BIO BASED AND BIODEGRADABLE MATERIALS POLYMERS AND NATURAL FIBRES: EMERGING MATERIALS FOR AN ENVIRONMENTALLY GREEN PLANET

Abstract

Plastics have been generally accepted to be to be the most valued materials, due to their exceptional adaptability as well as affordable cost. Their uses include packing, structural, vehicles, aviation parts, electrical components, biomedical, and consumer goods like as toys, cutlery, cameras, and watches. However, the increasing usage of plastics has been a major cause of worry due to their detrimental environmental effect; notably, the sources from which plastics are created and their biodegradability. Almost all synthetic plastics are derived from petroleum and its byproducts. Furthermore, plastics manufactured from fossil fuels are typically non-biodegradable. Biobased polymers or bioplastics are environmentally friendly, biodegradable, and biocompatible. They lessen our reliance on diminishing fossil fuels while being carbon neutral. Despite fulfilling a critical and timely demand for environmental sustainability, bioplastics have failed to establish a prominent position in the plastics sector. This is due to bioplastics' inferior characteristics when compared to synthetic counterparts. As a result, scientists and engineers worldwide have been investigating ways to enhance the characteristics of bioplastics by blending them with other polymers and fibres. Green composites, which are made by combining bioplastics and natural fibres, give a sustainable alternative that is completely biodegradable. Though, studies are being conducted to combine bioplastics with synthetic materials with natural fibres.

Keywords: Biodegradable, Natural Fibers, Polymers, Bioplastic.

Authors

Raghavendra Subramanya
Department of Mechanical Engineering
Sai Vidya Institute of Technology, Bangalore
Visvesvaraya Technological University. Belagavi, India
rvs.sdly@gmail.com

Ravi Kumar M
Department of Mechanical Engineering
BMS college of Engineering, Bangalore
Visvesvaraya Technological University
Belagavi, India
ravikumar.muk@gmail.com

Jatadhara G S
Department of Mechanical Engineering
Siddaganga Institute of Technology
Bangalore
Visvesvaraya Technological University
Belagavi, India
jatadhara@sit.ac.in

Manjunatha K N
Department of Mechanical Engineering
SJCIT, Chikaballapura
Visvesvaraya Technological University
Belagavi, India
bangaloreju@gmail.com

Chandra Shekar A
Department of Mechanical Engineering
Bangalore Institute of Technology, Bangalore
Visvesvaraya Technological University
Belagavi, India
acsmech@gmail.com

I. INTRODUCTION

Plastics have long been regarded as one of the most valuable materials, owing to their exceptional adaptability and low cost [1]. Polyolefins such as polypropylene, polycarbonate, polyvinyl chloride, polyethylene, polystyrene, and others are used to make the majority of plastics. All of these synthetic polymers are made from fossil fuels and its by-products. These natural resources form over thousands of years and are limited in number. Furthermore, plastics manufactured from fossil fuels are typically non-biodegradable. As a result, the depletion of oil reserves, as well as increased environmental consciousness and legislation, have prompted the development of next-generation materials that are environmentally benign and/or readily available to fulfil a growing need for polymers.

Biobased polymers, also known as bioplastics, are created from renewable materials and can be sustainably recycled by biological processes, preserving limited environmental assets (fossil fuels) and lowering greenhouse gas emissions [2-3]. Bioplastics are now sustainable, biodegradable, and biocompatible [4]. Bioplastics are being used in a wide range of industrial uses, including packaging for foods, the agricultural sector, decomposing bags, and healthcare [5].

Aside from those, it is expected that bioplastics are going to be employed in biomedical, structural, electrical, and various other everyday uses as the material's functionality improves.

Considering rising global plastic use, it is estimated that the need for biodegradable polymers would rise by 30% every year [6]. As a result, a great deal of effort is being directed to researching novel green polymeric materials in order to address the ever-growing demand for natural and biodegradable polymers. Some the various types of recognised bioplastics include polylactic acid (PLA), polyhydroxybutyrate (PHB), soy-based plastics, starch-based bioplastics, vegetable oil-derived bioplastics, poly (trimethylene terephthalate), biopolyethylene, and others.

Though bioplastics pique the curiosity of many researchers and technologists worldwide, they have poorer qualities as compared with the manmade substitutes. As a result, their applicability is limited in places dominated by fossil fuel-based polymers.

Biocomposites are extremely important in the material field due to their give distinctive qualities that are not found in nature. Their characteristics can also be altered by selected composition and developing methods. This promotes the adoption of biocomposites in a variety of industries, including aerospace, automotive, marine, consumer items, and electrical components.

II. DIFFERENT TYPES OF BIO POLYMERS

Bio-composites are made by combining bio-fibers such as coir, banana,Kenaf, Hemp, Rax, Jute, and Sisal with resin matrices derived from both renewable and non-renewable resources.

Corn,soy-bean oil, linseed oil, lactic acid, and vegetable oils are used to make biopolymers. As shown in Table 1, the majority of these resins are thermosets and so may be used in LCM techniques to create natural-fiber derived polymer composites.

Table1: List of Commercially Important Biopolymers

Name	Types of Resin	Resin Base
Polylactic Acid	Thermoplastic	Lactic acid
Epoxidized Soybean Oil	Thermoset	Soybean Oil
Polyester Bio-Resin	Thermoset	Soy
Epoxidized Linseed Oil	Thermoset	Linseed oil

Composites made from bio are created by reinforcing natural fibres with bio resins, causing the fibres to absorb liquid matrix and expand. As a result, the porosity of the wetted fiber-preform, and hence its permeability, decreases over time. The presence of cellulose molecules is the primary cause of enlargement and absorption in natural fibres. Because of this pre-wetting of fibres, short fibres are preferred.

1. **Poly Lactic Acid (PLA):** Through fermenting a source of carbohydrates, typically glucose produced by means of starch hydrolysis, lactic acid can be produced.Lactic acid has one asymmetric carbon in its molecule and so has two stereoisomers. L-lactic acid occurs naturally in many species, but D-lactic acid is extremely uncommon in nature.

   PLA is a favoured product above other biodegradable polyesters due to its availability and inexpensive cost. Depending on the qualities evaluated, PLA exhibits mechanical and thermal properties similar to poly(ethyleneterephtalate) (PET) or polystyrene (PS). When compared to polystyrene (PS), PLA has modest barrier qualities (water vapour permeability and oxygen permeability). However, its usage is limited due to its high density, high polarity, low heat resistance, and brittleness.

2. **Epoxidized Soybean Oil:** Among the several derived from petroleum resins, epoxy resins are thermoset polymers that are widely recognised for their outstanding qualities like strong adhesive strength, tensile strength, stiffness, electrical strength, and adequate heat and chemical resistance. Epoxy resins are used in a variety of industrial applications, including adhesives, electronics, coatings, and composites. Brittleness is one of the key disadvantages of epoxy resin. Many usable vegetable oils, including epoxidized soybean oil, can increase epoxy resin toughness while increasing the biobased content of the final composites.[8-9].

   Epoxidized soybean oil is the result of the conversion of soybean oil's double bonds into oxiran groups, which is a triglyceride comprising saturated and unsaturated fatty acids.

3. **Polyester Bio-Resin:** Unsaturated polyester (UP) polymers are employed in a wide range of commercial, domestic, and recreational applications. Fibre reinforced composites, fillers, cabinet equipment, buttons and many more are examples. UP resins are mostly low viscosity liquids, however some can be quite viscous. The two primary components are an unsaturated polyester and up to 60% monomeric styrene as a reactive diluent,

which decreases the total viscosity. Curing necessitates the use of a hardener/initiator. The hardener causes a chemical curing process between the polyester and styrene, resulting in a mechanically robust material.

4. **Epoxidized Linseed Oil:** Because of their outstanding dimensional and thermal stability, as well as a high level of processability, epoxy resins constitute an essential family of thermosets.The most prevalent vegetable oils are made up of fatty acids that include 14-22 carbon atoms and can have between 0 and 3 double bonds between carbon and carbon Linseed oil (LO) especially represents the group of the vegetable oils with the most carbon-carbon double bonds per triglyceride, with an average value of 6.6, which can be selectively functionalized due to their reactivity [10], making it one of the top choices for the synthesis of bio-based thermosetting resins. Linseed oil may be customised by epoxidation to generate oxirane rings as a result of double bond interaction with peracids.

   The processes of linseed oil produces epoxidized linseed oil (ELO), which has qualities comparable to some petroleum-based epoxy resins. By utilising amines [11], anhydrides [12], and anhydrides [13], ELO may be crosslinked in the same way as any other standard epoxy resin.

5. **Starch Based Biopolymers:** Starch-based polymers are distinct because they may be produced using only a resource that can be recycled, natural starch, as opposed to most other bio-based polymers, which need costly synthesis stages. Furthermore, the use of starch as a polymeric material represents an excellent potential for the starch firms to expand its non-food uses sector. Corn, wheat, potato, cassava, tapioca, and rice are the most common sources of starch. It is a polysaccharide composed of two distinct macromolecules based on glucose units, amylose and amylopectin. This polymeric substance is often known as thermoplastic starch (TPS) or plasticized starch. TPS is a thermoplastic polymer that, like oil-based thermoplastics, may be employed in a variety of industrial applications, notably in packaging.

6. **Natural Fibers:** The majority of natural leaf, bast, and seed fibres may be utilised to fill or reinforce thermoplastics. In general, the higher the aspect ratio of the fibre, the greater the increase in characteristics over virgin thermoplastic. Bast fibres are often the best for increasing tensile and bending strength, as well as modulus. Toughness is best achieved with coarse fibres such as sisal and coir fibre. Fines from the processing of wood, coir, agave, hemp, jute, and other natural fibres, as well as rice and nut hulls, cereal straws, and maize cobs, can be used to increase the dimensional stability and stiffness of thermoplastics.

   Some examples of natural fibers and their category are listed below.Table 3.2, the cellulose content and the percentage of several natural fibres is listed. Because cellulose makes up a major portion of natural fibres, swelling is to be considered if bio-resins, which are organic liquids, come into proximity to natural fibres.

Table 2: The Cellulose Percentages of Some Natural Fibers

Fiber	Cellulose Percentage (wt%)
Sisal	66-77.2

Banana	61.5
Bowstring Hemp	69.7
Pineapple	71.6
Ramie	91
Jute	75.3
Hemp	77.07
Kenaf	65.7
Coir	43
sugarcane	50

Sisal is an agave family plant. Sisal fibres are manufactured from the plant's leaves. The fibre is often acquired by crushing the leaf between rollers. The resultant pulp is scraped from the fibre, which is then washed and dried mechanically or naturally. Sisal fibre is coarse and stiff. It is valued for its strength, durability, affinity for certain dyestuffs, and saltwater resistance. Sisal ropes are utilised in a variety of applications, including marine, agricultural, and industrial.

Fibres made of jute. It is a bast fibre and one of the most affordable natural fibres. It has weak moisture resistance, brittles when exposed to light, and readily absorbs paint. Jute is made up of extremely small elementary fibres (0.7-6 mm in length) that are joined together by lignin to produce long brittle fibres (300-400 mm in length).

Coir husk fibres are found inside the husk and the coconut's outer shell. Coir processing is mostly influenced by demand because it is a byproduct of the manufacture of other coconut goods. Given the availability of manpower and other inputs, large amounts of coconut husk mean that coir manufacturers can respond to market circumstances and prices very quickly.

Ramie is a member of the Urticaceae (Boehmeria) family, which has over 100 species. Ramie's appeal as a textile fibre has been hampered mostly by producing locations and a chemical makeup that need more intensive pre-treatment processes than other commercially relevant bast fibres.

Kenaf is a member of the Hibiscus genus, which has over 300 varieties. Kenaf is a novel species in the United States with high potential for use as an ingredient in composite goods. Recent advancements in decortication machinery that separates the core from the bast fibre, along with fibre scarcity, have reignited interest in kenaf as a fibre source.

Natural fibre qualities varied across the papers given because various fibres were utilised, varied moisture levels was present, and various test methodologies were used. The performance of natural fibre reinforced polymer composites is evaluated by a number of parameters, such the chemical composition of the fibre, cell size, microfibrillar angle, defects, structure, physical characteristics, and mechanical properties, as well as the interaction of the fibre with the polymer. It is critical to comprehend the fibre properties in order to broaden the usage of natural fibres for composites and improve their performance. The variety of distinctive values, and they constitutes one of the downsides of all natural goods, is noticeably greater than that of glass fibres, which may be explained by variances in fibre structure related to overall environmental circumstances during growth. Natural fibres can be treated in a variety of ways to provide strengthening components with varying mechanical qualities. Many factors can alter the mechanical characteristics of natural fibres. If cellulose-fibers are utilised as reinforcement in plastics, their hydrophilic nature is a big issue. The moisture content of fibres is determined by the non-crystalline component content and the quantity of voids of the fibres.

The primary drawbacks of natural fibres in composite reinforcement were their lack of interaction with the matrix and their excessive moisture absorption. As a result, natural fibre modifications are taken into account when changing the surface characteristics of fibres to optimise their adherence with various matrices. A firm contact that is particularly brittle in nature with easy fracture propagation across the matrix and fibre might attain an outstanding strength and stiffness. A weaker contact might impair the effectiveness of stress transmission from the matrix to the fibre.

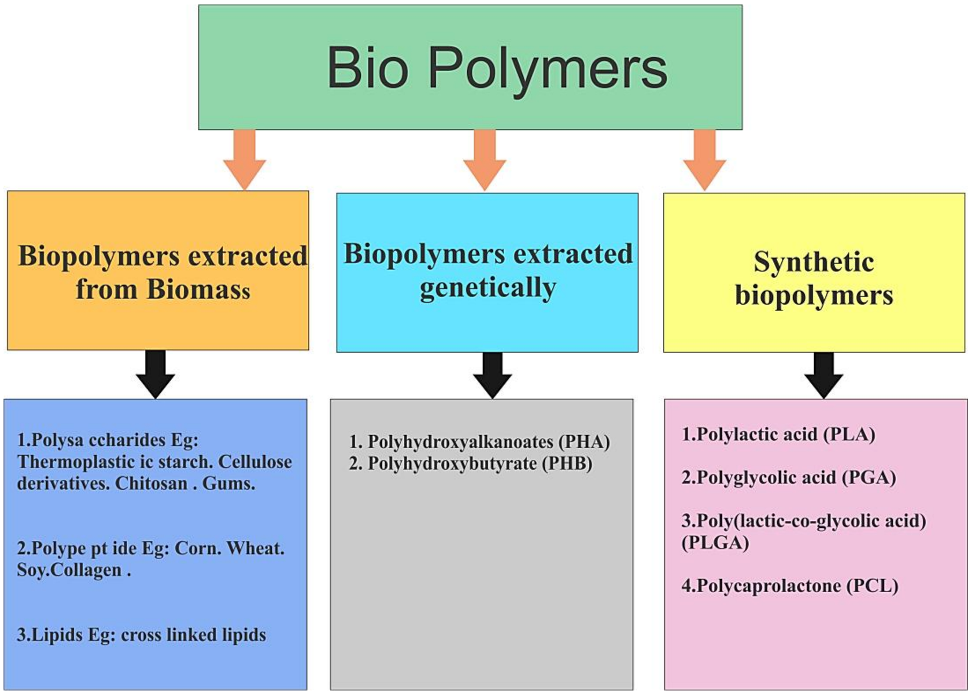

Figure1: Classification of Bio Polymers

III. PROCESSING OF BIO COMPOSITES

There are many approaches to develop the bio composites, few important methods are discussed below.

1. **Hand Lay-Up Method:** The fiber-matrix mixture is manually poured into an open mould, and light pressure is applied by roller to remove entrapped air and improve thermoset compatibility. The limitations are low cost, no size constraints, suitability for research and research and development work, slight surface polish, air pockets, and long curing time.

2. **Filament Winding Process:** Resin-impregnated continuous fibre is wound on a revolving mandrel in a manual, computer-controlled, and regulated fibre orientation. The restrictions are hollow tube-like shapes, continuous fibre, and thermoplastic resin, as well as a high fibre volume fraction.

3. **Pultrusion Process:** Resin-soaked fibres are then pulled through a die of the required shape; the shape of the result is determined by the die cross section. Overall cost is minimal, appropriate for thermosets and thermoplastics, and continues cross section is limited.

4. **Compression Moulding:** The heated closed mould is filled with the fiber-resin combination, and a compressive load is delivered via the upper part of the mould. High production rate, excellent surface polish, multiple component development, can be used for thermoset polymer for the development of vehicle parts.

5. **Liquid Transfer Moulding Process:** Resin is introduced into the enclosed moulded fibre, and the mould chamber is sucked or at atmospheric pressure. The key restrictions include a product with complicated geometry, a high fibre volume percentage, an excellent surface polish, resin injection, curing, and heat transmission.

6. **Autoclave Processing:** Prepregs are laid in the mould mechanically, and the complete assembly is vacuumed packaged and placed into the autoclave for curing. Larger fibre volume percentage, appropriate amalgamation of composite ingredients, no air pockets, high surface adhesion, aeroplane parts, and both types of polymers.

7. **Injection Moulding:** Extruder is utilised for pushing the necessary volume of fibre resin mixture into the cavity of the mould. Combination with both types of resin, high production rate, shorter curing time, and various car parts.

8. **Diaphragm Forming:** Thermoplastic prepregs strips are sandwiched between elastic diaphragms, which are then inserted into the mould for curing. Only for parts with a consistent size and an irregular fibre dispersion.

IV. CONCLUSIONS

The solid waste treatment issue, a lack of resources, and imbalance between environment, technology, and the economics connected to traditional polymer composites prompted the creation of nonconventional, namely natural and biodegradable composites (bio-composites). The study discusses several production strategies for the future growth of bio-composites. It discusses the primary characterisation characteristics and application possibilities of bio-composites in various engineering components. There is always room for developing and testing novel biodegradable fibres and polymers that compete against non-biodegradable fibres and polymers.

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