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 produce chemicals. The program promotes cost-effective industrial use of renewable biomass as feedstocks to manufacture high-volume chemical building blocks. Industrial commercialization of such processes would stimulate the agricultural sector by increasing the demand of 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 to demonstrate the feasibility of producing a chemical intermediate, succinic acid, and various derivatives, from renewable agricultural resources.

Many of the organic acids used by industry, such as citric and lactic acid, can be produced by fermenta-

tion. The organic acid, 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. However, this process produces the undesirable by-product gypsum.

The project's first generation or near-term goal is to demonstrate an economically competitive process for producing 1,4-butanediol from biologically produced succinic acid without gypsum production. Second generation or long-term research is also under way, that incorporates more advanced technologies to further reduce the cost of biologically producing succinic acid and its other value-added products including 1,4-butanediol. This bioprocess must be demonstrated and improved before it can compete with the petrochemical process.

Current Progress:

- Strains of microorganisms developed by the Michigan Biotechnology Institute show improvements in yield over that of the current microorgan-

ism, *Anaerobiospirillum succiniciproducens* (AnS). Additional strains developed by Celgene have been made available to the project. Metabolic and genetic engineering efforts to improve the productivity and yields of all strains have produced mixed results.

- Membrane electrodialysis for primary purification has been demonstrated,

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
National Institute of Standards and Technology
New Uses Council
U. S. Department of Agriculture
Economic Research Service

and the economic analysis shows a reduction in overall production cost of approximately \$0.06/lb compared to those of conventional fermentation organic acid recovery processes.

- An aqueous, catalytic conversion of succinate ester into 1,4-butanediol has been shown feasible.

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. The objectives of the second generation process development efforts are to incorporate and demonstrate the improvements to the 1,4-butanediol process and to demonstrate integrated processes for producing other derivatives from succinic acid.

Economics

A process economics model has 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.

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 the Michigan Biotechnology Institute and those from Celgene.

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.

Develop downstream conversion processes for producing other large-volume derivatives.

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

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