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Polyhydroxyalkanoates (PHAs): Sustainable Biopolymers for Eco-Friendly Applications

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Editorial

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ABSTRACT

Polyhydroxyalkanoates (PHAs) are biodegradable polymers produced by various microorganisms as intracellular storage compounds under nutrient-limited conditions. Due to increasing environmental concerns associated with synthetic plastics, PHAs have emerged as promising eco-friendly alternatives. These biopolymers exhibit excellent biodegradability, biocompatibility, and thermoplastic properties, making them suitable for a wide range of applications. This article discusses the classification, biosynthesis, properties, applications, and challenges of PHAs, highlighting their potential role in sustainable development and environmental protection.

Keywords

Polyhydroxyalkanoates, Biopolymers, Biodegradable Plastics, Microbial Synthesis, Sustainable Materials, Bioplastics

INTRODUCTION

The widespread use of petroleum-based plastics has led to severe environmental pollution due to their non-biodegradable nature. As a result, there is a growing need for sustainable and environmentally friendly alternatives. Polyhydroxyalkanoates (PHAs) are a group of biodegradable polymers synthesized by microorganisms and have gained considerable attention in recent years.

PHAs are accumulated as intracellular granules by bacteria under conditions of excess carbon and limited nutrients such as nitrogen or phosphorus. These polymers can be extracted and processed into materials with properties similar to conventional plastics, offering a viable solution to plastic pollution [1].

CLASSIFICATION OF PHAs

PHAs are classified based on the length of their monomer units:

Short-chain-length PHAs (scl-PHAs): These contain 3–5 carbon atoms and include polyhydroxybutyrate (PHB), which is rigid and brittle. Medium-chain-length PHAs (mcl-PHAs): These consist of 6–14 carbon atoms and are more flexible and elastomeric. Long-chain-length PHAs: These are less common and possess unique material properties for specialized applications [2].

BIOSYNTHESIS OF PHAs

PHA production occurs through microbial fermentation processes. Common PHA-producing microorganisms include *Cupriavidus necator*, *Bacillus* spp., and *Pseudomonas* spp. The biosynthesis involves three key enzymes:β-ketothiolase, Acetoacetyl-CoA reductase, PHA synthase. The process begins with the conversion of carbon substrates into acetyl-CoA, followed by the formation of hydroxyacyl-CoA intermediates, which are polymerized into PHAs [3].

PROPERTIES OF PHAS

PHAs possess several desirable properties: Biodegradability: They can be degraded by microorganisms in natural environments. Biocompatibility: Suitable for medical and pharmaceutical applications. Thermoplasticity: Can be molded and processed like conventional plastics. Renewability: Produced from renewable resources such as sugars, oils, and agricultural waste [4].

CHALLENGES IN PHA PRODUCTION

Despite their benefits, PHAs face several limitations:

High Production Costs: More expensive than conventional plasticsLow. Productivity: Limited microbial efficiencyProcessing . Limitations: Some PHAs have poor mechanical. Properties. Scale-up Challenges: Industrial production is still developing. Research is focused on improving production efficiency and reducing costs by using low-cost substrates and genetic engineering techniques [5].

FUTURE PERSPECTIVES

The future of PHAs is promising due to increasing environmental awareness and demand for sustainable materials. Advances in biotechnology, metabolic engineering, and fermentation technology are expected to improve production efficiency and reduce costs.

The use of agricultural waste and industrial by-products as substrates for PHA production can further enhance sustainability. Additionally, the development of PHA-based composites may expand their industrial applications.

CONCLUSION

Polyhydroxyalkanoates (PHAs) are a promising class of biodegradable polymers that offer a sustainable alternative to conventional plastics. Their biodegradability, biocompatibility, and renewable origin make them highly suitable for various applications. Although challenges such as high production costs remain, ongoing research and technological advancements are expected to enhance their commercial viability and contribute to a greener future.

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CONFLICT OF INTEREST

None.

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