Fuels From Agriculture

Ethanol, or grain alcohol, burns with a pure blue flame and makes an excellent fuel for automobiles. The traditional way to make ethanol is to convert the starch from corn into fermentable sugar by cooking a corn mash and treating it with malt. The sugar is then fermented into alcohol with a yeast. The process is an old and relatively simple one, but the ethanol it produces costs more than gasoline.

The aims of NRRC research in making ethanol are to bring down its cost by using cheaper raw materials, developing processes that consume less energy, and finding more efficient yeasts for fermentation. The Northern center has made progress in all these areas. If the day arrives when ethanol is competitive in price with gasoline, U.S. dependence on foreign oil supplies will be diminished and America's trade balance will be improved. There will also be a new and profitable market for millions of tons of surplus and waste products from agriculture.

Alcohol research began at NRRC during World War II, when shortages of corn and molasses dictated finding new sources of industrial alcohol, needed to manufacture munitions and synthetic rubber. Plenty of wheat was available, but distillers had had little experience in using it to make alcohol. NRRC researchers and others soon found ways to prepare mashes from wheat instead of corn. They selected yeasts from the Peoria culture collection suitable for fermenting the mashes, and they pioneered the use of mold enzymes, called fungal amylases, to convert wheat starch into sugar for fermentation. As a result of Government-industry cooperation, some 250 million bushels of wheat were used during the war to produce critically needed ethanol.

In research immediately after the war, a survey of more than 350 fungi from the NRRC collection turned up several with promise for converting cereal starch to sugar, and the fungal amylase process for making alcohol was improved and widely adopted by grain alcohol distillers. By using fungal amylase instead of malt, they were able to reduce the cost of making ethanol by from 1 to 3 cents per gallon.

The oil embargoes of the 1970's stimulated renewed activity to find cheaper ways to make alcohol as an alternative fuel to petroleum. Microbiologists made a thorough search of the Peoria collection of fungi and bacteria to identify microbes that could do a better job of fermenting alcohol from a variety of raw materials. They knew that if gasohol were ever to become an economical fuel, they would have to find more efficient ways to convert starch to sugar and to ferment that sugar to alcohol.

The microbe screening turned up several specimens with promise. One mold, used in Indonesia to ferment a popular food product, produced glucose when grown on cracked corn. Another, a bacterium, saved energy by tolerating the heat of cooked mash better than yeast. A fungus called the oyster mushroom freed cellulose for digestion to sugar, and yet another, found in a cow pasture, performed in a similar manner, exposing more cellulose for sugar conversion. In 1982, a yeast called *Candida wickerhamii,* originally found in Italy, proved capable of making alcohol directly from cellulose, a feat that ordinary yeasts were unable to perform.

Peoria chemical engineer Patricia J. Slininger and A. A. Lagoda, engineering technician, prepare a fermentor for growing cells of Pachysolen tannophilus, *an unusual yeast that can convert biomass to alcohol.*

The most promising candidate so far for converting biomass to alcohol, however, is *Pachysolen tannophilus,* an unusual yeast from France. Through a patented NRRC process, the yeast can convert xylose, or wood sugar, directly to ethanol. That's good news, because there is no shortage of xylose on the farm; it is a major component of straw, cornstalks, hulls, corncobs, and other plant residues. A chemical engineer in Peoria is now engaged in developing a continuous process for producing ethanol with *P. tannophilus.*

Other NRRC researchers have investigated using vegetable oils—or chemicals derived from them—as diesel fuels, especially for emergency use. In short-term tests, such oils performed well in diesel engines. They did less well in longer trials, however, because of high viscosity and low volatility of soybean and other vegetable oils. Low volatility is one cause of incomplete combustion; the oil is inefficient and leaves harmful residues. Highly viscous oil clogs mechanical engine parts and causes them to wear out faster. So far, NRRC researchers have been more successful at finding ways to lower the viscosity of vegetable oils than they have at increasing their volatility.

Four possible ways to improve performance have been explored, including: (1) Chemically converting the vegetable oils with alcohols to simpler chemicals called fatty esters; (2) mixing the oils with alcohols and water to form stable blends called microemulsions; (3) dissolving vegetable oils in conventional diesel fuel, and (4) heating the vegetable oils to break them down to a variety of chemicals with lower boiling points, or higher volatility. As 1991 began, however, the problem of incomplete combustion remained unsolved. Basic research is under way at NRRC today to provide researchers with a better understanding of the chemistry of combustion. With that information, scientists believe that it may yet be possible to design technologies to improve the combustion of diesel fuels derived from vegetable oils.