Zymomonas mobilis

Lowering the Cost of Converting Biomass to Ethanol

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF TRANSPORTATION TECHNOLOGIES

Transportation

FOR THE 21ST CENTURY

Background

Ethanol is a clean, renewable, domestically produced fuel that can reduce dependence on imported petroleum, while benefitting the Nation's farmers. Cost is the key impediment to the widespread use of ethanol in highway vehicles. For a number of years, The U.S. Department of Energy (DOE) has supported energy crop research at the National Renewable Energy Laboratory (NREL) to address these issues. In 1994, NREL developed a new, genetically engineered organism known as *Zymomonas mobilis*, which enhances the fermentation of biomass sugars, leading to greater yields of ethanol and lower costs. The advantages that *Zymomonas mobilis* holds over traditional yeast processes lead to more economical and environmentally friendly methods of producing ethanol.

The Technology

Researchers are using waste paper and cellulosic byproducts from agricultural crops, which make up more than 90% of the nation's waste, as feedstocks for ethanol. Glucose is a six-carbon sugar that is readily fermentable by common industrial yeasts. However, the common yeasts that ferment glucose are unable to ferment xylose, which is a five-carbon sugar. Using separate organisms to ferment five and six carbon sugars requires separate fermentation tanks, which represents a large portion of capital cost of the biomass to ethanol conversion process. NREL researchers sought to make this part of the conversion process less expensive by developing a microorganism that could ferment all the sugars in the process together (cofermentation). Researchers designed a process for evaluating and rating the effectiveness of different microorganisms for converting sugars to ethanol. They determined that the bacterium *Zymomonas mobilis* displayed many traits sought in an ideal biocatalyst for ethanol production, although it naturally ferments only six-carbon sugars. They then applied some highly sophisticated metabolic engineering and developed a strain of *Zymomonas mobilis* that produces ethanol from both xylose and glucose. Researchers at the University of New South Wales (Australia), in collaboration with NREL, are cloning the genes necessary for new strains of *Zymomonas mobilis* to convert starch directly to ethanol. This will represent a 5%-10% savings in enzyme costs for commercial ethanol processes. In 1995, NREL won an R&D 100 Award for its ability to convert multiple sugars to ethanol, and as of 1997, three worldwide patents were granted *on* the *Zymomonas mobilis* process.

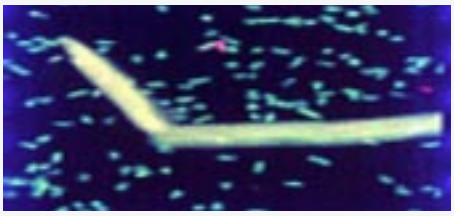
Commercialization

Research has been underway for more than 20 years to develop technologies for converting feedstocks to ethanol. In 1999, under a cooperative research and development agreement, NREL partnered with Arkenol, Inc., located in California, to evaluate Arkenol's concentrated acid hydrolysis process with *Zymomonas mobilis* for the production of low-cost ethanol from sugar cane wastes, softwoods, and napier grass. Arkenol's research should be completed by the end of 2000, at which time commercial production of *Zymomonas mobilis* will follow shortly thereafter. DOE is assisting Arkenol in building a new biomass-to-ethanol plant that will provide 8 million gallons per year of ethanol from rice straw using the *Zymomonas mobilis* process. This project provides an alternative to rice straw burning, which is being phased out in California for environmental reasons. Today, Arkenol's and NREL's research continues to improve sugar-fermenting microorganisms for enhancing commercial processes guided by requests from industry.

Benefits

- **An ethanol (E85) vehicle displaces 400 gal/yr of gasoline**
- **Ethanol vehicles produce**

  35% less CO
  42% less NO_X
  43% less NMHc
  39% less PM
  79% less CO_2
  over life cycle
- ***Zymomonas mobilis* has**
  - **shorter fermentation time (300%-400% faster than yeast)**
  - **higher ethanol yield (92%-94% versus 88%-90% for yeast)**
- **Converts sugar mixtures to ethanol with 90%-95% efficiency**



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