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The World of Biodiesel at Your Fingertips

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Supersized Algae Bioreactors

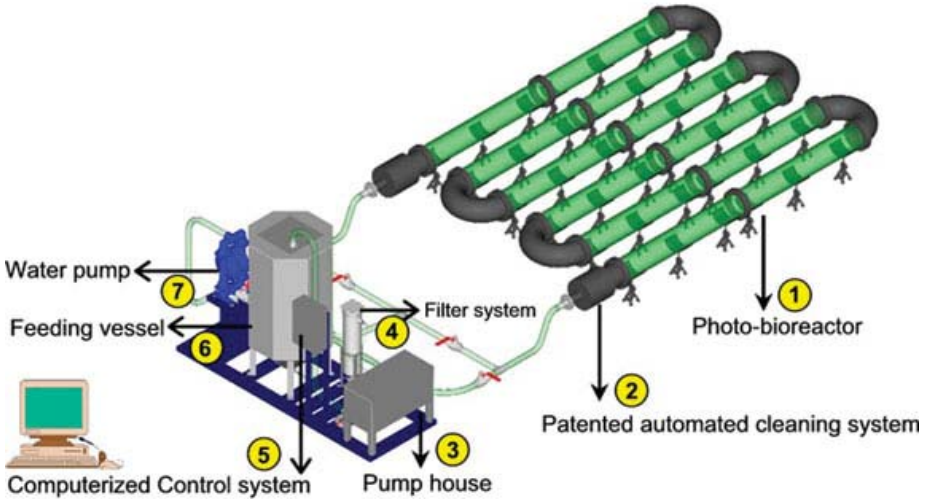
The biodiesel industry is facing a feedstock crisis and desperately looking for alternatives. Even the best alternatives to virgin vegetable oil could take years to develop. Or will they? A Dutch firm with ties to the biodiesel industry is the first to market an industrial-scale algae photobioreactor that may provide a solution to oil-hungry producers.

by Jerry W. Kram

Diesel prices are high but vegetable oil prices are even higher. That's the dilemma that biodiesel producers are facing as the industry's capacity has caught up with the feedstock supply. From canola in Canada, to camelina in Montana to jatropha in Mexico and palm oil in Malaysia, biodiesel producers are looking for new, economical sources of fatty acids that can be converted into biodiesel.

One promising new source is algae. Many companies and universities are working to unlock the potential of these single-celled plants, which can contain up to 50 percent oil by weight and double their numbers in a single day. (See "Algae on the Edge" in the March 2007 *Biodiesel Magazine*) Nearly all of these projects are still in the development stages, however, and won't be attempting a commercial-scale project until late 2008 or 2009.

One firm, however, has broken from the pack and is selling commercial-scale algae systems. AlgaeLink N.V. is a subsidiary of BioKing B.V., a manufacturer of biodiesel production equipment based in the Netherlands. The company began selling its AlgaeLink photobioreactor system in the third quarter of 2007. BioKing was started about five years ago, says Hans van de Ven, the company's president and CEO. The company started development of the AlgaeLink system almost immediately. "There was testing, testing, testing and testing," van de Ven says. "[The testing] involved our engineering department and our biotech department. We spent quite a lot of money in this whole process. We started selling the units when we were sure we had everything under control and our years of testing showed us the right numbers."



The AlgaeLink photo bioreactor system is scalable for producing from 1 to 100 dry-weight tons of biomass per day.

It was no coincidence that the company was the first to market a commercial system, van de Ven says. "Someone needed to be first," he says. "We have put at least four years of work into our system. We have put a great deal of money into it and have had engineers and biologists working on it all over the world. We are ready to sell commercial plants. A lot of people over the Internet have been ripped off by people who promised a lot and nothing happened. We have a very good name in the industry and we would like to keep it like that."

Photo Finish

Research conducted by the U.S. Department of Energy's Aquatic Species Program from the 1970s to the 1990s showed that many species of algae had the potential to produce sufficient quantities of oil to be economical feedstocks for biodiesel production. However, the most efficient method of raising algae—in open, racetrack-style ponds—was prone to contamination from undesirable algae species, and a lot of water was wasted through evaporation. Closed systems called photobioreactors didn't have the contamination and evaporation problems, but were expensive and experienced engineering problems.

AlgaeLink is a closed system consisting of clear tubes 36 meters (118 feet) long and 64 centimeters (25 inches) in diameter. The tubes are connected to a pumping station where two pumps regulate nutrient and acidity levels in the system. A water pump maintains a gentle circulation of water and algae through the photobioreactor. A harvest pump moves fluid to a filter system that removes the algae for processing.

The company sells AlgaeLink units in capacities ranging from a plant that produces 1 ton of dry-weight biomass per day to its largest facility that will produce 100 tons of dry-weight biomass per day. The company insists that its customers install the demonstration plant to start with so AlgaeKing can customize the mix of algae species and nutrients for the climatic conditions and water quality of the plant's location. A demonstration plant produces between 2 and 4 kilograms of dry-weight biomass per day. "We will only sell large equipment after we place a test unit on the premises for the client," van de Ven says. "We will monitor that plant on our computer system in the Netherlands. After between four and six months of monitoring we can make the design that will match what the customer is looking for in his particular area."

The price of the test unit is refunded if the client decides to buy a larger unit after the monitoring period, he adds. "If someone wants to put up money to buy a 100-ton plant, we won't sell it to them," van de Ven says. "We want to make sure that the customer gets what he is looking for. We can't just get the system and the algae and have success with it. That's not how it works."

The demonstration unit costs €69,000 (US $98,000), which includes six months of technical support and monitoring by AlgaeLink. The production units range in cost from €580,000 (US $821,000) for the one-ton-per-day model to €10 million (US $14 million) for the 100-ton-per-day model. This cost doesn't include equipment for centrifuging and drying the algae paste or extraction equipment to separate the oil. The prices are calculated on a per project basis, according to the company's price list. "We have four years of experience and know that it's really workable, it's profitable, but you need to have the right numbers," Van de Ven says. The company doesn't guarantee a specific cost of production due to variations in climate and other factors. That is another reason it insists that its

customers install a demonstration system before investing in a larger capacity plant. "It depends on so many factors," van de Van says. "For example, in our demo plant in the Netherlands, the oil costs us no more than 5 cents (euro or US 7 cents) a liter. But that is a demo plant without automatic dryers and everything. Now that it's winter in the Netherlands the cost will go up because we need to keep the water hot to keep it from freezing. But if you are in the right location and buy the right equipment you can produce your oil very inexpensively."

Van de Ven says AlgaeLink has already sold and is in the process of installing many of the demonstration plants. "In fact, [recently] a customer bought two of them for two different countries," he says. "Everybody is interested in them. They come to the Netherlands, they see the process. They see the results we get from our two demonstration plants in the Netherlands and Portugal. So they already know what they are buying when they buy the demo plant." Van de Ven says the company is working with customers from the United States, Russia, Kazakhstan, Australia and Malaysia.

AlgaeLink Photobioreactor Requirements

Capacity (tons per day)	Length (meters)	Carbon dioxide (kilograms per day)	Area (acres)	Electricity (kilowatts)	Cost (euros)
Demonstration	36	10	0.01	12	69,000
1	1,068	2,881	0.4	55	580,000
10	10,692	28,805	4.3	545	2.5 million
50	53,466	144,027	22	2,727	6 million
100	106,932	288,053	44	5,455	10 million

Note: AlgaeLink also sells 25-ton-per-day and 75-ton-per-day capacity plants.
Source: AlgaeLink N.V.

Advances

Van de Ven describes some the advances that allow AlgaeLink to make its systems more economical. One of the most important was a patented system that allows the company to ship the material for its photobioreactors as flat sheets that can be formed into tubes on-site. This lowers transportation costs considerably, he says. The company has also incorporated sophisticated sensors and computer controls that allow each unit to be monitored from anywhere in the world. "We have our own computer system designs and have written our own software," van de Ven says. "We are making our own sensors. They don't exist in the world and are not for sale anywhere even if you pay a million. They are not on the market."

Another advance is a cleaning system that is incorporated into the unit. That means the unit doesn't have to be shut down to remove algae that builds up on the internal sides of the tubes. The cleaning system in combination with the extensive monitoring allows the algae cultures to be maintained for long periods without crashing.

One of the challenges with algae systems is when the algae density is high, light will only penetrate a few centimeters into the culture. This usually prevents closed systems that use large tubes such as AlgaeLink from obtaining high efficiencies. Van de Ven says his company has patented a method for overcoming this handicap, but didn't describe it. "We are waiting on the patents and that takes a long time," he says. "We have a unique system and that's the reason nobody else can offer it. They don't know how to do it."

The company ships the demonstration plant with a mix of 10 species of algae. AlgaeLink is studying at least 16 species of algae for its suitability for oil production in different climates. AlgaeLink isn't limited to growing algae for biofuels feedstocks, van de Ven adds. Other species of algae are grown for the nutritional and pharmaceutical industries, and those species are perfectly happy in an AlgaeLink photobioreactor, he says. "I have a customer now who wants to burn (biomass) in his plants," van de Ven says. "He wants fiber and 2 percent oil in the algae. We have a lot of customers with different needs. We have another customer in the Middle East who wants to grow Spirulina (a nutritional supplement) and wants nothing to do with oil or biodiesel. So every reactor is unique to each customer." AlgaeLinks' preferred algae works well, van de Ven says, but the company is always on the lookout for an improved species. "We say we have very good algae," he says. "But there are many, many algae out there. Maybe in five years we'll find a better one. But for now, we have algae that fit every person. If they are looking for [biomass], if they are looking for oil, we have the right one. If they are the best one out there, we don't know. But we have to start somewhere."

Fuel School

BioKing offers a two-day algae production course in the Netherlands for €1,800 (US $2,547). The course covers the basics of algae biology and production. It includes time at the AlgaeLink test facility to see algae harvested, dried and the oil extracted.

AlgaeLink has published one of the first analyses of algae oil and its suitability for biodiesel production on its Web site at algaelink.com/algae_biodiesel_lab_analysis.htm. Because the wide range of algae species differ in the oils they produce, van de Ven cautions that this analysis may not be typical, but he thought it was important that the industry have some solid numbers to examine. "That is only one algae, but we put it on the Web site because nobody else in the world can give you specs on biodiesel from algae oil," van de Ven says. "It's just one species of algae, if a customer needs another algae, he will get the specs from the algae he is looking for. We are very careful about how much analysis we will put on the Internet because that has taken many years and a lot of money. We just put something there to show the people some algae."

The algae oil is highly unsaturated, with high levels of Omega 3 and Omega 6 fatty acids. It is low in phosphorus, which the company says means the raw oil doesn't need to be degummed. The iodine value is slightly higher than specifications call for, so it will need to be blended with a small amount of a feedstock with a lower iodine value. Because of the high level of Omega 3 and Omega 6 oils, additives that are readily available on the market need to be added to improve the biodiesel's oxidative stability to meet standard quality specifications. Values for ester content; copper corrosion; monoglycerides, diglycerides and triglycerides; and free and total glycerol in biodiesel made from crude algae oil were all within specifications.

For those who are skeptical about the practicality of algae as a biofuels feedstock, van de Ven has a challenge, "I say, come over to our company. Look at the records we have, the data we have for the past years," he says. "It is a computerized system and we cannot manipulate it. It shows what we've done, day by day, at our plant in the Netherlands and in the plant we just built down in Portugal. It surprises a lot of people when they see it."

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