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Industrial Innovations

FOR TOMORROW

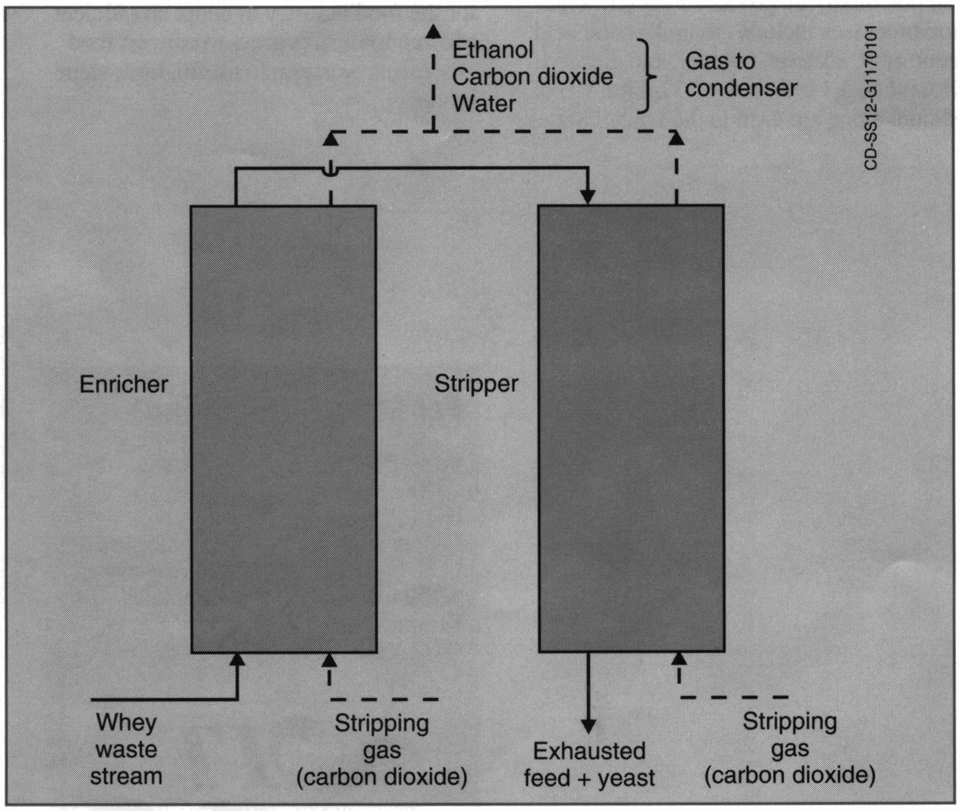
Advances in Industrial Energy-Efficiency Technologies

New Bioreactor Can Produce High-Value Chemicals from Food Processing Wastes

Fermentation processes for chemical production have not been competitive with refinery processes.

Many organic chemicals that are currently derived from petroleum can be produced through fermentation processes. Petroleum-based processes have been preferred over biotechnology processes because they were typically cheaper, easier, and more efficient. However, recent advances have resulted in new, cost-effective fermentation technologies that are more efficient and productive. These new technologies may enable fermentation-based chemicals to compete favorably with petroleum-based chemicals.

A critical need in the development of biotechnology processes for chemical production has been to find techniques for separating the desired product from the fermentation broth. The ideal approach is considered to be a bioreactor that combines fermentation and separation. Since 1984, the U.S. Department of Energy's Office of Industrial Technologies has sponsored efforts at Purdue University to develop an immobilized cell reactor-separator (ICRS) that can efficiently produce ethanol and other chemicals from fermentable food waste streams. The ICRS's ability to remove the product during fermentation represents a major advance in fermentation technology.



The two-column bioreactor produces ethanol from cheese whey; an inert stripping gas removes the ethanol from the fermentation broth in the columns.

Two large-scale ICRS pilot plants are being operated at Midwestern dairies.

The Purdue research has focused on using the ICRS to produce ethanol from cheese whey. In this application, the cells of the ICRS are lactose-utilizing yeasts adsorbed to a fibrous absorbent packing matrix that converts lactose to ethanol and carbon dioxide.

The reactor consists of two columns—a cocurrent gas-liquid enricher and a countercurrent gas-liquid stripper. In the enricher, the fermentable stream passes over immobilized cells that convert some of the stream to gaseous and liquid ethanol existing in equilibrium. The gaseous ethanol is taken out of the enricher and recovered by conventional adsorption or condensation methods. The fermentation broth then moves to the stripper column where the remaining ethanol is vaporized and removed with an inert stripping gas. The reactor-separator thus simultaneously converts the fermentable stream to ethanol and removes it from the fermentation broth.

The current phase of the project, under way since 1985, consists of two major efforts. The first involves scale-up, testing, design, and construction of large, demonstration-scale fermenters, and evaluation of economic feasibility. The second effort is focused on basic research to investigate alternative fermentation systems.

Based on the successful operation of small-scale systems in the mid-1980s, a full-scale pilot plant has been designed and constructed with cost-sharing from the Wisconsin Milk Marketing Board and private industry. This plant was recently installed at a Permeate Refining, Inc. site near a Swiss Valley Farms dairy in Hopkinton, Iowa. The 1980-gal (7500-L) plant uses concentrated sweet whey permeate to produce 500,000 gal/yr (1.89 million L/yr) of ethanol at 96% purity. The plant will undergo a 1-year test period during which researchers will gather data on liquid and gas flow characteristics, fermentation kinetics, and performance of the separation process. Several other Midwestern dairy sites are currently negotiating to install an ethanol plant.

Purdue researchers are also conducting studies on several advanced fermentation systems. Currently, eight projects are part of this basic research effort, including investigating the use of ICRS technology to produce lactic acid, diacetyl, acetic acid, and methane. One of the most promising applications is the use of dairy waste streams to grow yeasts; this process was demonstrated at a commercial dairy in 1992 using a 52-gal (200-L) pilot plant.

The ICRS process can put food wastes to practical use while reducing consumption of petroleum feedstocks.

There is no shortage of raw materials to use in the bioreactor. Each year, the U.S. food processing industry generates more than 3 billion lb (1.36 billion kg) of whey and whey permeate, 0.7 billion lb (0.32 billion kg) of potato wastes, 5.3 billion lb (2.4 billion kg) of molasses, 4.9 billion lb (2.2 billion kg) of citrus wastes, and 5.5 billion lb (2.5 billion kg) of corn and other food processing wastes. The chemicals that can potentially be produced via fermentation processes include ethanol, acetic acid, lactic acid, acetone, butanol, and diacetyl. More than 5.1 billion lb (2.3 billion kg) of ethanol alone are used in the United States each year, representing the largest available market commodity of chemicals made from food wastes.

Compared to both conventional fermentation processes and petroleum-based processes, the advantages of the ICRS process are numerous. The ICRS has higher reaction rates, higher conversion efficiencies, lower energy requirements, and better reliability than conventional stirred-tank fermentation reactors. The cost of energy to produce ethanol via fermentation is only $0.08 to $0.16/gal ($0.02 to $0.04/L), significantly less than that of petroleum-based production. In addition, the new bioreactor requires a low capital investment and has low operating and maintenance costs.

Using the ICRS process will simultaneously alleviate several concerns—the use of increasingly scarce petroleum feedstocks to produce chemicals and the disposal of billions of kilograms of food wastes each year. As the food processing industry continues to grow, processors will face significant pressure to do something productive with their wastes. The climate appears favorable for the food industry to adopt an efficient and economical process to convert food processing wastes into useful, high-value products.

For More Information

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This document was produced for the U.S. Department of Energy (DOE) by the National Renewable Energy Laboratory, a DOE national laboratory. • The document was prepared for the Office of Industrial Technologies in conjunction with Energetics, Inc.
DOE/CH10093-197 • DE93000062 • November 1993