Towards extracellular secretion of poly-β-hydroxybutyric acid (PHB) biodegradable polymer

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Conflict of Interest

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Abstract

Plastics' poor biodegradablility, bioaccumulation and biomagnification potential, and emission of hazardous chemicals during incineration, pose challenging disposal problems. Biodegradable, bio-renewable and biocompatible bacterial lipid-based storage polymer, poly-β-hydroxybutyric acids (PHB), offers a good functional replacement for petroleum-derived plastics. Originally nature's solution for helping bacteria moderate fluctuations in nutrient availability, progressive understanding of PHB biosynthetic pathway guided efforts aimed at overproducing the polymer via genetic engineering methods, or optimizing fermentation conditions and growth medium composition. Although increasing PHB production titer improves efficiency and reduces cost, the high price and lack of competitiveness of PHB in the consumer market stems largely from intracellular accumulation of PHB - where extraction and purification is the most significant cost component of PHB production. Additionally, use of toxic solvents and surfactants during PHB extraction may also contaminate the product. Thus, compared with increasing production titer, eliminating the extraction step would go further in reducing PHB's relative price (cost), and improves production sustainability; thereby, motivating the development of techniques for inducing the secretion of PHB. Given society's goal of mitigating climate change through reducing dependence on petroleum-derived chemicals, extracellular secretion of PHB would also help realize a bio-feedstock based chemical industry – where secreted PHB serves as precursors for synthesizing a range of platform chemicals. By tuning the size of PHB inclusion bodies and targeting them to appropriate cellular exporters through genetic engineering, recent research has described the creation of a recombinant *Escherichia coli* strain capable of secreting substantial fraction of size-limited PHB granules. Possible routes for increasing the amount of extracellularly exported PHB include: engineering PHB granules suitable for extracellular export, exploring and creating alternative export pathways and transporters through targeted genetic engineering and/or directed evolution, and creating "leaky" bacterial strains for facile PHB secretion. Overall, achieving progress on one or more of the above challenges would help advance PHB's role in a bio-renewable chemical industry. Additional topics such as the utility of PHB as bacterial storage polymers; the genes and metabolic pathways mediating its synthesis; and fermentation and extraction methods enabling its production provide context for a holistic discussion on the evolutionary origins, contemporary rediscovery and production of this incredibly useful and versatile biopolymer.

Keywords: biodegradable polymer; polyhydroxyalkanoates; downstream processing; environmental sustainability; nutritional stress response; microbial fermentation; PHB granules; inclusion bodies; extracellular secretion;

Subject areas: synthetic biology, biotechnology; metabolic engineering; cell biology; biochemistry; chemical engineering; bioengineering; systems biology;