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Biopolymers: A comprehensive review

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Abstract

Biopolymers are compounds prepared by using various living organisms, including plants. These are composed of repeated units of the same or similar structure (monomers) linked together. Rubber, starch, cellulose, proteins and DNA, RNA, chitin, and peptides are some of the examples of natural biopolymers. Biopolymers are a diverse and remarkably versatile class of materials that are either produced by biological systems or synthesize from biological sources. Biopolymers are used in pharmaceutical industry and also in food industry.Naturally derived polymers are also used for conditioning benefits in hair and skin care. Biopolymers have various applications in medicine, food, packaging, and petroleum industries. This review article is focused on various aspects of biopolymers with a special emphasis on role of biopolymers in green nanotechnology and agriculture.

Keywords: Biopolymer; Pharmaceutical; Production; Polysaccharides; Cellulose; Lignocellulose

1. Introduction

Biopolymers are the polymers that are developed from living organisms. The name "Biopolymer" indicates that it is a bio-degradable polymer. Biopolymers have been present on earth for billions of years and are older than synthetic polymers such as plastics.

These polymers play an essential role in nature. They are extremely useful in performing functions like storage of energy, preservation and transmittance of genetic information and cellular construction.

Sugar based polymers, such as polyactides, naturally degenerate in the human body without producing any harmful side effects so, they are used for medical purposes. Starch based biopolymers can be used for creating conventional plastic by extruding and injection molding method. Biopolymers of synthetic nature are used to manufacture mats. Cellulose based biopolymers, such as cellophane, are used as a packaging material. These chemical compounds can be used to make thin wrapping films, food trays and pellets for sending fragile goods by shipping. Classification of biopolymers

There are 4 different categories, amongst first three categories are obtained from renewable resources -

- Polymers from biomass such as the agro-polymers from agro-resources (e.g.- starch, cellulose).
- Polymers obtained by microbial production, e.g.- polyhydroxy-alkanoates.
- Polymers conventionally and chemically synthesised, whose the monomers are obtained from agro-resources, e.g. - poly (lactic acid).

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Polymers whose monomers and polymers are obtained conventionally, by chemical synthesis e.g. – polycaprolactones. [1, 2, 3, 4]

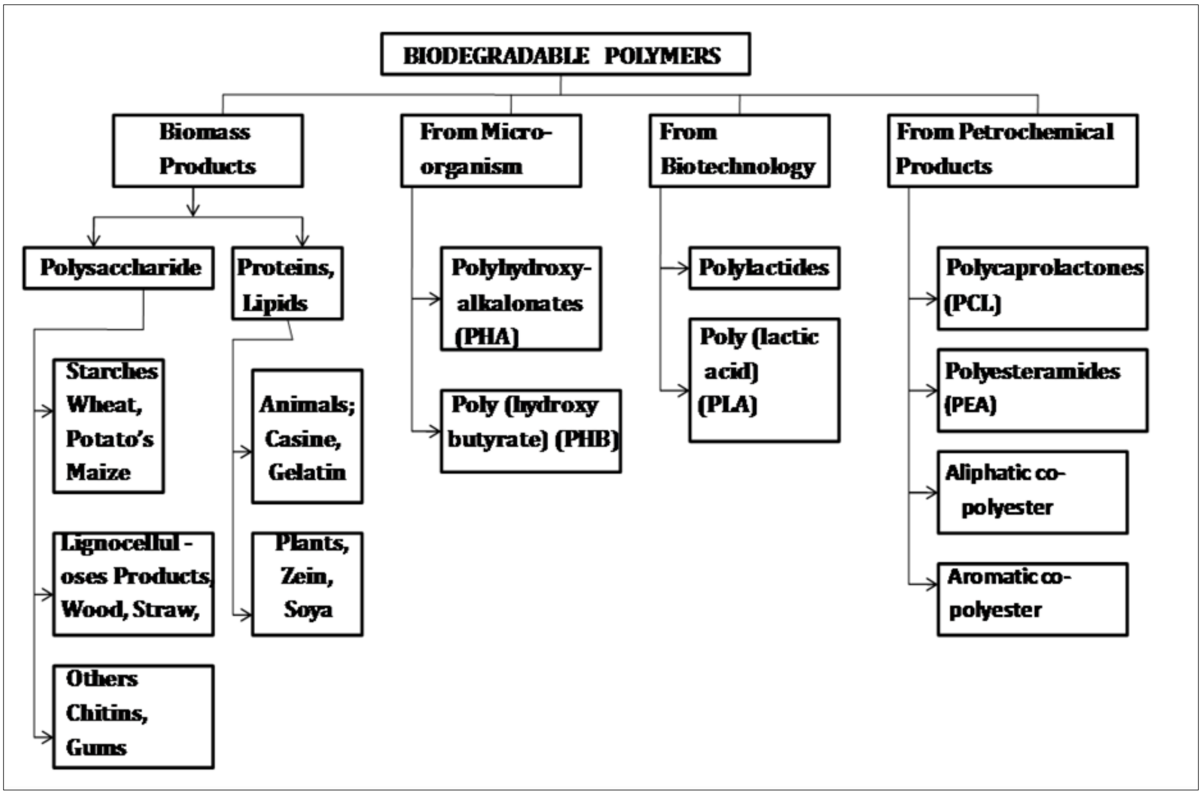

Figure 1 Classification of biopolymers

1.1. Biopolymer production

Table 1 Biopolymer production

Bio-based polymer (group)	Type of polymer	Structure /Production method
Starch polymer	Polysaccharides	Modified natural polymer
Polylactic acid (PLA)	Polyester	Bio-based monomer (lactic acid) byFermentation, followed by polymerization
Polyhydroxyalkonates	Polyester	Direct production of Polymer by fermentation or in a crops
Polyurethanes(PURs)	Polurethanes	Bio-based polyol by fermention or chemical
Nylon a)Nylon 6 b)Nylon 66	Polyamide	Purification plus petrochemical isocynate Bio-based caprolactum by fermentation Bio-based adipic acid by fermentation Bio-based monomer obtained from a Convential chemical transformation from Oleic acid via azelaic acid
Cellulose polymer	Polysaccharides	modifier natural polymer [5,6,7]

1.2. Extraction of biopolymers

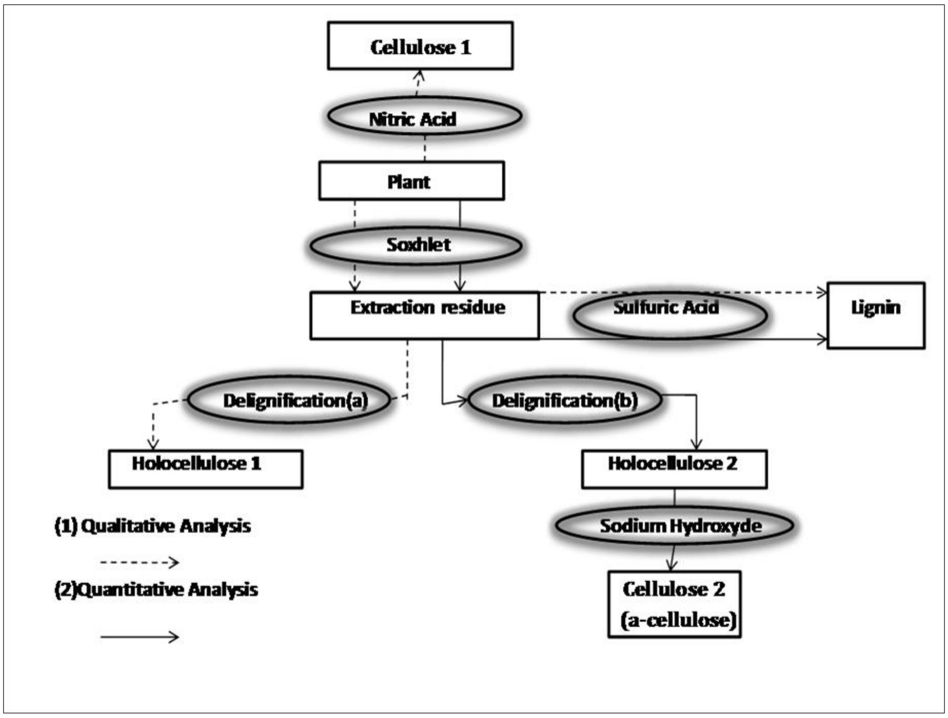

Figure 2 Extraction of biopolymers

Several analytical methods are available for the determination of lignocellulosic components but amongst those there are two widely used techniques, one for the determination of the plant composition (quantitative analysis) and the other for the extraction of native constituents of the fuel (qualitative analysis).

Lignocellulosic materials were determined by different gravimetric methods, according to normalized or published methods. Figure 2 show the experimental procedure performed on every fuel.

The extraction involves a multi-stage process from cellulose 1. The extractives are determined by Soxhlet extractions with dichloromethane for six hours. Then, the sample is washed with distilled water and oven-dried. From the extraction residue, the lignin, the holocelluloses 1, 2 and the cellulose 2 is obtained. The lignin "Klason" content is obtained by gravimetric analysis after a sulphuric acid attack. Holocellulose (i.e. cellulose + hemicellulose) content is also obtained by gravimetric analysis after reaction of the extraction residue with sodium chlorite in acetate buffer; this step is called delignification. The action of hydroxyl sodium on holocelluose 2 allowed for obtaining cellulose 2. The cellulose 1 content is determined according to the Kürschner method directly on the powders by a gravimetric analysis after reaction with nitric acid. As the chemical structure of hemicellulose and cellulose is very similar, there is no way to extract the native hemicellulose from the plant.[8, 9, 10]

1.3. Degradation of biopolymers

Biodegradability is considered to be one of the most important characteristics of biopolymers. After disposal, biopolymers are degraded in natural environments, such as soil, active sludge, fresh water, and seawater. Many prokaryotic and eukaryotic microorganisms secrete extracellular depolymerases capable of hydrolyzing biopolymers, and utilize the resultant decomposed compounds as nutrients. Finally, the compounds can be converted into renewable resources, such as CO_2 and biomass. Therefore, the decomposition of polymers to oligomers and/or monomers by depolymerases is important as the first step in biopolymer recycling. In regard to the stability of biopolymers and their controlled biodegradation after disposal, many researchers have investigated the biodegradation mechanisms of biopolymers, including polyesters, polysaccharides, proteins, lignins, and related polymers, from both physicochemical and biochemical aspects. The enzymatic degradation of biopolyesters, particularly PHAs,by extracellular PHA depolymerases.

A number of PHA depolymerases have been purified from diverse PHA- degrading microorganisms and characterized. Among them, PHB depolymerases have been extensively examined. The purified enzymes are composed of a single polypeptide and their molecular weights are in the range of 37-60 kDa. Genetic analysis reveals that PHB depolymerases generally have effects of solid-state structure and surface properties of PHAs on the enzymatic hydrolysis have also been investigated. For instance, the amorphous regions in PHA materials are preferentially hydrolyzed, so that the hydrolysis of crystalline regions is the rate limiting step in the enzymatic degradation process. Further, the enzymatic degradation rate of PHA materials decreases with increasing crystallinity, crystal size, and regularity of the chain packing state. The change of the surface properties of poly (lactic acid) induced by end-capping with alkyl ester groups leads to a decrease in the enzymatic degradation rate of the end-capped polymers. [11, 12]

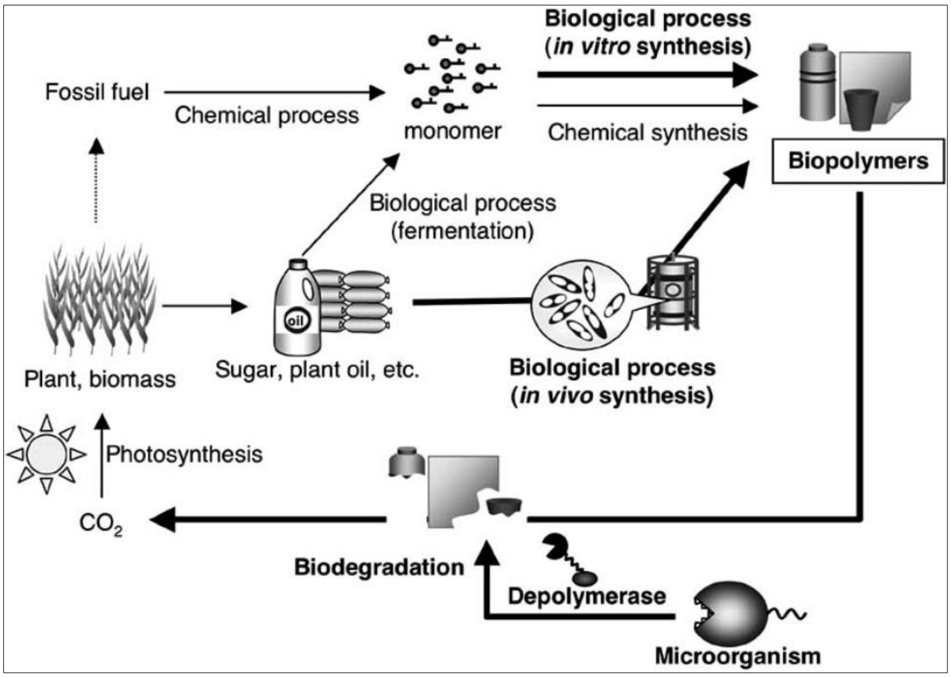

Figure 3 Biopolymer recyclable ecosystem involving biological and/or chemical synthesis and biological degradation

2. Examples of biopolymers

- **Cellulose –** Cellulose is the most plentiful carbohydrate in the world; 40 percent of all organic matter is cellulose. The most important skeletal component in plants, the polysaccharide cellulose is an almost inexhaustible polymeric raw material with fascinating structure and properties. Cellulose is a natural condensation polymer. Most dry plant material consists of up to 50% cellulose. Approximately 5 x 10^{11}tonnes of cellulose is produced each year by land plants. [13]
- **Starch or Sugar –** Starch is found in corn (maize), potatoes, wheat, tapioca (cassava), and some other plants. Annual world production of starch is well over 70 billion pounds, with much of it being used for non-food purposes, like making paper, cardboard, textile, sizing, and adhesives. Plants synthesize and store starch in their structure as an energy reserve. After cellulose, starch is the most abundant carbohydrate available from plant kingdom as raw material. Starch is the main carbohydrate and acts as a reserve food supply for the growth, dormancy and germination of plants. [14,15]
- **Chitosan as a biopolymer –**Chitosan, the polymer is obtained by the partial deacetylation of naturally occurring polymer, Chitin. The biopolymer chitosan is especially useful as it can be made available in a variety of morphologies including fibers, films, hydrogels, nanoparticles and microspheres.
- **Collagen -** Collagen is the most abundant protein found in mammals. Gelatin is denatured collagen, and is used in capsules for drugs and vitamin preparations and other miscellaneous industrial applications including photography.[16]
- **Polyesters -** Polyestersare produced by bacteria, and can be made commercially on large scales through fermentation processes. They are now being used in biomedical applications, and used to manufacture water-resistant bottles and other products.
- **Hyaluronic Acid -** Hyaluronic acid or hyaluronan, sodium hyaluronate, is a non-sulfated glycosaminoglycan and a biopolymer, which is distributed widely throughout connective, epithelial, and neural tissues. HA is

nontoxic, non-immunogenic and biodegradable. HA used in cosmetics preparations. HA is also used to treat osteoarthritis of the knee.

- **Acacia gum:**Gum acacia or gum arabic is the dried gummy exudates obtained from the stem andbranches of Acacia arabica. Acacia is used as suspending emulsifying agent and as a tablet binder. Its demulsant properties are employed in various cough, diarrhoea and throat preparations. The principal use of gum Arabic is in confectionery as an emulsifier, for preserving flavors of soft drinks and also in the manufacture of chewing gums. [17,18]

2.1. Application of biopolymers

- Biopolymers are used in pharmaceutical industry and also in food industry. Starches are used mainly in the food industry, pharmaceutical, medicinal, paper industries and textile industries. Carrageenans are used as gelling and thickening agent and also for controlled-release tablets. Gums are used in various forms as sustained release excipient, binder and as disintegrant.[19,20,21]
- Role of biopolymers in green nanotechnology **-**
- Biopolymers have diverse roles to play in the advancement of green nanotechnology. Nanosized derivatives of polysaccharides like starch and cellulose can be synthesized in bulk and can be used for the development of bionanocomposites. [19, 20, 21]
- Naturally derived polymers for conditioning benefits in hair and skin care **–**The polysaccharide polymer consists of galactose and mannose units and has a molecular weight in excess of 2 million Daltons. In a shampoo or body wash formulation the polymer is able to flocculate upon dilution delivering actives to the hair and skin as well as imparting a unique combination of sensorial and skin conditioning and protection benefits.
- Biopolymers use in office products such as calendars and wall charts, pens, highlighters, office stationery. Biopolymers use inFood service as gloves**,** aprons and bibs**,** straws**,** cutlery, cups and plates. It is use inpackaging which include of bags, trays, wraps, confectionery/bread, savoury snacks, biscuit and sweet wraps, bottles for fresh drinks, boxes etc. It is also use in Horticulture/Agriculture such as mulch film, plant holders, netting, plant pots and trays etc.[22]
- Industrial**:** The increasing level of enquiries from business customers seeking help with improving the sustainability of their products or packaging. The products are optimized for films, fibres, coatings and moulded parts we are now also working on larger roto-moulded items. [22]

3. Conclusion

Biopolymers are polymers produced by living organisms and contain monomeric units that are covalently bonded to form larger structures.Biopolymers are diverse and remarkably versatile classes of materials that are either produced by biological system or synthesized from biological source materials. Biopolymers have various applications in medicine, food, packaging and petroleum industries. Polymers have properties that make them suitable for use in protecting products from moisture, increasing shelf-life and making products easier to dispense .Biopolymer like Starch as a matrix for the synthesis of nanoparticles. Global polymer production capacity is estimated to reach 766,000 metric tons (MT) by 2009 and 1.5 million MT by 2011.

Compliance with ethical standards

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Disclosure of conflict of interest

None

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