Green Car Congress
Energy, Technologies, Issues and Policies for Sustainable Mobility

Researchers Propose Milking Diatoms to Yield Massive Amounts of Oil or Bio-Hydrocarbon Fuels

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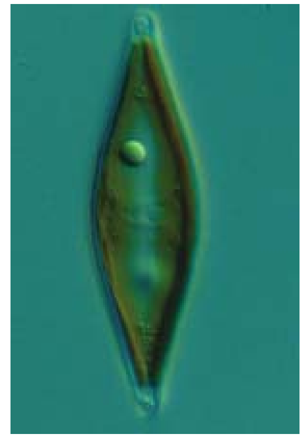

A pennate diatom, NaVicula sp., showing an oil droplet. Click to enlarge.

Scientists in Canada and India are proposing a variety of ways of harvesting oil from diatoms—single cell algae with silica shells—using biochemical engineering and also a new solar panel approach that utilizes genomically modifiable aspects of diatom biology, offering the prospect of "milking" diatoms for sustainable energy by altering them to actively secrete oil products. Their communication appears online in the current issue of the ACS' bi-monthly journal *Industrial Engineering & Chemical Research*.

Richard Gordon, T. V. Ramachandra, Durga Madhab Mahapatra, and Karthick B note that some geologists believe that much of the world's crude oil originated in diatoms, which produce an oily substance in their bodies. Barely one-third of a strand of hair in diameter, diatoms flourish in enormous numbers in oceans and other water sources. They die, drift to the seafloor, and deposit their shells and oil into the sediments. Estimates suggest that live diatoms could make 10-200 times as much oil per acre of cultivated area compared to oil seeds, Gordon says.

> *The transparent diatom silica shell consists of a pair of frustules and a varying number of girdle bands that both protect and constrain the size of the oil droplets within, and capture the light needed for their biosynthesis. We propose three methods: (a) biochemical engineering, to extract oil from diatoms and process it into gasoline; (b) a multiscale nanostructured leaf-like panel, using live diatoms genetically engineered to secrete oil (as accomplished by mammalian milk ducts), which is then processed into gasoline; and (c) the use of such a panel with diatoms that produce gasoline directly. The latter could be thought of as a solar panel that converts photons to gasoline rather than electricity or heat.*
>
> —Ramachandra *et al.*

Noting that milk is not harvested from cows by grinding them up and extracting the milk, the researchers propose that diatoms essentially be allowed to secrete the oil at their own pace, with selective breeding and alterations of the environment maximizing production.

> *Mammalian milk contains oil droplets that are exocytosed from the cells lining the milk ducts. It may be possible to genetically engineer diatoms so that they exocytose their oil droplets. This could lead to continuous harvesting with clean separation of the oil from the diatoms, provided by the diatoms themselves...Higher plants have oil secretion glands, and diatoms already exocytose the silica contents of the silicalemma, adhesion and motility proteins, and polysaccharides, so the concept of secretion of oil by diatoms is not far-fetched.*

The researchers also note that produced in the range of C_7-C_{12} hydrocarbons, about 1/3 of tested diatoms produced α, β, γ, and δ-unsaturated aldehydes.

> *With some optimism about the power of systems biology and how malleable microalgae might be, perhaps we could engineer diatoms that would make these compounds, or the lower-molecular-weight alkanes and alkenes, in great quantities...Given that pathways exist for the production of many alkanes, starting with 12-alkane, the production of shorter alkanes within genetically manipulated diatoms might be plausible. If not, we could fall back on known organic chemistry reactions to convert the natural products to*

alkanes.

—Ramachandra *et al.*

Also noting that with more than 200,000 species from which to choose, and all the combinatorics of nutrient and genome manipulation, finding or creating the "best" diatom for sustainable gasoline will be challenging, the authors offer some guidelines for starting species:

- Choose planktonic diatoms with positive buoyancy or at least neutral buoyancy.
- Choose diatoms that harbor symbiotic nitrogen-fixing cyanobacteria, which should reduce nutrient requirements.
- Choose diatoms that have high efficiency of photon use, perhaps from those that function at low light levels.
- Choose diatoms that are thermophilic, especially for solar panels subject to solar heating.
- Consider those genera that have been demonstrated by paleogenetics to have contributed to fossil organics.
- For motile or sessile pennate diatoms that adhere to surfaces, buoyancy may be much less important than survival from desiccation, which seems to induce oil production. Therefore, the reaction of these diatoms to drying is a place to start. The reaction of oceanic planktonic species to drying has not been investigated, although one would anticipate that they have no special mechanisms for addressing this (for them) unusual situation.
- Genetic engineering of diatoms to enhance oil production has been attempted, but it has not yet been successful.

Generally, cell proliferation seems to be counterproductive to oil production on a per-cell basis, which is a problem that has been expressed as an unsolved Catch-22. However, this balance may shift in our favor when we start milking diatoms for oil instead of grinding them.

—Ramachandra *et al.*

Resources

- T. V. Ramachandra, Durga Madhab Mahapatra, Karthick B and Richard Gordon (2009) Milking Diatoms for Sustainable Energy: Biochemical Engineering versus Gasoline-Secreting Diatom Solar Panels. *Ind. Eng. Chem. Res.*, Article ASAP doi: 10.1021/ie900044j

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