Two bacteria better than one in cellulose-fed fuel cell

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No currently known bacteria that allow termites and cows to digest cellulose, can power a microbial fuel cell and those bacteria that can produce electrical current cannot eat cellulose. But careful pairing of bacteria can create a fuel cell that consumes cellulose and produces electricity, according to a team of Penn State researchers.

"We have gotten microbial fuel cells to work with all kinds of biodegradable substances including glucose, wastewater and other organic wastes," says John M. Regan, assistant professor of environmental engineering. "But, cellulose is tricky. There is no known microbe that can degrade cellulose and reduce the anode.

"We overcame this by putting together a microbe that can degrade and ferment cellulose and an anode-reducing bacterium that can live off the fermentation products," he says.

Microbial fuel cells work through the action of bacteria that can pass electrons to an anode. The electrons flow from the anode through a wire to the cathode, producing an electric current. In the process, the bacteria consume organic matter in the water or sediment.

Plants produce cellulose to use as their cell walls and to provide rigidity to their structure. Along with lignin and hemicellulose, they make up huge amounts of the biomass produced by plants. Some animals, ruminants and termites for example, can break down cellulose with the aid of bacteria that live in their digestive tract. Humans and most

vertebrates derive little nutrition from cellulose.

The researchers, who include Regan; Thomas E. Ward, research associate; and Zhiyong Ren, graduate student, looked at Clostridium cellulolyticum, a bacterium that ferments cellulose, and Geobacter sulfurreducens, an electroactive bacterium. Both are anaerobic, living in places where no free oxygen exists. This fermenter produces acetate, ethanol and hydrogen. The electroactive bacteria consumed some of the acetate and ethanol. They report the results of their study in a recent online issue of *Environmental Science and Technology*.

"We thought that maybe we did not need a binary setup, maybe uncharacterized bacterial consortia would work" says Regan. "It worked, but not as well as the two specifically paired bacteria."

One problem with anaerobic bacteria – and the reason the researchers looked into an uncharacterized mixture of bacteria – is that currently the most efficient microbial fuel cells use an air cathode. Unfortunately, it is impossible to have an air cathode without some oxygen leaking into the reaction chamber, killing strictly anaerobic bacteria and reducing output.

"We tried an aerobic cathode with the binary culture and it will not work," says Regan.

The researchers settled on a two-chamber fuel cell that produced a maximum of 150 milliwatts per square meter.

"We achieved a low power density because of the two chamber system," says Regan. "Current fuel cell designs produce about ten times that."

Currently the researchers are using pure, processed cellulose without any hemicellulose or lignin. They are just beginning to look at other cellulose products so the fuel cells can operate on less manufactured feedstock. As

a proof of concept, the researchers are happy with their results, but they would like to see the power density increase. One approach would be to find a community of bacteria that could tolerate small amounts of oxygen because some of the bacteria use up the oxygen before it reached the anaerobic bacteria. Another approach would be to improve the design of the oxygenless fuel cell.

Source: Penn State