ENVIRONMENTAL BENEFITS OF ECO-FRIENDLY NATURAL FIBER REINFORCED POLYMERIC COMPOSITE MATERIALS

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ABSTRACT

The mounting global environmental and social concern, high rate of decline of petroleum resources, and novel environmental policy have enforced the search for green composite materials, attuned with the environment. The strategy discussed in this report aims to add value to the crops by processing the fibers into so called natural fiber composites. Composites are hybrid materials made of a polymer resin reinforced by fibers, combining the high mechanical and physical performance of the fibers and the appearance, bonding together and enriching the physical properties of polymers. The two main classes of biodegradable polymers are synthetic and natural, which are produced from feedstock derived either from petroleum resources (non renewable resources) or from biological resources (renewable resources).Starch is a natural polymer which possesses many unique properties. Therefore, by combining the individual advantages of starch and synthetic polymers, starch-based biodegradable polymers are potential due to the wide variety of available manufacturing processes, each resulting in their own characteristic products, the design possibilities are numerous. Consequently, a composite product and its manufacturing process can be chosen to best fit the environment in which the products will be made and used. Besides the technical feasibility, manufacturing of composites becomes also financially feasible when using domestically grown natural fibers in combination with simple manufacturing processes..

Keywords: FRP, Eco-polymers, Cardanol, Starch, Fibers, Composites

1. INTRODUCTION

In the present era of environmental consciousness, more and more material are emerging worldwide, Efficient utilization of plant species and utilizing the smaller particles and fibers obtained from various lignocellulosic materials including agro wastes to develop eco-friendly materials is thus certainly a rational and sustainable approach. Any lignocellulosic waste matter can, therefore, be turned into composite products through appropriate R & D work and development in technological aspects. These approaches offer much simpler materials for future use in comparison to metal based composites. Resilience property which makes plastics ideal for many applications like food industries, packaging, construction field and sanitation products etc. petroleum-derived plastics can lead to waste disposal problems, as these materials are not readily biodegradable and because of their resistance to microbial degradation, they accumulate in the environment. Biodegradable plastics and polymers were first introduced in 1980s. There are many sources of biodegradable plastics, from synthetic to natural polymers. Natural polymers are available in large quantities from renewable sources, while synthetic polymers are produced from non renewable petroleum resources. Biodegradation takes place through the action of enzymes and/or chemical deterioration associated with living organisms. Biodegradability depends not only on the origin of the polymer but also on its chemical structure and the environmental degrading conditions. Biobased polyesters such as PLA and polyhydroxyalkanoates (PHA's) have begun to be more accepted since they are prepared from renewable feedstock rather than petroleum and are biodegradable. PLA in particular is finding wider application in areas such as textile, carpet making and food packaging industries [1]. Fiber which is the main element of the composite can be of natural, synthetic or hybrid which is made of combination of any two different classes of materials which can classified in Fig.1.

2. FIBER CLASSIFICATION

Nowadays natural fibers form an interesting alternative for the most widely applied fiber in the composite technology, the use of fibers like flax, hemp, jute or sisal is small since availability of a durable semi-finished product with constant quality is often a problem. Recent research and development have shown that these aspects can be improved considerably. Knowing that natural fibers are cheap and have a better stiffness per weight than glass, which results in lighter components, the grown interest in natural fibers is clear. Secondly, the environmental impact is smaller since the natural fiber can be thermally recycled and fibers come from a renewable resource. Their moderate mechanical properties restrain the fibers fromusing them in high-tech applications, but for many reasons Natural fibers can compete with glass fibers [6].

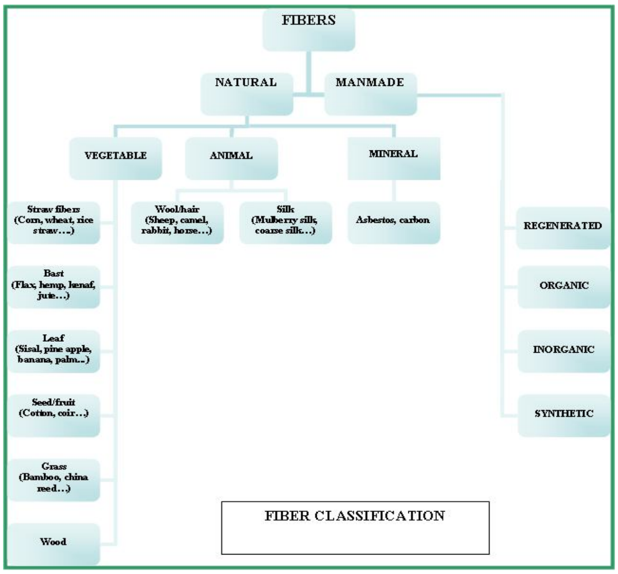

Fig.1 Fiber classification

Table.1 Properties of Fibers

Properties	Glass	Jute	Coir	Sisal	Cotton
Density (g/cm^3)	2.567	1.47	1.25	1.34	1.51
Tensile strength (N/mm^2)	2450	400-800	220	600-700	400
Stiffness (KN/mm^2)	72	10-30	7	38	12
Elongation at break (%)	3	1.8	15-25	2-3	3-10
Moisture absorption (%)	-	12	10	11	8-25

The properties of different natural fibers when compared with Glass fiber is given in Table.1

2.1 Plant fibers: They are generally comprised mainly of cellulose; examples include cotton, jute, flax, ramie, sisal, coir and hemp. This fiber can be further categorizes into following.

Seed fiber: Fibers collected from the seed and seed case e.g. cotton.

Leaf fiber: Fibers collected from the leaves e.g. sisal.

Skin fiber: Fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn and fabric some examples are flax, jute, banana, hemp, and soybean.

Fruit fiber: Fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.

Stalk fiber: Fibers are actually the stalks of the plant. e.g. straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood is also such a fiber.

2.2 Animal Fiber (wool or hair)

Animal fiber generally comprises proteins; it is taken from animals or hairy mammals. E.g. Sheep’s wool, goat hair (cashmere, mohair), alpaca hair, horse hair, wool, silk etc.

Avian fiber: Fibers obtained from birds, e.g. feather fiber.

2.3 Mineral fiber

Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories:

Asbestos: The only naturally occurring mineral fiber. Varieties are serpentine and amphiboles, anthophyllite.

Ceramic fibers: Glass fibers (Glass wood and Quartz), aluminum oxide, silicon carbide, and boron carbide.

Metal fibers: Aluminum fibers

3. MANMADE FIBER

3.1 Regenerated

Recovered after use in a previous application, re-ground into pellets and then re-used on new products, these materials usually come from a single source (i.e. CD cases, car batteries or drinks bottles) and are therefore of good quality and consistency.

3.2 Renewably Sourced

Bio-plastic materials have ingredients from non-depletable resources and can be derived from a selection of sources. Use of these materials is subject to debate, with certain sources potentially depleting the food chain. There are however a range of non-depleting sources available and these options are all an essential part of the selection process.

3.3 Biodegradable

Standard petrochemical derived polymers can last thousands of years. Biodegradable materials are designed to last for the expected life span of a product and then breakdown after use. Additives also exist that will enable a standard materials to biodegrade though it is not fully understood the long term effects of any bi-products are created as a result of the chemicals used.

3.4 Synthetic

Polymers with hydrolysable backbones are susceptible to biodegradation under particular conditions. Polymers that have been developed with these properties include polyesters, polyamides, polyurethanes and polyureas, poly (amide-enamine)s, polyanhydrides. Advantages and disadvantages of natural fibers determine the choice:

Advantages:

- Low specific weight of fibers which results in a higher specific strength and stiffness than glass. This is a benefit especially in parts designed for bending stiffness.
- It is a renewable resource, the production requires little energy, and CO_2 is used while oxygen is given back to the environment.
- Producible with low investment at low cost, which makes the material an interesting product for low-wage countries.
- Eco-Friendly processing, no wear of tooling, no skin problems.
- Thermal recycling is possible, where glass causes problems in combustion furnaces.
- Good thermal and acoustic insulating properties

Disadvantages:

- Low impact strength properties.
- Variation in quality, depending on unpredictable influences such as weather.
- Moisture absorption, which causes swelling of the fibers
- Restricted maximum processing temperature.
- Lower durability, fiber treatments can improve this considerably.
- Poor fire resistance

4. BIODEGRADATION OF POLYMERS FROM PETROLEUM BASE

Synthetic polymers with hydrolysable character, such as polyesters, polyamides, Polyurethanes, polyanhydrides etc are added with additives like antioxidants. Majority of the conventional polymers which are derived from petroleum possessions are resistant to degradation. To facilitate their biodegradation, additives are added. One method of degrading polyolefin consists by introducing antioxidants into the polymer chains. Antioxidants will react under UV, inducing degradation by photo-oxidation.

5. BIODEGRADATION OF POLYMERS FROM RENEWABLE SOURCES

Polymers which are bio-degradable obtained from renewable sources attracted the vision of entire world to focus on this. Research in Biopolymers is happening at fast rate with new inventions day by day. Natural polymers are found in nature abundantly during the growth cycles of all organisms. Natural biodegradable polymers are called biopolymers. Starch, Polysaccharides, and cellulose represent the most attribute family of these natural polymers. Proteins which are another one polymer used to produce biodegradable materials. These are the two main renewable sources of biopolymers. To improve the mechanical properties of such polymers or to enrich their degradation rate, natural polymers are modified using chemicals. Proteins are thermoplastic hetero polymers and are constituted by both different polar and non polar α-aminoacids. One important way of thermoplastic processing is mixing proteins and plasticizers. Plasticizers improve the flexibility. The biodegradation of proteins is achieved by enzymes, as protease, and is an amine hydrolysis reaction.

Necessity of Blending Biodegradable Polymers

Integrating biopolymers such as starch or biodegradable polymers with each other can improve their fundamental properties.

Starch

Starch is a linear polysaccharide of repeating glucose groups; starch consists of two major molecules of 25% amylose and 75% amylopectin. The linkage of amylase to plasticizers such as sorbitol and glycerine allows starch to become flexible and produce a range of different individuality when plasticizer quantity is varied. The addition of nonvolatile and high-boiling hydrophilic plasticizers, such as glycerol to pure starch allows the heated molecules to behave like a thermoplastic synthetic polymer; thermoplastic starch (TPS), the most widely used bioplastic today. However, high-starch-content plastics such as TPS will readily disintegrate when makes contact with water. Blending with other synthetic polymers or composites using natural reinforcing materials will weaken the rigid structure to an amorphous state. TPS is made by mixing starch with any thermoplastic using any one mixing device. As Starch is completely biodegradable and is an environmentally friendly material, moreover starch is very easily available and has very low cost. But the main disadvantage of starch is its high sensitivity to water and has relatively poor mechanical properties compared to other. As a result the only way to improve the mechanical strength and its biodegradation property is to blend starch with any thermoplastic. These blends present several advantages. The material properties can be varied according to the need of the application by modifying its composition. These kinds of blends are intended to be more biodegradable than traditional synthetic plastics.

6. CLASSIFICATION OF ECO-POLYMERS

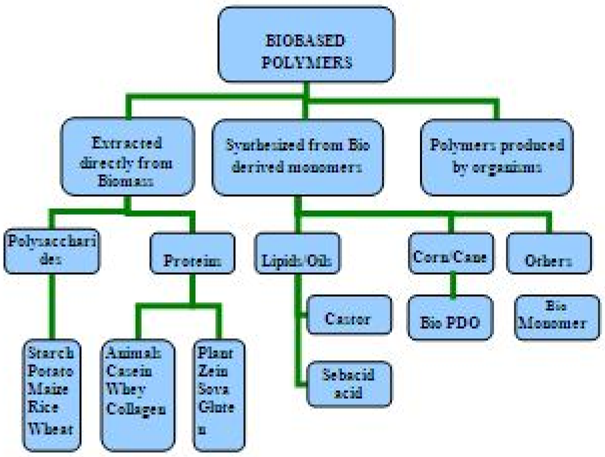

Fig.2 Classification of Eco-polymers

Fig.2 shows the classification of Eco-Polymers. Natural biodegradable polymers or Eco-Polymers are formed in nature during the growth cycles of all organisms. Polysaccharides, as starch and cellulose, represent the attribute family of these natural polymers. Other natural polymers as proteins can be used to produce biodegradable materials. These are the two main renewable sources of biopolymers.

6.1.1 Protein from animal origin

The primary protein component of animal connective tissues is Collagen. There are twenty two types of collagen exist. Collagen is composed of different polypeptides, which contain mostly glycine, proline, hydroxyproline and lysine. The glycine content; which determine the flexibility of the collagen. More flexibility is obtained with an increase content of glycine. Collagen is enzymatically degradable and has unique biological properties. Gelatine is also a protein which is soluble in water and it has good film forming abilities.

6.1.2 Protein from Green origin

Protein derived from plant like wheat is gluten a by-product of the starch fabrication. It is readily available in high quantity and at affordable cost. Wheat gluten consists of two main groups; they are gliadin and glutenin. Gliadins are protein molecules with disulphide bonds with low molecular weight and low level of aminoacids with charged side groups. Glutenins are more complicated proteins, with a three dimensional structure. Their molecular weight is at least ten times higher than that of gliadins. Wheat gluten materials have the fastest degradation rates because; Gluten is fully biodegradable and non-toxic.

6.2 Polysaccharides

The main polysaccharides used in polymeric material applications are cellulose and starch, and all others like Chitin; also exploited on a lesser scale. It is the second most abundant natural biopolymer. It is a linear copolymer of *N*-acetylglucosamine and *N*-glucosamine with β-1, 4 linkages. These units are randomly or block distributed throughout the biopolymer chain depending on the processing method used to obtain the biopolymer. Cellulose is another widely known polysaccharide produced by plants. It is a linear polymer with very long macromolecular chains of one repeating unit, cellobiose. Cellulose is crystalline, infusible and insoluble in all organic solvents

7. COMPOSITES

Composites are hybrid materials made of a polymer resin reinforced by fibers, combining the high mechanical and physical characters of the fibers. The short and discontinuous fiber composites known as whiskers are responsible for the biggest share of successful applications. Whereas, in case of long fibers. By altering the alignment and the direction of fiber orientations, the material properties can be tailored to the external loads. To optimize the construction multiple adjusted layers (laminae) can be used to form a laminate. For instance, composites combine a high stiffness and strength with a low weight and their admirable feature of corrosion resistance in polymeric composites. These composites have economic benefits by using inexpensive raw materials and zero maintenance during service [10]. Composites are now a part of everyday life, and have entered nearly all major industrial, commercial and domestic sectors, including aerospace, packaging, sports industry, hose hold appliances etc.

Attention towards biodegradable polymers is increasing day by day due to severe concerns on managing carbon emissions in a sustainable manner, and the environmental requirements on safe and effective disposal of plastic polymers after use. Poly lactic acid (PLA), produced from annually renewable biofeedstock like corn, is one of the most important biodegradable polymers and is used in lot of commercial applications. Blends of PLA and starch offer cost-performance benefits with increased biodegradability, without compromising environmental benefits. Starch can enhance biodegradability and reduce cost while PLA offers superior mechanical properties. Most eco composite materials can be recycled (composted or digested) or burned, without residues. Plant fibers can be produced by sustainable agricultural systems (Mitchell and Bainbridge, 1991).

7.1 Resin materials

In combination with a suitable resin, the natural fibers can be turned in to NF composites. The resin after heating converted to liquid form and then turns to solid when after curing happens. Whereas the fibers nothing but the reinforcements add strength to the composite.

A good resin should possess the following characteristics:

• Good impregnation to allow all the different fibers to bind with resin to form a single material

• Control moisture content of the natural fibers after processing and should not permit the ingredients to get deteriorated due to change in Environmental factors

• Non-toxic, since major applications are domestic it should not create any harmful effects due to change in environmental conditions.

• High availability, it should be readily available at affordable cost.

7.2 Polymer dispersions (latices)

Polymer dispersions are a mixture of finely divided solid particles in a fluid, usually water. The use of water instead of a chemical solvent results in a non-toxic character. The words latex, polymer emulsion, polymer dispersion and polymer colloids are used interchangeable when talking about polymer dispersions. The particles must be small enough to flow together with the water between the smallest fibers. Upon drying the water evaporates and the remaining particles form a solid layer. Various latices exist, both natural (natural rubber latex for instance) and synthetic (PVC ‘Polyvinyl Chloride’, PP ‘Polypropylene’). Whereas a PVC resin results in a stiff construction, a rubber latex-based composite is still flexible. Phenolic resins have been the first synthetic resins to be commercially exploited [7]. After a decreasing application in past decades, nowadays phenolic resins are more and more used. These resins combine low costs with flame retarding properties and are non-toxic.

7.3 Fiber reinforced Plastic

In the past few decade, there is a growing interest in NF reinforced composites because of their high performance in terms of mechanical properties, significant processing advantages, chemical resistance, and low cost. On the other hand, for environmental reasons, there is an increased interest in replacing reinforcement materials (inorganic fillers and fibers) with renewable organic materials [5]. NFs represent environmentally friendly alternatives to conventional reinforcing fibers (glass, carbon, Kevlar). Advantages of NF over traditional ones are low cost, high toughness, low density, and good specific strength properties, reduced tool wear (nonabrasive to processing equipment), enhanced energy recovery, CO_2 neutral when burned, biodegradability. NFs are complex in their chemical structure; generally they are lignocellulosic, consisting of helically wound cellulose microfibrils in an amorphous matrix of lignin and hemi-cellulose. Mechanical properties are determined mainly by the cellulose content and microfibrillar angle. Young’s modulus of NF decreases with the increase of diameter. A high cellulose content and low micro fibril angle are desirable properties of a fiber to be used as reinforcement in polymer composites [9]. NFs have an advantage over conventional reinforcement fibers in that they are less expensive, abundantly available from renewable resources, and have a high specific strength. Since FRP does not corrode or deteriorate, it can be recycled. More importantly, however, virgin production of FRP usually has less environmental impact than even recycling alternate materials, such as steel and aluminum. FRP composite products have high resistance to corrosion, a longer and more economical service life and require less frequent energy-intensive maintenance and replacement. These inherent advantages lead to superior overall sustainability of FRP products.

8. CARDANOL TO ENHANCE FIBER PROPERTIES

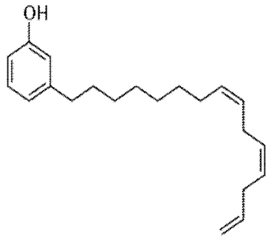

Fig.3 Cardanol chain

Fig.4 Cardanol treated sisal fiber

Cardanol is a phenol obtained from anacardic acid, the main component of cashew nutshell liquid (CNSL), a byproduct of cashew nut processing. Cardanol finds use in the chemical industry in resins, coatings, frictional materials, and surfactants used as pigment dispersants for water-based inks. It is used to make phenalkamines, which are used as curing agents for the durable epoxy coatings used on concrete floors. The name of the substance is derived by contraction from the genus Anacardium, which includes the cashew tree, Anacardium occidentale. The name of the genus itself is based on the Greek word for heart. Friction particles are made by polymerizing the unsaturated side chain of cardanol, followed by cross-polymerization with phenol to yield a cardanol-formaldehyde resin by a process analogous to the formation of phenol-formaldehyde resins such as Bakelite. Cardanol-phenol resins were developed in the 1920s by Mortimer T. Harvey, then a student at Columbia University. These resins found use in vehicle brakes after it was found that they had a coefficient of friction that was less sensitive to temperature changes than phenol-formaldehyde resins. In terms of physical properties, cardanol is comparable to nonylphenol. Cardanol is hydrophobic and remains flexible and liquid at very low temperatures; its freezing point is below −20 °C, it has a density of 0.930 g/mL, and boils at 225 °C under reduced pressure (10 mmHg). Fig 3 shows the cardanol chain structure which is then coated over the natural fiber mesh made of sisal fiber in order to withstand high processing temperature.

Fig.5 Die to make FRP lay-up

Fig.6 Setup to make FRP

Treated fiber with 20% NaOH [2] is then coated with diluted Cardanol in order to withstand high processing temperature and to prevent the natural fiber from deterioration [3], is then dried in a hot air oven for few seconds. Then pure rubber latex in liquid is coated over the fiber mesh. In order to increase the bonding of Polypropylene resin with the natural fiber mesh, moreover the presence of 5% latex [4], in addition to 15% of starch material in polypropylene granule will be blended by maintaining a temperature of 165 degree centigrade and severe mechanical stirring helps in getting a uniform resin in colloidal form. Then the resin is poured inside the die and the fiber is placed immediately and coated over the fiber mesh and then it is compacted with uniform pressure using compression molding process. After few seconds another one layer of resin coating is made and the same process is repeated until the desired thickness of the composite is obtained. To eliminate the chance of delamination, the dies are provided with heating provisions. Because the main chance of delamination arises in places where there is a weak contact between the fiber mesh and the matrix resin, as coating is made with latex the adhesion with polypropylene finds to be good and better bonding happens because of uniform heating allover. Due to the presence of latex the fabricated composite is proven to have good tensile property.

Degradation is a factor which is permissible after prolonged usage in order to save the environment to avoid dumping of plastic. Can be made by the following ways; 1. Modify the polymer for microbial utility by the addition of natural polymers or pro oxidants to polypropylene, 2. Modify the microbes to utilize the polymer by modifying medium composition and hence enhancing the utilization of polymer or genetically modify the microorganism to utilize the polymer, 3. Over express the enzyme which is responsible for biodegradation. Apart from fungal species (aspergillus niger), microbial communities such as Pseudomonas and vibrio have been reported to biodegrade PP. A decrease in viscosity and formation of new groups namely carbonyl and hydroxyl were observed during the degradation process [8].

Fig.7 Natural Rubber Latex

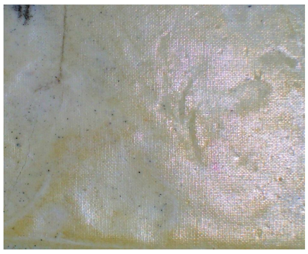

Fig.8 Latex Enriched composite

Figure 7 shows the Natural resin latex which is obtained from Rubber plantations which is the main ingredient to enhance the plasticity of the composite which is shown in Figure.8 upon certain usage the disposal of this material won't be a problem. Because, the ingredients such as natural sisal fiber, Cardanol, Natural latex which deteriorates because of fugal action in the presence of starch as this is blended with PP resin.

9. CONCLUSION

The future outlook for development in the field of biopolymers materials is promising because of its Environment friendly behaviour. Bio-composites often lead to a reduction in weight and costs and potential applications in the fields related to environmental protection and the maintenance of physical health. For these reasons the popularity of these composites is increasing in the western countries and already a significant amount of scientific knowledge is generated. Starch is a vegetable matter renewable from carbon dioxide, water and sunshine. It is biodegradable, cheap and to be physical or chemical modified easily. This means someday it is unnecessary to rely on petroleum resources. This will ensure their continued interest in agro forestry. This is necessary for keeping alive the tempo of tree growing which is necessary for the very survival of humanity.

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