Using microbes to make carbon-neutral fuel

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Researchers at Washington University in St. Louis have discovered a new way to train microbes to make a readily usable biofuel.

A team of biologists and engineers modified a microbe called *Rhodopseudomonas palustris* TIE-1 (TIE-1) so that it can produce a biofuel using only three renewable and naturally abundant source ingredients: carbon dioxide, solar panel-generated electricity and light.

The resulting biofuel, *n*-butanol, is an authentically carbon-neutral fuel alternative that can be used in blends with diesel or gasoline. The results are reported Nov. 3 in the journal *Communications Biology*.

The study was led by Arpita Bose, associate professor of biology in Arts & Sciences, and co-authored by members of her laboratory and engineers from the McKelvey School of Engineering, also at Washington University.

"Microorganisms have evolved a bewildering array of techniques to obtain nutrients from their surrounding environments," Bose said. "Perhaps one of the most fascinating of these feeding techniques uses microbial electrosynthesis (MES). Here we have harnessed the power of microbes to convert carbon dioxide into value-added multi-carbon compounds in a usable biofuel."

The first author of the study is Wei Bai, a Ph.D. graduate of McKelvey Engineering's Department of Energy, Environmental & Chemical Engineering. Bai worked as a research assistant in the Bose lab in Arts & Sciences from 2015-2020. Bai is now a scientist at Amyris, a manufacturer of sustainable ingredients made with synthetic biology.

"The fuel we made, *n*-butanol, has a high energy content and low tendency to vaporize or dissolve in water without combustion," Bai said. "This is especially true when compared with ethanol, which is a commonly used biofuel."

Microbes that feed through microbial electrosynthesis attach themselves directly to a negatively charged cathode inside the MES reactor so that they can "eat" electricity. Previous research from the Bose lab helped illuminate how microbes such as TIE-1 use electrons to fix carbon dioxide and also how they can be used to create sustainable bioplastics.

As scientists learn more about these microbes, their potential uses are more and more promising, Bose said, though she acknowledged that improvements are needed before the techniques can be rolled out on industrial scales.

Producing a sustainable biofuel

Other researchers previously have explored the use of microbes such as cyanobacteria to produce sustainable biofuels. However, these types of organisms produce oxygen during photosynthesis, which tends to limit their efficiency for synthesizing biofuels, as many of the enzymes involved in the biosynthetic pathways are oxygen-sensitive.

To explore how TIE-1 could be exploited to produce biofuel, Bai and Bose constructed a mutant form of the microbe that could not fix nitrogen. The scientists then introduced an artificial *n*-butanol biosynthesis pathway into this new mutant.

The form of the microbe they built was unable to grow when nitrogen gas was its only nitrogen source. So instead, this version of TIE-1 channeled its effort into producing *n*-butanol—increasing its yield of biofuel without increasing electricity consumption significantly.

"To the best of our knowledge, this study represents the first attempt for biofuel production using a solar panel-powered microbial electrosynthesis platform, where carbon dioxide is directly converted to liquid fuel," Bai said. "We hope that it can be a steppingstone for future sustainable solar fuel production."

"Industrial-scale manufacturing of bioplastics and biofuels using microbial electrosynthesis can be achieved using the electricity produced by solar panels, creating a fully sustainable cycle," Bose said.

"The United States and the European Union recognize microbial electrosynthesis as a key technology for sustainability and climate change solutions," Bose said. "Ultimately, by exploiting a microbial metabolism that evolved in the distant past, we hope that new methods will emerge to help address some of the most pressing problems of our time."

More information: n-Butanol production by Rhodopseudomonas palustris TIE-1, *Communications Biology* (2021). DOI: 10.1038/s42003-021-02781-z

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