The Power of Pond Scum: Biodiesel and Hydrogen From Algae

By Willie D. Jones

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A start-up may have the key to boosting algae's chances as a future fuel, and scientists see a path to hydrogen production from pond scum

PHOTO: VALCENT PRODUCTS

21 April 2008—Food riots erupting around the world have been partly blamed on the growing use of food products to produce fuels like biodiesel and corn ethanol. But biofuels need not come from food crops. According to some researchers, the best source of biofuel may be algae, best known as pesky green pond scum.

As anyone who has had to clean a swimming pool or fish tank knows, algae grow quickly. All they need is light, carbon dioxide, and a little water to grow like, well, weeds. It turns out that algae produce oil that can be processed to make biodiesel. In some species, this oil represents more than half of the plantlike organism's mass. Researchers are also trying to genetically alter algae to make them give off copious amounts of hydrogen to meet the needs of future fuel-cell-powered cars.

Algae's biodiesel capacity compares well with today's sources, says Glen Kertz, president and CEO at Valcent Products, a Vancouver, B.C., start-up that aims to become a leading algae oil supplier. A single hectare planted with corn will yield about 40 liters of oil per year; a hectare planted with oil palm would yield 1000 L. But according to Kertz, an algae bioreactor occupying the same space could yield more than 48 000 L. "And we think we can do far better than that," says Kertz. "In a few years, when we come to understand more about this crop we're growing, we could see bioreactors producing more than [150 000 L per hectare per year]."

Valcent's proprietary technique, called Vertigro (which the company is also applying to the cultivation of plants like lettuce), is one of a bunch of approaches to growing algae. Instead of growing pond scum in large open ponds —whose yields are affected by seasonal variations like air temperature and relative humidity—Valcent uses the area above a plot of land to increase its yield. Hence the name Vertigro.

Kertz began working on vertically oriented crop production for other plants about 15 years ago, when he noticed that he was paying to heat and cool a huge amount of space above and below the crops on a surface in a traditional greenhouse. Growing vertically increases the surface area that is exposed to light, making the method very efficient at capturing solar radiation. "Though I'm not the first person to think of it, so I can't take credit for it, I was determined to find an economically viable way to use all that space," says Kertz.

The Vertigro process starts off with a volume of algae-infused water in an underground tank, where its temperature will stay pretty constant. A pump pushes the fluid up to a holding chamber located 3 meters above the surface in a greenhouse. The pump then squirts the algae water into a series of clear plastic sheets, each containing several interconnected bladders arranged in a raster pattern. As gravity pulls the fluid through the bladders, the algae-laden liquid soaks up sunlight. The fluid is collected in a second containment chamber at the bottom of the sheets and then returned to the underground tank. Inside the tank, the algae receive carbon dioxide, and the oxygen from the photosynthesis process is extracted. Then the whole cycle begins again.

Once the algae density reaches a predetermined level—say, 1.5 grams per liter of fluid—the harvesting begins. Over a 24-hour period, half the fluid is skimmed off, the algae is removed, and the water is returned to the tank. Because the skimming rate is set to match the rate at which the algae will grow back to their original density, the system becomes a continuous process, perpetually generating oil as long as CO_2 and sunlight are available, says Kertz.

A continuous process is far better for energy production than the process used with crops like corn and soybeans, which have a defined growing season, says Kertz. "If you have to wait 70 or 80 days for the feedstock to grow, then harvest it, plant it again, and wait some more, it just doesn't make any economic sense."

Valcent is currently building a small-scale production facility in El Paso, Texas, that will serve as a test of the company's ability to scale up its biomass production to the levels Kertz predicts. The plant, which Valcent expects to have up and running by this summer, will also allow the company to calculate the true cost of growing algae on a commercial scale, including the ratio between energy input and output, and how much water will be consumed in the production of a given amount of oil. Depending on the results, Valcent plans to build a 1-acre pilot plant that will produce a steady stream of the feedstock that refineries can use to make biodiesel.

"If we don't run into any major issues—and I don't foresee any—we're looking at 18 to 24 months before we would have a commercially viable alternative to light crude oil that we could scale up," says Kertz.

Meanwhile, other researchers are trying to ratchet up algae's natural production of hydrogen to make pond scum bioreactors a fuel source for fuel cells. One group hoping this is the answer to the world's energy crises is ANSER, short for the Argonne-Northwestern Solar Energy Research Center, a joint effort between researchers at Argonne National Laboratory and Northwestern University, both just outside of Chicago.

David Tiede, a senior scientist at Argonne, says he and his colleagues are looking to manipulate an enzyme called hydrogenase, which generates small amounts of hydrogen gas during a process that is concurrent with photosynthesis. Tiede hopes to take the part of the hydrogenase enzyme that produces hydrogen and insert it into a protein integral to photosynthesis. Doing so, he says, could yield amounts of hydrogen equivalent to as much as 10 percent of the algae's mass, or roughly the same as the amount of oxygen they create.

Tiede admits that attempts to get hydrogen from algae are still in the basic research stage. But he and Valcent's Kertz agree that the funding now being focused on algae will hasten the pace of that research. For example, ANSER is one of a half dozen so-called Energy Frontier Research Centers soon to be funded under a $100 million U.S. Department of Energy (DOE) solar energy program. The program was originally slated to begin in 2006 but remained on hold until early this month, when the DOE issued a new call for proposals.

Algae's fecundity is so great that researchers at the DOE's National Renewable Energy Laboratory say that algae bioreactors covering less than 40 000 square kilometers—roughly one-tenth of the sun-baked state of New Mexico—could churn out enough biodiesel, bioethanol, and molecular hydrogen to completely replace petroleum as transportation fuel in the United States, the world's largest automotive market. That's a lot of pond scum, considering that in 2006, U.S drivers burned through more than 800 billion L of fuel, according to the Energy Information Administration, which is part of the DOE.

But biofuel experts foresee a day when algae bioreactors like Valcent's will be set up not only in places like New Mexico's deserts but also in urban areas, atop the smokestacks of industrial plants or coal-burning electric generation plants, and in rural areas where the algae would act as remediators, using human or animal waste streams as a food source. "The reality is that from an ecological standpoint, algae already play a huge role because they're the primary oxygen source for the planet," says Kertz. "Most people don't know that. But I think it's time for some algae awareness."