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An Overview of Bioplastics

Lini K. Mathew*

Research Scholar, Department of Chemistry, S.N College, Kollam, Kerela, India

Corresponding author

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Poly hydroxy butyrate (PHB)

A B S T R A C T

Bioplastics have similar structural and functional characteristics to plastics but are derived completely or partially from biomass resources with a great diversity of polymers in use or being developed as bioplastics. The growth of bioplastic industry depends on the discovery of new molecules, the blending of molecules, searches for new plasticisers and attempts to make identical thermoplastics to the petro-plastics but using renewable raw materials of biological origin. The life cycle of a bioplastic includes growth of biomass source, harvesting, processing prior to biorefining, fermentation and downstream processing and subsequent incorporation to make products. The eco-friendly nature of biolastics, especially less carbon emission potential has contributed very much to environmental conservation modalities.

Introduction

Bioplastics are plastics educed from renewable biomass source, such as vegetable oil, corn-starch, potato-starch or microbia, and fibers from pineapple and henequen leaves and banana stems, rather than from petroleum. Corn is the principal source of starch for bioplastics, whilst more researchers is appraising the potential use of starches from potato, wheat, rice, barley, oat and soy-source and bacterial micro-organisms or natural fibers (Beilen and Poirier, 2012). The characteristics of bioplastics like low water vapour and gas permeability, increased shelf-life with better strength are further added by incorporating nanometer-sized particles.

In short, bioplastics are plastics made out of biopolymers. Some, like biopolyethylene, are identical to their oil derived form except that the source of the monomers is different. Others are unique and have no petro-polymer equivalent.

Bioplastics can be made using plant, animal, or bacterial sources. Some bioplastics are biodegradable while others are not which is advantageous, as many products need to be resilient and not degradable (Phillips, 2008). However, bioplastics field is still in its infancy but is explicating quickly.

Classification

Starch based plastics

Starch, the storage polysaccharide of cereals, legumes and tubers is the key raw material for bioplastics. Flexibilisers (sorbitol) and plasticizers (glycerin) are added during the processing of bioplastics. For use as bioplastic, starch hould attain adequate and required mechanical properties like high percentage elongation, tensile and flexural strength unless it is treated by either plasticization, blending with other materials, genetic or chemical modification or combinations of different approaches.

Bioplastics from biobased monomers

Polylactic acid is the polymer with the highest potential for a commercial production as bioplastic. However, a wide range of other bio polyesters can also be made by fermentation. Very high cost of the production of the monomers was the major restriction.

Polylactic acid (PLA) plastics

PLA is a biodegradable, thermoplastic, aliphatic polyester derived from lactic acid which itself produced from the fermentation of agricultural by-products such as corn-starch or other starch-rich substances like maize, sugar or wheat. The ratio between the two mesoforms of the lactic acid monomer determines the properties of PLA. The use of 100% L-PLA results in a material with a very high melting point and high crystallinity. On the other hand, a 90%/10% D/L co-polymers gives a material which can be polymerized in the melt and is easily processable meeting the requirements of bulk packaging.

Poly hydroxy alkanoate (PHA) and poly hydroxy butyrate (PHB)

PHA and PHB are the most common polyester produced by bacteria by processing glucose or starch. The properties of PHA are dependent and relates upon the composition of monomer unit, the microorganisms used in fermentation, as well as the nature of the carbon source used during the fermentation process. PHA has low water-vapour permeability which more or less same to that of LDPE. Moreover, PHA has similar properties of polystyrene. PHB resembles isotactic polypropylene (iPP) in relation to melting temperature (175-180°C) and mechanical behaviour. The incorporation of 3HV or 4HB co-monomers in PHB produces remarkable changes in the mechanical properties. Stiffness and tensile strength decrease with increase of toughness with increasing fraction of the respective co-monomer.

PHB is produced by bacteria, algae, and genetically modified plants requiring no extra polymerization step within the cell *via* a complex enzymatic process. The raw material for the biological synthesis is Acetyl-CoA, which is part of the tricarboxylic acid (TCA) cycle. First, a β-ketothiolase catalyzes the production of acetoacetyl-CoA by condensing two molecules of acetyl-CoA together. Next, acetoacetyl-CoA reductase reduces the acetoacetyl-CoA producing β-hydroxybutyryl-CoA. The final step is carried out by PHB synthase, which catalyzes the polymerization of β-hydroxybutyryl-CoA to PHB. The PHB is present as cysts within the cytoplasm of the cell. The production of PHB requires bioreactors since microorganisms produce the polymer.

Table.1 Properties of bioplastics (Pandey *et al.*, 2010)

Physical properties	
Mold shrinkage	0.0125-0.0155 in/in
Density	1.4g/cm³
Apparent viscosity (180ºC, 100 sec^{-1})	950 Pa-s
Thermal properties	
Melting point	160-165ºC
Heat distortion temperature	143ºC 78ºC
Vicat softening temperature	147ºC
Mechanical properties	
Tensile strength	26 MPa(3800psi)
Shrinkage	0.93% caliper
Tensile modulus	3400 MPa(494,000psi)
Tensile elongation brake	3%
Compressive yield Stength	65MPa (approx)
Compressive Modulus	2GPa (approx)
Flexural strength	44 MPa(6390psi)
Izod impact strength	26 J/m(0.5 ft lbs/in)
Hardness	54 shore D(90ºC,2.16kg)
Bending module	387 MPa
Moisture absorption	0.16% (23ºC, 50% RH)
Transparency	High
Oxygen barrier	Medium-high
Other Properties	
Stackability	Fair
Puncture Resistance	Excellent
Crystallinity	60

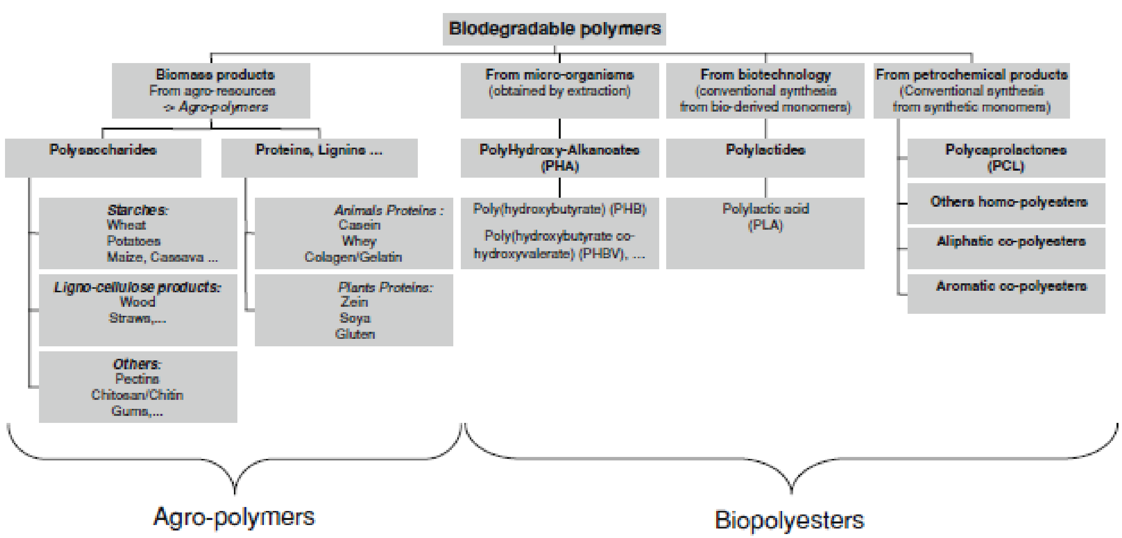


Fig.1 Classification of biodegradable polymers (Amass *et al.*, 1998)

Fig.2 Structure of PHA

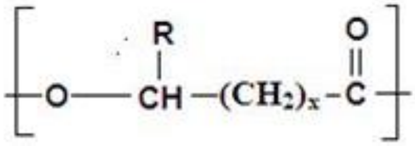


Fig.3 Structure of PHB

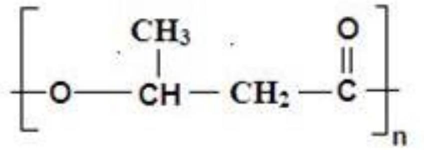


Fig.4 Biosynthesis of PHB

Substrate

↓

Acetyl CoA

↓ Acetyl CoA acyltransferase

Acetoacetyl CoA

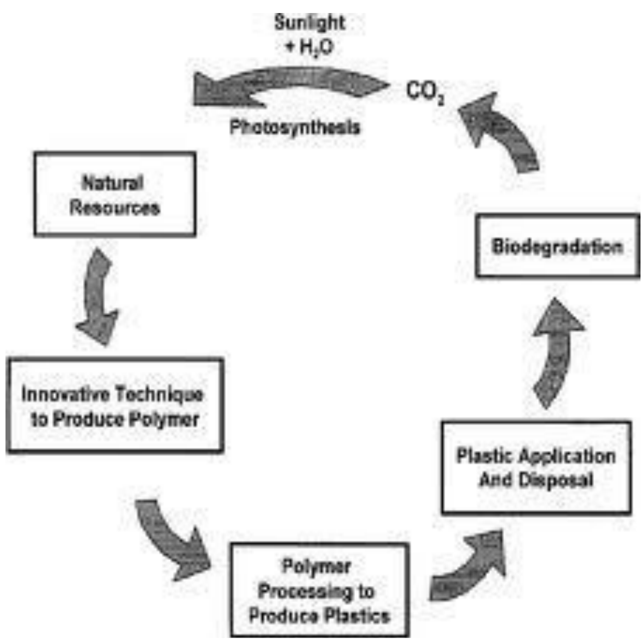
↓ Acetoacetyl CoA reductase

3 Hydroxybytryl CoA

↓ PHB Synthase

Poly-β-hydroxybutyrate

Fig.5 A typical bioplastic cycle



Polyamides 11 (PA11)

PA11 is a biopolymer derived from natural oil which is used in high-performance application like automotive fuel lines, pneumatic airbrake tubing and flexible goods.

Polycaprolactones

It is a biodegradable thermoplastic polymer derived from the chemical synthesis of crude oil which has good water, oil, solvent and chlorine resistance. The use of polycaprolactones as thermoplastic polyurethanes, resins for surface coatings adhesives and synthetic leather and fabrics are commendable.

Plastics have become a pivotal part of our daily lives. However, the incessant consumption of plastics creates a wide spectrum of ecological and public health reverberations among life on earth. It provoked scientists to partially substitute petrochemical-based polymers with biodegradable bioplastics. Various studies around the world revealed that bioplastics are eco-friendly as compared to traditional plastics. Moreover, the emission of green house gases during production and degradation of bioplastics are very low when compared to plastics.

Conclusion

Bioplastics are made by converting the plant sugars into plastic by fermentation which makes bioplastics renewable and more eco-friendly than conventional plastics. Bioplastics production, though small, is uprising quickly, with many new products and applications emerging as a result of extensive research and development efforts. In short, bioplastics have attracted the attention of policymakers because of their use of renewable resources and the implications for sustainable development, particularly within the context of an emerging policy focus on the bioeconomy.

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