Advancing Circular Bioeconomy Through Scalable Production of Biodegradable Polymer from Waste Glycerol

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The growing demand for plastics, coupled with the environmental burden of landfilling over 50% pf post-use plastics, underscores the urgent need for sustainable plastic solutions. Biobased biodegradable plastics offer a lower carbon footprint than conventional fossil fuel-based plastics. Due to their inherent biodegradability, many bioplastics can be considered as carbon neutral within the carbon cycle. Among these, polyhydroxyalkanoates (PHAs), bio-polyesters produced by microbial fermentation, are particularly promising as high-performance alternative to conventional plastics. However, their widespread commercial adoption has been hindered by high prices, mainly due to the high-cost fermentation substrate and energy- and chemical-intensive downstream recovery processes.

Utilizing industrial carbon waste as fermentation substrate and integrating physical methods for downstream processing can potentially reduce PHA production cost and enhance process scalability. This study demonstrates a scalable approach for producing poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), a type of short-chain length PHA, using waste glycerol as a carbon source. *Haloferax mediterranei*, a halophilic archaeon, was employed for its capability of utilizing crude glycerol as fermentation substrate. Post-fermentation, high-pressure homogenization (HPH) was applied for cell disruptions to separate PHBV. The results showed that pilot-scale fermentation achieved 5.7 g/L cell biomass containing 38% PHBV content. HPH enabled 85% recovery of PHBV from the fermentation broth with a PHBV purity of 90%. Material characterization revealed that HPH-based extraction slightly reduced the molecular weight of PHBV, but its thermal properties were not altered, retaining high thermal stability. Compared to commercial PHA, poly(3-hydroxybutyrate-co-4-hydroxybutyrate) (P3HB4HB), the PHBV produced in this study had improved mechanical performance, exhibiting higher young's modulus and greater tensile strength, underscoring its great potential for packaging applications.

Overall, this study demonstrates an optimized fermentation process integrated with a physical extraction method to convert underutilized carbon source into high-performance biopolymers. The findings can potentially reduce the environmental impact of waste disposal while supporting the growing social demand for sustainable bioplastic materials.