Professors see solutions in slime

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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 at Arizona State University’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. There are 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 ASU professors of applied biological sciences 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.

Clean and green

One of those problems is agricultural wastewater. Runoff from crops and livestock contains fertilizer, pesticides, and other materials that can contaminate water supplies. People living in rural areas often pump drinking water from private wells that are not monitored for these contaminants.

Nitrates found in fertilizers are particularly dangerous to human health, especially to babies less than six months old. When nitrate-laden water is used to mix infant formula, the contaminants can interfere with oxygen absorption, causing "blue baby syndrome." The syndrome can cause brain damage and death.

Agricultural runoff also makes its way into the oceans, disturbing the balance of aquatic life. Too much fertilizer in ocean water can produce algal blooms that deplete oxygen, "choking" other plants and animals. Also, some species of algae produce toxic blooms known as red or brown tides, which can poison fish and mollusks.

Sommerfeld and Hu want to fight algae with algae. By running wastewater through bioreactors that contain algae, they can produce their own isolated algal blooms that don't disrupt anything around them. The algae gobble up nitrogen and phosphorus—two common fertilizer nutrients—leaving the water cleaner and safer than before.

The wastewater feeds the algae. The ASU scientists can then harvest the algae for a variety of possible uses.

"We're working on algae that have a purpose," Sommerfeld explains. "The goal is to collect the algal biomass and use it as fertilizer or animal feed, and return the water free of nutrients."

Fish tank to gas tank

Another potential use for all this algae is biofuel.

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 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. Biodiesel comes from renewable sources such as vegetable oils or 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.

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.

The problem with using food crops for fuel came to international attention early in 2007 with the Mexican “tortilla crisis.” As international corn prices skyrocketed, the cost of corn tortillas rose nearly 14 percent from 2006 to 2007. Low-income Mexican families became unable afford this staple of their traditional diet. Economists point to the increased demand for corn-based ethanol as the main reason for the price increases.

Unlike corn plants, algal bioreactors can be placed on land that isn’t suitable for farming. The algae require only water and sunlight. 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. However, 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, it turns out, 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's not uncommon to spot roadrunners or Gambel's quail trotting alongside students rushing off to class. 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.

Their lab 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. The researchers have also teamed with faculty and students from the Department of Mechanical and Manufacturing Engineering Technology.

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 40-60 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.

Source: by Diane Boudreau, Arizona State University