hemoglobin, an oxygen carrier, grew more efficiently at a lower oxygen concentration (by two times) than those without the hemoglobin gene. This method can dramatically improve the growth and productivity of genetically engineered aerobic microorganisms.

The production of aerobically fermented products in the United States in 1987 was about 300 million pounds. Use of these genetically engineered microorganisms can help resolve critical barriers that currently impede the production technology of energy- efficient aerobic fermentation processes. Two broad-based patents for the above technology were filed.

Designing Biocatalysts for Energy-Efficient Chemicals Production

There are several technical barriers to the development and application of biocatalysts for producing fuels and chemical feedstocks. The development of a molecular-level reaction model for enzyme systems is an initial scientific step toward removing these barriers. During the past three years, the California Institute of Technology, with DOE funding, has developed software for computer-based graphic displays of three-dimensional structural models of molecules. The models permit the user to display and rotate a three-dimensional representation of the structure of any biological molecule of interest, such as an enzyme or pharmaceutical. The interaction of the atoms in the molecule and any structural changes imposed by the user-specified conditions (e.g., increases in temperature, pressure, or the removal/ substitution of any given atom) can be displayed. The models simulate real molecules by using a set of analytic force fields to describe the interactions among the atoms. When the models were used for predicting the molecular structure of the enzyme thermolysis as a function of temperature and inhibitors, excellent agreement with crystallographically determined structures of thermolysis resulted.

This tool is now being used to design new molecular structures for drugs, catalysis, and a wide variety of other applications. The simulation models may enable the design of supports for immobilizing enzymes without degrading performance and enable the design of enzymes for selectivity and resistance to poisons.

High-Productivity Bioreactor

Batch fermentation processes using microorganisms suspended directly in the fermenting broth suffer from low product yields, accumulation of impurities that contaminate the desired product, and loss of microorganisms from the batch when processing is completed. To increase productivity sufficiently for industrial fermentation processes to be competitive, more efficient continuous processing techniques need to be used.

DOE research in continuous fermentation processes has increased ethanol productivity 10 times in an advanced fluidized-bed reactor system. In addition, the study of the kinetic properties of immobilized microorganism biocatalysts has led to a better understanding of the behavior and predictability of bioreactors.

The A.E. Staley Company has expressed interest in the research and has provided raw corn dextrose slurry and corn light steepwater for laboratory tests. Experiments in a continuously stirred tank reactor using yeast extract as a nutrient source have been completed. The steady-state productivity was not changed when glucose was substituted for crude corn dextrose or when yeast extract was replaced with a 1:5 dilution of light steepwater. The only operational difficulty was some fouling because of the high lipid content of corn dextrose. During the 300-hour run, 25 grams per liter-hour of ethanol were produced at a 90% conversion rate. These results suggest that higher productivities for a fluidized-bed column at greater than 200 grams per liter-hour are possible when industrially acceptable feedstocks and media such as corn dextrose and light steepwater are used.

Coal-fired Steam Turbine Cogeneration

Cogeneration systems for industrial processes can potentially save thousands of dollars per year. Cogeneration is not widely used in such industries as textiles manufacturing, however, either because of space limitations or because the temperature of the turbine exhaust is too low for process use. To encourage use of cogeneration systems in this industry, DOE and Riegel Textile cofunded the design, installation, and evaluation of an innovative 4.1-megawatt, high-back-pressure steam cogeneration system at one of the firm's textile plants.