



algae, algae,



everywhere...

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Where some people see slime, *Milt Sommerfeld* and *Qiang Hu* see **fuel** and **food**. They also see solutions to some of the trickiest environmental problems looming right in front of us.

and plenty of biofuel, too!

Image credit: CSIRO

by *Diane Boudreau*

You know algae. It's the gunk that collects on the sides of a fish tank when you forget to clean it. It's the slime that makes you slip on rocks while crossing a stream. You probably think of algae as a nuisance, if you even bother to think of it at all.

Milt Sommerfeld and Qiang Hu think of algae as one of the most useful substances in existence. And they think about it every day. In fact, they have an entire laboratory dedicated to the study of algae. The Laboratory for Algae Research & Biotechnology (LARB) is located in Mesa at ASU's Polytechnic Campus.

"We have algae everywhere," says Sommerfeld with a smile, gesturing around the lab at flasks and beakers filled with bright green liquid. There are algae spinning in centrifuges and algae shaking on platforms. There are algae growing in bubbling bioreactors, algae in refrigerators, and algae under microscopes.

No murky pond scum here—these algae are the shade of a shamrock on St. Patrick's Day.

Where other people see slime, the Arizona State University scientists see solutions.

They see environmentally friendly fuel. They see pollution control. They see food. They see fertilizer. In short, they see it as an answer to many problems that currently stare humanity in the face.

So do others, including the editors at Time. The magazine lauded Sommerfeld and Hu's

usable fuel from algae. Sommerfeld and Hu are working on a way to produce algae-based biodiesel for cars and trucks.

Biodiesel is a cleaner alternative to regular diesel fuel. Diesel is produced from nonrenewable petroleum, while biodiesel comes from renewable sources such as vegetable oils or

"The solitary algal cell is one of nature's most efficient energy conversion systems."

work on developing algae-based biofuel as among their "Best Inventions of 2008."

The editors wrote: "The work is raising algae for conversion to a biofuel that would be virtually identical to gasoline." But the new fuel would be carbon neutral, because algae consume carbon dioxide as they grow.

Fish tank to gas tank

Imagine if you could scoop algae out of your fish tank and put it in your gas tank. It's not quite that easy, but it is possible to extract



Milton Sommerfeld, 2007

animal fats. Biodiesel also burns cleaner than diesel, and it is biodegradable. Pure biodiesel can only be used in modified engines, but a diesel-biodiesel mixture can be used in existing diesel engines.

The researchers also have funding from the Defense Advanced Research Projects Agency (DARPA) to develop another type of fuel from algae—Jet Propellant 8, or military jet fuel. Scientists around the world are working to produce alternative fuels from a wide variety of plant materials. Ethanol derived from corn is already widely used. Unlike corn, however, algae aren't food crops. And algae doesn't have to be grown on arable soil—soil that could be used for growing food.

Unlike corn plants, algal bioreactors can be placed on land that isn't suitable for farming. The algae require only water and sunlight.

“We know we can make diesel fuel from algae. The next question is—is it economical?”

Arizona has plenty of sunlight and numerous farms producing nutrient-rich wastewater.

“One dairy cow produces 800 pounds of nitrogen per year,” says Hu. “The average dairy farm has 1,000 to 2,000 cows. We can convert 100 percent of the nitrogen they produce into fuel. In Arizona we have plenty of waste nutrients. Any kind of farm that produces manure—cattle, hogs, chickens—would work.”

Another reason algae make good candidates for biofuel is their sheer productiveness. Like all plants, algae turn sunlight into fuel using photosynthesis. But algae do it more efficiently. “What makes algae interesting is that every cell is like a leaf cell,” says Sommerfeld. “Every cell is photosynthetic. Algae are more productive than corn or soybeans because every cell is a factory.”

“Plants have roots and stems. But only the leaves can photosynthesize. Most algae are single-celled. The entire organism can do photosynthesis and access nutrients from all directions instead of only roots. Its metabolism is 10 to 20 times faster than rooted plants,” adds Hu.

The researchers choose from among the nearly 40,000 known species of algae. They look to find types that are highly productive in Arizona's climate. So far they are working only with naturally occurring species, but they are open to the possibility of further genetic

modification down the line, if necessary.

If anyone knows algae, it's Sommerfeld. He has been studying the properties of various algal species at ASU for more than 30 years. He is always on the lookout for species that reproduce rapidly. “Our goal was to have organisms that could do at least one doubling per day,” he says. His group is now working with cells that can reproduce two to three times in a 24-hour period.

The researchers are also looking for species that produce the largest quantities of lipids—or fats—under local conditions. Biodiesel is produced from the lipids. Growing algae in a reactor helps increase lipid production.

“Algae increase production of oils when they are stressed. They grow fast in a bioreactor,” Sommerfeld says. “When they've used all the nutrients they can, and can't grow any more due to nutrient limitations, they store chemical energy in fat. That is in contrast to humans. When we eat too much, our bodies accumulate fat. Algae accumulate fat when they are starved.”

Reacting with efficiency

Located in Mesa on the eastern end of the Phoenix metropolitan area, ASU's Polytechnic Campus and the surrounding area are just beginning to hit their own growth spurt. Set against a backdrop of the Superstition Mountains, the campus still has a desert wilderness feel. It was all this open space—space for a laboratory, and land space for bioreactors—that lured Sommerfeld and Hu from ASU's main campus in Tempe.

The LARB is housed in the new, crisply modern Interdisciplinary Science and Technology Building 3. But their green potions are not constrained to just one lab. Out behind ISTB3 stretches a 30-foot-long bioreactor. Although the tank is only a fraction of the size that a full-scale production model would be, it allows the researchers to test and tweak the efficiency of the reactor.

Hu is the go-to guy for bioreactor design. A biologist by training, he has always been strongly interested in engineering and in developing bioproducts.

Efficient bioreactor design is imperative for producing a commercially viable fuel. Obviously, the researchers don't want to expend more energy than they produce. So they are working to create the most efficient, cost-effective reactors possible. The reactor located behind ISTB3 holds 1,000 liters. It is a small-scale testing reactor that can produce about 20 pounds of algae feedstock per batch. That in turn yields about 2 gallons of biodiesel—



enough to fuel a small car for 40 to 60 miles.

The reactors don't require much energy, but they do need some. For example, pumps are needed to circulate the water. And in hotter weather, the reactor runs an evaporative cooling system.

In addition, the algae need to be harvested and dried. Currently the researchers run it through a centrifuge, kind of like the bathing suit dryers you'd find at the gym. The centrifuge spins the water out of the algae, leaving a paste. The machine can process 450 gallons of liquid per hour.

Sommerfeld and Hu are always looking for ways to make their production more efficient.

“We know we can make diesel from algae,” explains Hu. “The next question is—is it economical?”

The pair is betting that it is. They believe that algal-based biofuel could be a commercially viable technology in three to five years. If that happens, people may start thinking a lot more highly of that slimy green gunk.

Excerpted and updated version of “Fuels of Green,” the cover story for Fall/Winter 2007 issue of ASU Research Magazine.

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a look back...



Milton Sommerfeld, Stephen Ellingson and Patti Tyler as featured in ASU Research Magazine's Spring 1987 issue.

“Based on current technology, the Solar Energy Research Institute estimates that sometime before the year 2010, microalgae could be used to produce gasoline-type fuel at a cost of \$1.60 to \$2 per gallon. Allowing for inflation, such prices could make algal fuels competitive with conventional fossil fuels.”

– *SERI Report, 1987*

“Help us to lead a green revolution,
developing new sources of clean energy that will
power our economy and preserve our planet.”

– President Barack Obama

ASU Commencement Speech – May 13, 2009



ASU Research Magazine
Spring 2007 Issue

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