More than mere pond scum

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Researchers first grow algae in the lab to find the optimum growing conditions - and then scale up to mass-produce it. Credit: Joel Cuello

(PhysOrg.com) -- Algae could soon become a valuable biofuel resource, according to research at the University of Arizona.

It's green, it's slimy and it smells. It also abundantly produces lipids, sugars and sometimes hydrogen gas, all of which are sought-after sources for renewable energy. You may think of it as mere pond scum, but algae could be a highly productive biofuel crop in the near future.

More than 300 times as productive a source for renewable energy as corn, algae could be used to make biodiesel to power vehicles and industries – if it can be produced at a low enough cost to be feasible economically.

In a collaborative research effort between several departments, scientists and engineers at the University of Arizona are studying ways to optimize the production of biofuels from algae.

The challenge: How to use environmental factors to control the rate at which the algae grow and produce lipids to maximize production while also reducing the cost of resources needed to grow algae.

"Right now the cost of production still exceeds the value of the final product," said Joel Cuello, professor in the department of agricultural and biosystems engineering. "So the challenge research-wise is trying to lower the production cost while increasing algae productivity."

One way to lower production cost is to use treated secondary wastewater to grow the algae. The algae purify the water by absorbing nutrients such as nitrogen and phosphorus, and at the same time eliminate the need to use costly fertilizers to supply the algae with nutrients.

"Wastewater has nitrates and phosphates that need to be removed anyway, so why not just feed it to the algae?" said Cuello.

Algae cells store fat as lipids, oil molecules that can be processed to make biodiesel. The researchers grow colonies of algae in flasks to test the effects of different environmental conditions on growth and lipid production.

Kimberly Ogden of the department of chemical and environmental engineering has a lab full of algae-filled flasks: "We grow the algae and then separate the lipid material that can be turned into fuel from the rest of the algae, which is mostly protein."

The goal, said Ogden, is to learn enough about the chemical structure of the oils to be able to process them into biodiesel with the same facilities currently used to process petroleum. Eventually algae oil could be blended with petroleum oil to make biodiesel.

"We use alternative water supplies and look at water recycling and reuse," said Ogden. "We don't want to use tap water – for one thing all the chlorine is probably not a good idea, and we don't want to be using the freshwater supplies."

An open pond system is one way to mass-produce algae for biofuels. Credit: Joel Cuello

One of the challenges is selecting a species that produces the right lipids at the right rate, said Mark Riley, professor and head of the department of agricultural and biosystems engineering.

"We can look at algae that grow very quickly, but they generally make very little oil. Or there are algae that grow really slowly, but they make a lot of oil. So the challenge is how to mix the two of those characteristics to maximize the amount of oil."

"One of the ways to try to stimulate the algae to produce a lot of lipids is to deprive them of one resource," said Riley. "The idea is to give them some sugar or a lot of sunlight, and then not give them nitrogen because they need nitrogen to make protein and they can't replicate unless they can make protein. What happens is the algae keep running photosynthesis and instead of being able to replicate they store all of those compounds inside their cells."

"Ideally what we want to do is control how the algae work so that they grow a whole lot, and then we say: ‘OK, you're done growing, now it's time to start making lipids,'" said Riley.

"We also look at life cycle assessment," said Ogden. "We look at the impact of the entire process on the environment, everything from the nutrients that the algae need, such as phosphate, nitrogen and carbon dioxide, through the actual processing. We're trying to understand how to optimize production from what we learn in the lab and apply that knowledge to methods for mass production of algae."

Obviously, if you want to produce enough biodiesel to power a truck, you're not going to get very far on a few flasks of algae.

There are two ways to mass produce algae: In outdoor open ponds or inside a container called a bioreactor.

The researchers are experimenting with the first option at an outdoor facility in Tucson, Ariz. However, controlling environmental factors becomes much more difficult with the larger-scale, outdoor operation.

"The water, the sunlight and the ambient temperature are all factors you want to keep in a fairly narrow range," said Riley. "One of the problems in these large ponds is just the temperature change from day to night. If the liquid gets too hot, then you kill the algae. If it gets too cold, then you decrease their rate of growth and their rate of metabolism."

The second option to mass-produce algae involves a bioreactor.

Cuello's lab developed a device called the accordion photobioreactor – which very loosely resembles the musical instrument – to provide a controlled environment for growing algae.

"A bioreactor is just a container or a vessel where you can control various environmental factors inside such as light, temperature and pH," said Cuello.

"So there's this long chain of events," said Riley. "We've got to grow the algae and then switch the metabolism to produce the lipids, and not just any lipids but the right lipids, then purify them and process them to make the biodiesel."

And algae don't just make lipids. Some species also are capable of producing hydrogen gas, another alternative fuel. Cuello is experimenting with one such species, Chlamydomonas reinhardtii.

Algae only produce hydrogen gas when they're not photosynthesizing. Photosynthesis yields oxygen, which inhibits the enzyme that catalyzes the hydrogen-producing reaction.

"In order to produce hydrogen gas the oxygen needs to be depleted or markedly reduced," said Cuello. "One interesting technology in this area was developed at the University of California, Berkeley, and that's essentially depriving the algae of sulfur."

Sulfur is a component of certain amino acids and proteins the algae need for photosynthesis. Depriving the algae of sulfur stops photosynthesis so that oxygen can't be produced and the algae instead will make hydrogen gas.

"That's a great idea and it works," said Cuello. "But it's cumbersome because you have to transfer the algae from a sulfur-containing medium to a non-sulfur-containing medium to produce hydrogen gas, and then back again to allow the algae to photosynthesize and recover."

On a quest for a more efficacious method, Cuello and his team came up with a way to make the algae switch between photosynthesizing and producing hydrogen gas using light. The researchers are able to turn parts of the photosynthesizing machinery on and off by exposing them to different wavelengths of light.

"I collaborated with professor Stanley Pau in the College of Optical Sciences, who is an expert on lasers," said Cuello. "We both thought it would be interesting if we could demonstrate production of algae using a laser as the light source because no one had done that before."

Cuello and Pau were able to grow algae successfully using lasers, which can be set to very specific wavelengths to control photosynthesis. "Bottom line, the method works," said Cuello.

With continuing innovations, both open ponds and bioreactors could be used to mass-produce algae in the near future. "I would think that probably it will take another five years for biofuel production from algae to become feasible economically," said Cuello.

Provided by University of Arizona

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