Microbial and Biocatalytic Production of Advanced Functional Polymers

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A premier initial interface between biotechnology and materials science is the utilization of biosynthesis and biocatalysis for the production of novel biomaterials with specified properties. Industrial biotechnology or "white biotechnology" is an emerging field that uses enhanced microorganisms like yeast, moulds, and bacteria as "cell factories", along with the enzymes derived from them, to produce high-added value specialty biopolymers from renewable sources. The present study aims at the development of novel sustainable biosynthetic and biocatalytic processes for the production of high-added value bioproducts (e.g., advanced functional lactic acid- and PHA-based polyesters with desired molecular properties, water-soluble chitosan and alginate biopolymers, functional polysaccharide-based biosurfactants), not accessible by conventional chemical technologies.

Synthetic polymers have been associated with a large variety of practical applications of every-day life with food applications as the most representative ones. However, the growing reliance on these polymers has raised a number of environmental and human health concerns. Most of these materials are neither biodegradable nor derived from renewable resources. In the last decades there has been an increasing interest towards the production of polymers from biological precursors by applying modern biotechnology. Certain biopolymers are very similar to conventional polymers (i.e., polypropylene and polyethylene) and, provided that their production becomes economically viable, could be considered as attractive alternative materials. However, with regard to polymer synthesis, successful examples like the production of polylactic acid from cornstarch are rare. Other processes like the microbial synthesis of poly-β-hydrobutyric acid still suffer from poor life-cycle analysis impact. Current research efforts are directed towards the production of high-added value specialty products, commodity polymers and the exploitation of specific advantages offered by the superior stereo- and regio-selectivity of the bioprocesses, for the biosynthesis of functional molecules.

Despite the advantages regarding sustainability and selectivity of product formation, biocatalysis is still not viewed as a first-line alternative, but only as a last resort when other synthetic schemes have failed. Major technological advances are needed to influence industry in adopting enzymic/microbial production routes. To address this challenge, the following radical innovations need to be pursued:

- Novel biocatalysts: Exploration of native or manipulated microorganisms for the low-cost production of a wide spectrum of tailored enzymes with respect to substrate specificity, reaction rate, thermal stability and optimum pH. Improvement of the stability, performance and catalytic efficiency of enzymic systems using immobilization technologies. Biocatalysis in organic media.
- Metabolic pathway engineering of multiple reactions to generate novel metabolic products, for enhancing naturally occurring pathways to generate intermediates and to broaden the utilizable substrate range to various renewable and waste carbon sources.
- Innovative downstream processing operation for the recovery of bioproducts.
- Digital bioproduction and bioprocessing: The application of advanced modeling, monitoring and control methods to the inherently complex and time varying nature of bioprocesses will bring new prospects for substantial improvements in production efficiency and product quality.

It is the objective of the present study to explore the microbial-based and novel biocatalytic routes for the production of specialty biopolymers based on a limited amount of bio-based platform chemicals derived from renewable sources.

Back to program