Biologically Produced Succinic Acid: A New Route to Chemical Intermediates

Alternative Feedstocks Program

The U.S. Department of Energy (DOE) Alternative Feedstocks (AF) program is forging new links between the agricultural community and the chemicals industry through support of research and development (R&D) that uses "green" feedstocks to manufacture high-volume chemical building blocks. Industrial commercialization of such processes would stimulate the agricultural sector by increasing the demand for agricultural and forestry commodities. New alternatives for American industry may lie in the nation's forests and fields.

A Fresh Approach

The AF program provides new approaches to research partnerships. A unique consortium of five DOE national laboratories has been formed that can provide industry with easy access to the national laboratory system and can offer new approaches for collaborative research. The objective of the consortium is not to commercialize technology directly, but rather to provide industry with a broad range of expertise and to help lower the risk of new process development through federal cost sharing. Successful partnerships have been formed and are focusing on developing economic, environmentally friendly technologies for producing chemicals and materials from renewable resources.

Succinic Acid From Corn Syrup

The national laboratory consortium has undertaken a joint R&D project with the Michigan Biotechnology Institute (MBI) to demonstrate the feasibility of producing a chemical intermediate, succinic acid, and various derivatives, from renewable agricultural resources.

Succinic acid is currently produced using a hydrocarbon-based process that oxidizes n-butane to maleic anhydride. The maleic anhydride is then hydrated to the acid form and hydrogenated to yield succinic acid.

A fermentation process using glucose derived from corn syrup can also produce succinic acid, but with an undesirable solid waste by-product. The project's first generation or near-term goal is to demonstrate an economically competitive process for producing 1,4-butanediol and other derivatives from biologically produced succinic acid without generating a major salt waste. The second generation or long-term goal is to incorporate more advanced technologies to further reduce the cost of biologically producing succinic acid and its other value-added products including 1,4-butanediol, 2-pyrrolidinone, tetrahydrofuran, gamma-butyrolactone, and degradable polymers. The competitiveness of this bioprocess compared to the petrochemical process must be demonstrated.

Current Progress

- *Anaerobiospirillum succiniciproducens* (AnS) fermentation results were validated. Other microbial strains developed by MBI show improvement in product concentration over that of AnS. Metabolic and genetic engineering efforts have identified areas where research should be focused to improve yield.
- Two-stage membrane electrodialysis for primary purification has been demonstrated. Energy requirements and membrane life were determined. This

process does not generate a major salt waste stream.

- A novel secondary purification process has been demonstrated to yield a purified succinate ester which can be converted into 1,4-butanediol.

DOE Laboratory Consortium

Argonne National Laboratory
Idaho National Engineering Laboratory
National Renewable Energy Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory

Selected Examples of Collaborators

Alternative Agriculture Research Center
Environmental Protection Agency
Risk Reduction Laboratory
Michigan Biotechnology Institute
National Corn Growers Association
Degussa
Carbone
Celgene

Research Partnerships within Alternative Feedstocks

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

- An aqueous phase process for the direct conversion of succinate ester into 1,4-butanediol has been shown to be technically and economically feasible with purified fermentation broth. A second generation two-stage process is under development that affords significant economic advantages.
- Novel degradable polymers, derived from succinic acid, have been made at the bench scale.

Process Development

The objectives of the first generation process development effort are to demonstrate an integrated process and to provide sufficient succinic acid derived 1,4-butanediol for material testing by users. The integrated process will be operated continuously for a period long enough to test critical parameters in the fermentation, recovery, and catalytic conversion processes. This project is currently in the middle of this first generation process development stage. The objectives of the second generation process development efforts are to incorporate, integrate, and demonstrate improved processes for producing succinic acid and its derivatives.

Economics

A process economics model had been developed within the AF program. Case studies and sensitivity and risk analyses are performed to estimate the effect of new technology on production costs. These analyses are conducted on an ongoing basis to investigate the impact of each processing step on the overall production economics and are used to direct research efforts. The economic analysis shows that membrane electrodialysis results in a reduction in overall production cost of approximately \$0.06/lb compared to those of conventional fermentation organic acid recovery processes. The production costs for 1,4-butanediol produced by the current process is estimated to be approximately \$0.45/lb. In the envisioned completed first generation process, this is estimated to be about \$0.40/lb.

Industrial Partnerships

Industrial producers or users of 1,4-butanediol and related chemicals are being sought to lead the demonstrations of both the first- and second-generation phases. The partner should have technical expertise, have resources to devote to this cost-shared collaborative effort, be a real user or seller of 1,4-butanediol, and have a plan for commercialization.

First Generation Process Development

Evaluate replacements for the AnS organism including the improved strains from MBI and other sources.

Investigate immobilized-cell and cell-recycle fermentor configurations that could improve process economics through higher productivity.

Assess the feasibility of whole broth desalting electrodialysis to eliminate filtration steps.

Evaluate direct catalytic reduction of impure succinic acid to 1,4-butanediol.

Investigate novel esterification techniques for conversion of succinic acid into butanediol.

Second Generation Process Development

Improve product yield, productivity, and product tolerance through the use of metabolic engineering.

Confirm the enhanced performance of improved organisms in continuous and high-density bioreactors and in novel reactors in which fermentation and separation occur simultaneously.

Develop improved separation and purification processes.

Investigate novel esterification techniques for purification and for production of succinate esters.

For more information on this technology or the DOE Alternative Feedstocks program, contact:

Brian Davison

Succinic Acid Project
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6194
Phone: (423) 576-8522
Fax: (423) 574-6442
Internet: bod@ornl.gov

Gloria Kulesa

Alternative Feedstocks Program
U.S. Department of Energy
EE-233, 5F-059
1000 Independence Avenue, SW
Washington, DC 20585
Phone: (202) 586-8091
Fax: (202) 586-3180
Internet: gloria.kulesa@hq.doe.gov

*This document was produced for the U.S. Department of Energy (DOE) by the National Renewable Energy Laboratory, a DOE national laboratory.
DOE/GO-10095-208
DE95013107
Revised September 1995*

Printed with a renewable source ink on paper containing at least 50% wastepaper

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.