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Bioethanol needs biotech now

The last time biofuels figured prominently on the editorial pages of this journal was July 1996. Back then, we were struck by how many biofuel projects appeared to be "solutions in search of a problem." Ten years later, a problem has been found. Biofuels, in particular ethanol, are being touted as a partial solution both to the world's mushrooming energy demands and to the challenge of reducing greenhouse gas emissions from fossil fuels. And even though ethanol production from corn grains—currently the method of choice in the United States—falls some way short of an ideal environmentally friendly alternative to gasoline, biotech may provide some near-term solutions to its drawbacks, at least until a better means of producing renewable energy comes along.

The rationale for turning more vegetation into ethanol runs along the following lines. Consumption of oil continues to climb; from 2002 to 2004, the Worldwatch Institute estimates that world oil demand increased by 5.3%, most notably in China, the United States, Canada and the United Kingdom. In 2005, the world's biggest polluter, the United States, consumed over 140 billion gallons of transportation fuel, and its gas-guzzling vehicles pumped more than 308 million metric tons of carbon into the atmosphere, with potentially dire consequences for the Earth's climate. At the same time, 'peak oilers' are claiming that the world's fossil fuel reserves are running out, and foreign policy hawks are lamenting the West's "dangerous dependence" on foreign oil. All of which explains why governments around the world are looking to diversify their energy sources with nuclear, hydroelectric, wind and biofuel energy.

They have a range of biofuels to choose from. Bioethanol, biodiesel (methyl and ethyl esters), biohydrogen, alkanes and various other hydrocarbon mixtures (such as wood gas and syngas) are all under development. Today, however, ethanol is by far the most widely available; in the United States, for example, it constitutes 99% of all biofuel produced (a total of over 4 billion gallons in 2005 from the fermentation of sugars derived from corn).

Indeed, ethanol seems to have many things going for it: it's biodegradable, it produces slightly less greenhouse emissions than fossil fuel (carbon dioxide is recycled from the atmosphere to produce biomass), it can replace harmful fuel additives (e.g., methyl tertiary butyl ether; MTBE), it produces jobs for farmers and refinery workers (about 150 jobs for every job created by the oil industry) and it provides a convenient excuse for US and European politicians to subsidize their agriculture.

In reality, though, ethanol's credentials as a green fuel are less than perfect. Paradoxically, US ethanol production is increasingly moving away from natural gas—the relatively clean traditional energy source for running biofuel refineries—and switching over to coal, a more environmentally pernicious choice. Indeed, one major ethanol producer, Archer Daniels Midland, has already paid hundreds of millions of dollars in air pollution fines, operating a coal-powered ethanol plant in its hometown of Decatur, Illinois, another one in Cedar Rapids, Iowa, and building a third in Clinton, Iowa. There are plans for more.

Deriving ethanol from corn also has costs in terms of the copious amounts of nitrogen fertilizer and extensive top-soil erosion associated with cultivation of this particular crop. Each year, pesticide, herbicide and fertilizer runoff from corn fields bleed into groundwater; contamination of the Mississippi River is such that algal blooms cause an enormous 'dead zone' in the Gulf of Mexico. If this were not bad enough, ethanol importation by industrialized nations could lead to increased ecological destruction in developing countries, as indigenous natural habitats are cleared to make way for energy crops, such as sugar cane. So much for an environmentally friendly fuel.

But these drawbacks are exactly the kinds of problems that biotech could help solve. For ethanol currently derived from corn grain and sugar cane, recombinant technology is already available that could both enhance ethanol yield and reduce environmental damage from the feedstock, and enhance bioprocessing efficiency at the refinery.

For example, it may be possible to further optimize energy crop yield by boosting the carbon-fixing efficiency of photosynthesis. Similarly, there should be ways to manipulate nitrogen metabolism or fixation pathways to reduce the dependence on environmentally damaging fertilizers, such as atrazine. As for pesticide runoff, many strains of *Bacillus thuringiensis* toxin corn that would reduce chemical runoff are already commercially available. Although success has been limited in engineering such traits as drought-, salinity- and cold-resistance and reduced winter dormancy, varieties of this type could potentially reduce seasonal variations in energy crop harvests.

The enzymatic machinery (e.g., amylases) for breaking down endosperm starch into simpler sugars could also be introduced into plants under the control of promoters inducible upon harvesting. And once the grain has arrived at the ethanol refinery, companies like Genencor are engineering thermostable glucoamylases that can convert granular starch to fermentable sugars on a continuous basis, without the need for an energy-intensive 'cook step' in ethanol production. Other more preliminary approaches attempt to encapsulate enzymes in silicon or carbon nanostructures, providing enzymes with protection from pH or thermal denaturation. And in the fermentation stage, budding yeast and *Zymomonas mobilis* strains have been created with the capacity to convert pentose sugars (in addition to their natural hexose substrates) to ethanol, or with increased tolerance to high sugar/ethanol concentrations and the accumulation of inhibitors.

In the long term, it is also clear that biotech innovations will be central in transitioning bioethanol production from corn grain to more sustainable, energy-efficient, but recalcitrant feedstocks, such as cellulosic biomass (wood chips, corn stalks, willow trees and switchgrass). But in the meantime, although corn remains the preeminent energy crop, biotech can make bioethanol both more profitable and more environmentally friendly. Doing so might do wonders for biotech's own public image as well. After all, it's difficult to oppose a technology that's helping to save the planet.