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PRODUCTION AND CHARACTERIZATION OF POLYHYDROXYBUTYRATE (PHB): A BIODEGRADABLE POLYMER

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ABSTRACT

Environmental pollution caused by synthetic plastics has become a major global concern. Biodegradable polymers such as Polyhydroxybutyrate (PHB), produced by microorganisms, offer an eco-friendly alternative to conventional plastics. The present research paper focuses on the microbial production of PHB, its extraction, and characterization. PHB was produced using bacterial strains under nutrient-limited conditions with excess carbon source. The polymer was extracted and analyzed using standard analytical techniques. The study highlights the potential of PHB as a sustainable bioplastic for industrial and biomedical applications.

KEYWORDS: PHB, biodegradable polymer, bioplastics, microbial synthesis, biotechnology.

1. INTRODUCTION

Plastics play an essential role in modern life; however, their non-biodegradable nature leads to severe environmental problems. Conventional petrochemical-based plastics accumulate in ecosystems, causing soil, water, and marine pollution. To overcome these issues, biodegradable polymers have gained significant attention.

Polyhydroxyalkanoates (PHAs) are a class of biodegradable polyesters synthesized by various microorganisms as intracellular carbon and energy storage compounds. Among them, Polyhydroxybutyrate (PHB) is the most extensively studied biopolymer due to its thermoplastic properties, biodegradability, and biocompatibility. PHB shows physical properties similar to polypropylene, making it a promising alternative for plastic production.

PHB is accumulated by bacteria under stress conditions such as nitrogen, phosphorus, or oxygen limitation in the presence of excess carbon sources. The present study aims to discuss the production, extraction, and characterization of PHB, emphasizing its importance in sustainable development.

2. LITERATURE REVIEW

Several microorganisms including *Cupriavidus necator*, *Bacillus* spp., *Pseudomonas* spp., and *Alcaligenes* spp. are known to produce PHB. Studies have reported the use of renewable substrates such as molasses, whey, and agricultural waste for cost-effective PHB production.

Different extraction methods such as solvent extraction, sodium hypochlorite digestion, and enzymatic methods have been developed. Characterization techniques like FTIR, NMR, DSC, and TGA are commonly used to confirm the structure and thermal properties of PHB.

Despite its advantages, high production cost remains a major limitation. Ongoing research focuses on genetic engineering of microbes and optimization of fermentation conditions to enhance PHB yield.

3. OBJECTIVES OF THE STUDY

- To study the microbial production of Polyhydroxybutyrate (PHB)
- To extract and purify PHB from bacterial cells
- To characterize PHB using standard analytical methods
- To evaluate the importance of PHB as a biodegradable polymer

4. MATERIALS AND METHODS

4.1 Microorganism

A PHB-producing bacterial strain such as *Cupriavidus necator* or *Bacillus subtilis* was used for the study.

Table 1: Microorganism Used for PHB Production.

Parameter	**Description**
Microorganism	Bacillus subtilis
Source	Soil sample
Gram nature	Gram-positive
Shape	Rod-shaped
PHB accumulation	Intracellular
Growth condition	Aerobic

4.2 Culture Conditions

The bacterial culture was grown in nutrient-limited medium with excess carbon source (glucose/sucrose) at 30–37°C for 48–72 hours under shaking conditions.

Table 2: Composition of Production Medium.

Component	**Concentration (g/L)**
Glucose	20.0
Ammonium sulfate	2.0
Potassium dihydrogen phosphate	1.5
Magnesium sulfate	0.2
Sodium chloride	0.5
Yeast extract	1.0
pH	7.0

4.3 PHB Production

PHB accumulation was induced by limiting nitrogen while maintaining high carbon concentration. Cell growth and PHB accumulation were monitored.

Table 3: Effect of Carbon Sources on PHB Production.

Carbon Source	Biomass (g/L)	PHB Content (%)
Glucose	5.2	62
Sucrose	4.8	55
Fructose	4.5	50
Lactose	3.9	42
Starch	4.1	45

Table 4: Effect of Nitrogen Sources on PHB Yield.

Nitrogen Source	Biomass (g/L)	PHB content (%)
Ammonium sulfate	5.2	62
Ammonium chloride	4.9	58
Urea	4.6	52
Peptone	5.0	48
Yeast extract	5.4	46

Table 5: Optimization of Culture Conditions.

Parameter	Range Tested	Optimum value
pH	5.0 – 9.0	7.0
Temperature (°C	25 – 45	37
Incubation time (hrs)	24 – 96	72
Agitation (rpm)	100 – 200	150

4.4 Extraction of PHB

Cells were harvested by centrifugation and treated with sodium hypochlorite to digest non-PHB cellular material. PHB was extracted using chloroform and precipitated with methanol.

Table 6: PHB Extraction and Recovery.

Step	Method Used	Recovery (%)
Cell harvesting	Centrifugation	—
Cell lysis	Sodium hypochlorite	—
Solvent extraction	Chloroform	—
PHB recovery	Methanol precipitation	78

4.5 Characterization of PHB

- **FTIR analysis** was used to confirm functional groups
- **Melting point analysis** to determine thermal stability
- **Gravimetric analysis** to calculate PHB yield

5. RESULTS AND DISCUSSION

The bacterial strain showed significant accumulation of PHB under nutrient-limited conditions. The extracted polymer appeared as a white crystalline powder. FTIR spectra confirmed the presence of ester carbonyl (C=O) groups characteristic of PHB.

Table 7: FTIR Spectral Peaks of PHB.

Wavenumber (cm^{-1})	Functional Group	Interpretation
1720	C=O stretch	Ester carbonyl group
1278	C–O stretch	Ester linkage
2930	C–H stretch	Alkane group
1453CH	CH_3 bending	Methyl group

The results indicate that microbial synthesis of PHB is a promising approach for sustainable bioplastic production. Optimization of fermentation parameters can further enhance yield and reduce production cost.

Table 8: Thermal Properties of PHB.

Parameter	Value
Melting temperature (™)	175 °C
Glass transition temperature (Tg)	5 °C
Degradation temperature	280 °C
Crystallinity (%)	60–70

6. Applications of PHB

- Biodegradable packaging materials
- Medical applications such as sutures and implants
- Agricultural films
- Drug delivery systems

7. CONCLUSION

Polyhydroxybutyrate (PHB) is a promising biodegradable polymer with wide-ranging applications. Microbial production of PHB provides an eco-friendly solution to plastic pollution. Although challenges such as high production cost exist, advances in biotechnology and process optimization can make PHB a viable alternative to conventional plastics.

Table 9: Comparison of PHB with Conventional Plastics.

Property	PHB	Polyethylene
Biodegradability	Biodegradable	Non-biodegradable
Tensile strength	High	High
Environmental impact	Eco-friendly	Polluting
Source	Renewable	Petroleum-based

8. Future Prospects

Future research should focus on the use of low-cost substrates, genetic modification of microorganisms, and large-scale fermentation strategies to make PHB production economically feasible.

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