A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

National Renewable Energy Laboratory

Innovation for Our Energy Future

Jet Fuel from Microalgal Lipids

Probably our most pressing energy need is to develop domestic, renewable substitutes for imported transportation fuel. Ethanol made from starch or sugar such as corn grain already displaces about 2% of gasoline and making it from cellulosic biomass will allow much greater displacement. Biodiesel made from oil crops such as soybeans can displace some of our diesel use.

Unfortunately, neither of these biofuels can help supply jet fuel, for which energy density and low-temperature fuel properties are critical. Ethanol is not dense enough having only about half the energy per volume of jet fuel. Biodiesel has about 80% the energy density of kerosene, but can solidify at the low temperatures of high altitude flight. In addition, the quantity of biodiesel that could be produced from oilseed crops is quite limited.

The solution may come from a combination of hydroprocessing—a technology already used by petroleum refineries—and microscopic algae. The National Renewable Energy Laboratory (NREL) has extensive experience cultivating and manipulating microalgae to produce lipids or oils. NREL's past research was done with a view toward using the microalgal oil to make biodiesel by the same process as from macroscopic plant oils. But with various hydroprocessing technologies used by refineries to catalytically remove impurities or reduce molecular weight, the algal oils could be made into a kerosene-like fuel very similar to petroleum-derived commercial and military jet fuels or into a fuel designed for multi-purpose military use.

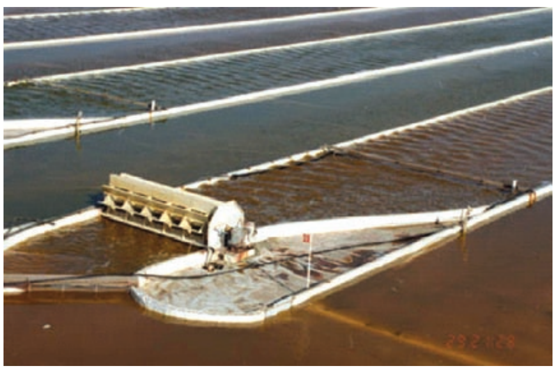
The recipe for getting microalgae to produce lipids sounds like a daydream for using underutilized resources: put them in salty water unfit for other use, expose them to the sun in areas unsuitable for growing crops, feed them power plant or other exhaust gas that threatens the world climate, and deny them certain vital nutrients. Many microalgae naturally store energy as oil when the lack of nutrients makes them unable to use the energy for normal growth. They also use the lipids to regulate their buoyancy. By manipulating nutrients and other growth conditions and by selecting and genetically engineering strains to increase this oil production, NREL researchers were able to attain quite high lipid production levels.

Selection from an extensive culture collection, along with metabolic manipulation and genetic engineering, were ways NREL researchers developed strains of microalgae producing high levels of lipids for biofuel production. PIX 03987

As it happens, many microalgae grow best in saline water, and like any plants, they require sunlight and carbon dioxide. Unlike terrestrial plants, they do not require precipitation or good soil. Much of the U.S. Southwest and other warm climate desert and seashore areas are unsuitable for traditional agriculture, but highly suitable for microlagae growth. Originally, inexpensive

shallow ponds were seen as the most cost-effective way to grow the microalgae. Growth rates far exceeded those of terrestrial plants and oil production reached as much as 50 times that per acre of oilseed crops. Today, the low cost of plastic containers makes the possibility of growing the algae in closed systems such as transparent tubular reactors a very realistic possibility and yields could be even higher.

The ability of microalgal cultures to utilize high volumes of carbon dioxide is so great that development of the technology was also motivated by the idea that greenhouse gas emissions could be reduced by passing flue gas from power plants, ethanol plants, oil and gas drilling operations, or other industrial sources through the cultures. Again, there are a number of major power plants in the U.S. Southwest and other areas highly suitable for microalgae growth.



A raceway pond system in Israel growing microalgae for nutraceutical production. PIX 08332

NREL is now looking to reestablish its microalgal oil research in partnership with oil refiners, with a particular view towards jet fuel production. The program was discontinued at a time when diesel was less that $0.60 per gallon. Both diesel and jet fuel now obviously cost far more. Military jet fuel also carries a very high added cost and logistic difficulty of transport around the world. But there is considerable refining capacity strategically located around the world that could be used for hydroprocessing microalgal oil to jet fuel, with both offshore and onshore locations highly suitable for microalgae growth nearby. Genetic engineering and screening technologies have also advanced dramatically since 1996 when the original research program was closed out.

Top research priorities include the following:

- Applying current strain selection, screening, and genetic engineering technology to increase lipid yields
- Genetically manipulating the mechanism by which microalgae switch back and forth between normal growth and lipid production to maintain high rates for both
- Optimizing the lipids produced for hydroprocessing into jet fuels or multi-purpose military fuels
- Working with oil refiners to tailor hydroprocessing to use for converting microalgal oil to premium diesel or jet fuel.

For further reading:
A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae Close-Out Report
http://www.eere.energy.gov/biomass/pdfs/biodiesel_from_algae.pdf

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