Bioconversion of Heterogeneous Polyester Wastes to High-Value Chemical Products

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Project Summary and Significance

We propose a new biomanufacturing platform to produce high-value chemicals from low-value plastic wastes. The team aims to discover, evaluate and develop pathways for mechanical and biochemical recycling of waste polyesters into small molecule products with added value in the chemicals and materials industries. The project will enable industry to demonstrate and deploy high-performing drop-in chemicals as an alternative to conventional unsustainable sources.

The overall plastics recycling rate in the U.S. has stagnated at around only 9%, with the remainder ending up in landfills or leaking to the environment (e.g., ocean). Mechanical recycling results in inferior secondary feedstocks due to degradation and contamination, while typical thermochemical recycling methods are energy intensive and reduce the embodied energy in the plastics. This project will explore a ***three-step, energy efficient hybrid mechano-biochemical process to deconstruct and convert the heterogeneous polyester waste stream into high-value chemical intermediates*** suitable for a wide range of applications. The project objectives are:

1. Determine the most prevalent forms of film and fibers in post-consumer and industrial waste streams and track their physical characteristics before and during biodegradation.
2. Explore pretreatment and reactor design for efficient terephthalate (TPA) production.
3. Generate *E. coli* strains that produce key enzymes for biodegradation and bioconversion of PET into TPA and develop the enzymatic reaction system.
4. Create the *P. putida* strain that will be used for whole-cell conversion of TPA to muconic acid and adipic acid and develop the bioconversion reactor system.
5. Determine conversion kinetics, efficiency and separations strategies for the target products.
6. Evaluate the economics and environmental impact of the process under investigation.

Advantages and Outcomes

We will acquire real, heterogeneous waste stream samples of PET with structural diversity, and we will investigate pretreatments including granulation and molecular weight reduction to improve accessibility to enzymatic hydrolysis. We will create an *E. coli* enzyme expression system to make PET hydrolases at high yield and low cost, and identify the enzyme recipe that achieves the highest biodegradation rate. We will design a hybrid mechanical/chemical enzymatic degradation process suitable for large-scale PET waste treatment, and generate high-quality monomer streams for further bioconversion. We will build a new *P. putida* strain that expresses the genes responsible for converting TPA into maleic and adipic acids. Finally, we will conduct techno-economic and life cycle assessments to ensure commercial feasibility of the approach.

The proposed work has significant potential to mitigate the impact that global plastic consumption is having on the environment. The diverse microstructural and chemical features of the PET waste stock have unknown consequences for microbial deconstruction schemes. Because of this project's focus on **realistic, heterogeneous PET waste streams** and our plan to **screen multiple enzymes**, the research is more likely to reach DOE targets for breaking down multiple plastics streams simultaneously and tolerating contaminants generally found in mixed plastics waste streams.