can be used in sound insulation as well as in thermal insulation materials, increased energy efficient buildings.[47-49]

In order to make easy availability and application of the bio-based composites, few points should be taken in to consideration:

(i) Conception which is an important step in the development of bio-based composites resources improvement for future needs of applications.
(ii) Designing of experimental set up for suitable bio composite material.
(iii) Material development by selecting appropriate fabrication techniques.
(iv) Functionality of the developed composites.
(v) Marketing, to estimate the market demand and regulation acts for promotion of the developed composites.[50]

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Conflict of Interest

Authors have no Conflict of Interest.

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