Are microbes the answer to the energy crisis?

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The answer to the looming fuel crisis in the 21st century may be found by thinking small, microscopic in fact. Microscopic organisms from bacteria and cyanobacteria, to fungi to microalgae, are biological factories that are proving to efficient sources of inexpensive, environmentally friendly biofuels that can serve as alternatives to oil, according to research presented at the 108th General Meeting of the American Society for Microbiology in Boston.

When it comes to alternative fuels, currently ethanol is king. Almost all ethanol produced in the United States is fermented from readily available sugars in corn. Ethanol from corn has also come under much criticism lately, accused of being responsible for rising food prices.

Researchers are looking at alternate biomasses as food for microorganisms to ferment into ethanol. The most attractive are known as lignocellulosic biomass and include wood residues (including sawmill and paper mill discards), municipal paper waste, agricultural residues (including sugarcane bagasse) and dedicated energy crops (like switchgrass). The problem is, unlike corn, the sugars necessary for fermentation are trapped inside the lignocellulose.

Govind Nadathur and his colleagues at the University of Puerto Rico have been looking at unusual ecosystems and unusual organisms to find enzymes to help extract these sugars.

"Wood falls into the ocean. It disappears. What's eating this biomass? We found mollusks that eat the wood, with the help of bacteria in their stomachs that produce enzymes that break down the cellulose. We found something similar in termites," says Nadathur. They plan on using these enzymes as a key step in a closed, integrated system that would not only produce ethanol, but would also produce sugar, molasses, hibiscus flowers and biodiesel with a minimum of waste.

It all starts with sugar cane and hibiscus flowers, grown on local lands. These produce not only the obvious products such as refined sugar, molasses (which is used to make rum) and flowers, but also a large amount of waste in the form of biomass. Using the enzymes in their library, Nadathur and his colleagues could break down the biomass to sugars and ferment them to ethanol, trapping the carbon dioxide that is produced during fermentation. They then would feed the carbon dioxide to microalgae in ponds that would produce a polymer that could be refined into biodiesel or jet fuel. The spent microalgae could then be harvested and used as fertilizer for the next round of sugar cane and hibiscus, thereby closing the cycle.

"There used to be a booming sugarcane industry in Puerto Rico, but in the mid-1990s it died. It could not survive economically. By creating a closed-loop system that utilizes the waste to create additional products and feeds back upon itself, suddenly growing sugar cane becomes economically feasible again," says Nadathur.

They are currently working with a company called Sustainable Agrobiotech of Puerto Rico to build a pilot program which they hope to have running by early 2009. Should the pilot program prove successful, there is plenty of adjacent farmland to upscale.

Another promising biofuel is hydrogen. Already many car manufacturers are producing hydrogen concept cars and pilot programs using hydrogen-powered buses already are gaining acceptance in Los Angeles, with Burbank announcing the addition of a hydrogen-powered bus to its fleet in the summer of 2008. As more buses come online, there will be a greater need for hydrogen. Unfortunately, current chemical manufacturing processes for hydrogen are not that efficient or use fossil fuels as a source.

Sergei Markov of Austin Peay State University has developed a prototype bioreactor that uses the purple bacterium Rubrivivax gelatinosus to produce enough hydrogen to power a small motor.

"Certain purple bacteria, which usually grow in the mud of various ponds and lakes, have the ability to convert water and carbon monoxide into hydrogen gas (note: only a certain set could use CO). The problem was how to effectively supply each bacterial cell in a liquid bacterial soup with gaseous carbon monoxide," says Markov.

The answer was attaching the bacteria to numerous tiny hollow fibers inside an artificial kidney cartridge. Water and gasses can freely diffuse through the fibers, but bacteria, due to their large size, cannot. The hydrogen gas from a small fifty milliliter "artificial kidney bioreactor" has been directly injected into fuel cells and has produced enough electricity to power small motors and lamps. The only drawback is that carbon monoxide is not readily available , but Markov says it can be easily produced from biomass using a specific thermochemical process. There are also other bacteria that produce carbon monoxide.

One researcher and her lab, though, are investigating what could perhaps be considered the holy grail of hydrogen production: pure hydrogen from only water and sunlight, with a little bacterial help. Pin Ching Maness of the National Renewable Energy Lab in Golden, Colorado, is researching cyanobacteria that harness the power of the sun to break the bonds in water, separating the hydrogen from the oxygen. There is a problem. One of the hydrogenase enzymes the cyanobacteria uses in this process is sensitive to O2, which makes sustained hydrogen production extremely difficult.

Luckily a certain purple bacterium use a similar hydrogenase, but one that is tolerant to O2. Maness and her colleagues have identified the genes that the purple bacterium uses to produce the tolerant hydrogenase. They have also identified the genes a particular model cyanobacterium uses to produce the sensitive hydrogenase and have knocked it out. They are currently in the process of cloning the genes for the tolerant enzyme into the model cyanobacterium. The next step is to verify that the genes have been successfully incorporated into the genome and are expressed. Over the next few years additional research will need to be done to ensure all the requirements are there for the construction of an active hydrogenase enzyme.

Source: American Society for Microbiology

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