# A Review Article on Biopolymers

**Diya Jaison & Sulfath Nassim**

**Abstract:**

The environmental effect of plastic wastes is raising a global accentuate issue and disposal methods are limited. The growing consciousness about the problem has attracted research interest in biodegradable natural polymers. The applicability of biopolymers is widespread in the fields of medicine, food, and petroleum industries. Biopolymers can be produced from renewable sources hence they are biodegradable and thus are excellent substitutes for many synthetic compounds. Plants, animals, and microorganisms can produce and excrete a good number of polysaccharides in normal production conditions. The polysaccharides produced by microorganisms are adopted both as commercial products and have the potential for commercialization. The recent advancement in microbiology and biotechnology helped scientists to view organisms and the materials they secrete. The limiting factor in the development of these polysaccharides is the lack of efficient technology for their extraction and purification. However new applications in agronomy, foods, cosmetics and therapeutic could in a near future will prominent the effort of research for their development. Biopolymers are produced mainly through a biological process like fermentation and a chemical process like polymerization. The main focus is on microbial production of biopolymers as they are more efficient. So, this review concentrates on various useful biopolymer, their production as well as their applications in various fields.

**Keywords**: Biopolymers, renewable resources, biodegradable, microorganisms, applications, polysaccharides

## Introduction

Biopolymers are polymeric biomolecules. They are made out of living organisms. As the rise of modern civilization along with all its technologies had a huge impact on the earth it was not a concern till recently when there were raising questions about the overuse of fossil fuels and petrochemical plastics. We are facing a very large and important issue as we have loaded our mother nature with many undesirable waste products and we literally are choking the life out of it. So there comes a need to release our earth from this hamartia and give its full life back. That was the time when biopolymers were invented as a substitute or to be more precise biopolymers were there even before we came out with the discovery of plastic but we were dumb enough to try out synthetic ones. So, the main advantage of biopolymer is that it is degradable that is unlike synthetic sources it will never be a burden to the earth. They account for a greater part of the human body as well as the ecosphere. So, through this presentation, we outline the summary of information that we have gathered through our investigation of biopolymers.

## What is a Biopolymer? [1]

Biopolymer is a biodegradable chemical compound that is developed from living beings.

- A biopolymer consists of repeating monomer units that can either be homopolymers or heteropolymers.
- A homopolymer consists of one type of monomer in a repeating fashion while a heteropolymer consists of more than one type of monomer in complex and often branched structures.
- Some biopolymer examples are proteins, carbohydrates, DNA, RNA, lipids, nucleic acids, peptides and polysaccharides.

**Biopolymer Classification.**

Based on the first type of classification biopolymers are broadly divided into four:-

1. **Sugar-based biopolymers**:- starch or sucrose is used as the input for sugar based biopolymers. The main examples are polyactides or lactic acid polymers which are produced from potatoes, maize, wheat, and sugar beet. These polyactides are resistant to water.[7]
2. **Starch-based biopolymers**:- starch act as a natural polymer and is stored in plant tissues as a form of carbohydrate. They are mainly obtained from wheat, tapioca, maize and potatoes. Starch is a polymer of glucose monomers and is only found in plants and not in animal tissues.[10}
3. **Biopolymers based on synthetic materials**:- synthetic compounds like petroleum can also be used for making biodegradable polymers. Though these compounds are made from synthetic components they are completely compostable and biodegradable. Examples are aliphatic aromatic copolyesters.[15]
4. **Cellulose based biopolymers**:- this polymer is composed of glucose and is used for packing cigarettes, CDS and confectionery. It is obtained from cotton, wood, wheat and corn.

**Biopolymer Types**.

There are primarily two types of biopolymers:-

1. Bio-based biopolymers:- they are produced from plants, animals and microorganisms.
2. Fossil fuel-based biopolymers:-they are produced from renewable resources but require polymerization.

**Sources of Biopolymer.**

Biopolymers can be produced from biological and chemical sources and they are modified and designed for various applications. [6]The biological sources are mainly plants, animals and microorganisms while the chemical synthesis is done by polymerising biological monomer units such as sugars, amino acids, nucleotides and oils.[5]The production of novel biopolymers from plants provides a bio-renewable method for its synthesis.[14]Industrially biopolymers are produced in bulk and shaped for specific end-use.[12]Microorganisms play a very important role in producing a variety of biopolymers like polyesters and polyamides.[9]

**Artificial Production of Biopolymers.**

Microorganisms produce a wide variety of biopolymers like polysaccharides, polyesters and polyamides. Mainly they are produced by fermentation and for large-scale production of biopolymers, fermentation is done in large bioreactors. These biopolymers are then extracted from the bioreactors and chemically processed to form the end product.[11] The physical properties of biopolymers can be altered by the genetic manipulation of the microorganisms thereby making them efficient in various fields like industries and pharmaceuticals. For the production of biopolymers from microorganisms, certain environmental conditions and nutrient composition should be maintained. Biopolymers are also produced by the chemical polymerization of monomer units.[13] Bioplastics can be produced from renewable biomass sources such as vegetable oil, corn starch, pea starch etc. Algae can be used for the production of bioplastics because of their high yield and ability to grow in a wide range of environments. The use of algae has other merits like the utilization of carbon thus neutralizing greenhouse gas emissions. Bioplastics from algae are

more efficient than those produced from biomass.[16] An example of biopolymer production from *Pseudomonas aeuruginosa* is stated below:-

- Isolation , purification and cultural conditions[2]:

A sample of the sediment was collected from the Karachi coast. The bacterial strain was isolated, purified and coded as CMG607w, and the strain CMG1421was isolated from the dry soil. It was also purified and both were preserved in 20%glycerol at -70degree Celsius. Both the strains were identified by using an API kit and were found to be *Pseudomonas aeruginosa*. The strain CMG607w was maintained at 30 degrees Celsius in artificial sea water, in 1L of distilled water. It is supplemented with tryptone and a 10 g carbon source (glucose/sucrose). To carry out polyhydroxyalkanoate[PHA] synthesis same cultural conditions were used. The incubation time was increased from 24-120hr at 30 degrees Celsius and 200rpm. For the synthesis of hydro absorbent polysaccharide, CMG1421was grown in the minimal medium supplemented with a 20g /L carbon source. After growing in the minimal medium,1 ml (48h old) seed culture was inoculated into a 2L minimal medium and it was incubated at 30 degrees Celsius for 15 days.

- Extraction and purification [3].

For the extraction of the PHA, a lyophilised cell material was used with chloroform at 65Degree Celsius for 4hr in the screw cap bottles. The extraction is repeated three times with the same material. By passing through the cellulose filter the cell debris was removed and by using a rotary evaporator the chloroform solution was concentrated. The polymer was precipitated by pouring chloroform solution into ethanol. By filtration, the precipitated polymer was separated and it was dried by exposure to hot air. The precipitation was repeated for further purification. The viscous culture broth of CMG 1421 was diluted with the half volume of sterilized distilled water and it was placed in a shaking incubator at 30 degrees Celsius for 1 hour. The bacterial cells were

regimented by centrifugation at 10,000rpm or 30 minutes at 4 degrees Celsius. To precipitate the extracellular Protein fractions, trichloro acetic acid [TCA] 5 to 10% was added to the cell-free supernatant. To collect the protein fractions, it was centrifuged at 9000 rpm for 30 minutes at 4 degrees Celsius. The clear supernatant was added to equal volumes of absolute ethanol. The precipitates were collected around the glass rod. To obtain uniform white precipitates, the dissolution and precipitation process was carried out for 4 to 5 hours. The sample was dried in the wheaten dry seal vaccum desiccators. The crude hydroabsorbant was dialyzed against the distilled water lyophilized.

**Applications of Biopolymers.**

Biopolymers are caused due to their biocompatible and biodegradable nature.

It is used to improve the performance of the other biologically active molecules in a product.

It has various applications including;

1. **Synthesis of nanomaterials**[17]

- Nanotechnology means research which deals with the synthesis, characterization, and applications of nonmaterial.
- Nowadays researchers are more focusing on developing the synthesis of nanoparticles.
- The main focus is synthesis protocol shifted from physical and chemical processes towards green chemistry and bioprocesses.
- Metal nanoparticles process various novel properties due to their quantum size effect.
- Synthesis protocol causes a major threat to the environment.
- Synthetic organic solvents and reducing agents used in synthesis protocol include organic solvents and toxic reducing agents like hydrazine, N-dimethylformamide and sodium

borohydride which are highly toxic to the environment and these chemicals pose potential environmental and biological risks.

- For synthesizing different nanoparticles biopolymers like chitosan, heparin, soluble starch, cellulose, gelatine, PVA and PVP are used to replace various toxic reagents.
- Biomedical applications Biopolymer materials have great interest nowadays because of their biomedical applications such as in tissue engineering, pharmaceutical carriers, and medical devices.
- Gelatine is a common biopolymer and is widely used for applying to wounds and as an adhesive.
- Biomaterials are made from proteins, polysaccharides and synthetic biopolymers.
- The properties of biomaterial are improved by cross-linking, most of these causes cytotoxicity and cause undesirable changes to the function of biopolymers.

2. **Food industry**[18]

- Bio-based films and containers replace oil-based packaging materials.
- Biopolymers are used for food coatings, food packaging, and encapsulation matrices to functional foods.
- Certain biodegradable polyesters and thermoplastics like starch, PLA, PHA, and so on are the most commercially viable materials in food packaging.
- Starch and PLA biopolymer are the most attractive type of biodegradable material.
- PLA is particular interest in food packaging due to its excellent transparency and relatively good water resistance.

- Other materials extracted from biomass recourses, such as proteins, polysaccharides and lipids also have excellent potential.
- Chitosan has shown great potential as an antimicrobial packaging agent to preserve food against several microorganisms.
- Lysozyme is a naturally occurring enzyme and is the most frequently used antimicrobial enzyme in packaging materials.
- Amylose when mixed with plasticizers has excellent potential for forming thin films for various food and packaging applications.
- Starch has a high sensitivity to relative humidity due to its hydrophilic nature and can reduce by introducing plasticizers and starch.

3. **Packaging applications**.[4]

- Biodegradable polyesters are the most commercially viable materials in food packaging.
- These materials are used in monolayers and multilayer applications in the food packaging field.
- Sustainable biopolymers are used in monolayer packaging including starch, PHA, and PLA. Starch and PLA biopolymers are the most attractive types of biodegradable materials.
- If they improve their barrier and thermal properties so that they perform like polyethylene terephthalate (PET).
- To improve the barrier properties of biopolymer is to add various nanofillers like nanoclays and metal oxide nanoparticles.

- Polyglycolic acid is one of the most promising new commercially available barrier polymers due to its excellent barrier properties. It can now be produced via a natural metabolic route, the glyoxylate cycle.

4. **Water purification.**[16]

- Through the effective purifying mechanisms nanotechnology has promising developments in providing safe drinking water.
- Safe drinking water is significant.
- It has been proved that several nonmaterial has antibacterial and antifungal properties.
- Release antibacterial materials like silver nanoparticles into water is an effective way of providing microbial-safe drinking water for all.
- When developing stable materials which can release nanoparticles continuously.
- New polymer i.e.; chitosan shows superior performance where many conventional polymers fail. Chitosan is used as a water treatment process in the environment over periods of weeks or months or years. Chitosan removes metals from water by forming chelates.

**Conclusion**

Biopolymers are excellent in absorption capacities. They are used in different fields such as chemical biological fields etc. Through this article, we present the properties, applications, and sources of biopolymers. Biopolymers are important alternatives to unsustainable products. They have a high rate of biodegradation in the environment. Nowadays many studies are going on to think about natural and biodegradable polymers replacing synthetic polymers in various applications and different fields. They are mainly produced during the life cycle of plants, animals

and fungi, etc. So they can be widely used and nowadays they are used due to their advantages. Boogieman may be bacteria or fungi that can adhere to a surface tightly to form communities and can resist antibiotics. Biopolymers are the key to the survival of a pollution-free generation and for the survival of our mother nature. Newer research methodologies and production strategies for the production and applications of biopolymers are still under investigation. Usage of recombinant technology for the microbial production of biopolymers will be very useful since other applications like medicinal values can be added along with the novel uses of biopolymers. Moreover, this information will serve a great scope of further research in these fields for better application and will be useful to companies interested in the production and application of biopolymers.

**References.**

1. Kumar, Sushant & Pandey, Swarnima & Madhav, NV. (2021). Biopolymer: A Novel Bioexcipient. 10.5772/intechopen.97191.
2. Van de Velde, K., & Kiekens, P. (2002). Biopolymers: an overview of several properties and consequences on their applications. *Polymer testing*, *21*(4), 433–442.
3. Anjali Pal and Subhadeep Biswas (2021).Application of biopolymers as a new age sustainable material for surfactant adsorption: A brief review
4. Introduction to biopolymers from renewable resources by David L Kaplan
5. Honarkar, Hengameh & Barikani, Mehdi. (2009). Applications of biopolymers I: Chitosan. Monatshefte für Chemie - Chemical Monthly. 140. 1403-1420.
6. Moradali, M. & Rehm, Bernd. (2020). Bacterial biopolymers: from pathogenesis to advanced materials. Nature Reviews Microbiology. 18. 1-16. 10.1038/s41579-019-0313-3.

7. Subajiny Sivakanthan, Sarathadevi Rajendran, Ashoka Gamage, Terrence Madhujith, Sudhagar Mani. Antioxidant and antimicrobial applications of biopolymers: A review. *Food Research International* **2020,** *136* .

8. Amar K. Mohanty , Manjusri Misra , Lawrence T. Drzal , (2005) Natural fibers, biopolymers, and biocomposites ,CRC press.

9. Singh, Amit & Giri, Debaprasad & Kumar, Sourab. (2011). Statistical mechanics of stretching of biopolymers. Journal of Statistical Mechanics: Theory and Experiment. 2011. P05019. 10.1088/1742-5468/2011/05/P05019.

10. Elnashar, Magdy. (2011). Biotechnology of biopolymers. Biopolymers: processing and products by Niaounaki William Andrew, 2014

11. Niaounakis, M.. (2013). Biopolymers: Reuse, Recycling, and Disposal. Biopolymers: Reuse, Recycling, and Disposal. 1-413.

12. Plank, Johann. (2004). Applications of biopolymers and other biotechnological products in building materials. Applied microbiology and biotechnology. 66.

13. Flaris, Vicki & Singh, Gurpreet. (2009). Recent Developments in Biopolymers. Journal of Vinyl and Additive Technology. 15. 1 - 11. 10.1002/vnl.20171.

14. David Plackett & Vimal Katiyar, Functionalized biopolymer films and coatings for advanced applications. Biopolymers. New materials for sustainable films and coatings. John Wiley & Sons Ltd, 2011. p. 301-315.

15. Sneha Mohan, Oluwatobi S Oluwafemi, Nandakumar Kalarikkal, Sabu Thomas, Sandile P Songca (2016).Biopolymers–application in nanoscience and nanotechnology.

16. Khan, Taous & Park, Joong & Kwon, Joong-Ho. (2007). Functional biopolymers produced by biochemical technology considering applications in food engineering. Korean Journal of Chemical Engineering. 24. 816-826.
17. Gowthama Prabu Udayakumar, Subbulakshmi Muthusamy, Bharathi Selvaganesh, N Sivarajasekar, Krishnamoorthy Rambabu, Selvaraju Sivamani, Nallusamy Sivakumar, J Prakash Maran, Ahmad Hosseini-Bandegharaei (2021).Ecofriendly biopolymers and composites: Preparation and their applications in water-treatment 52.
18. Yadav, Preeti & Yadav, Harsh & Shah, Veena & Shah, Gaurav & Dhaka, Gaurav. (2015). Biomedical Biopolymers, their Origin and Evolution in Biomedical Sciences: A Systematic Review.Journal of Clinical and Diagnostic Research. 9.21-25.