E. coli metabolism reversed for speedy production of fuels, chemicals

August 10 2011

Rice University engineering researchers Ramon Gonzalez (left) and Clementina Dellomonaco reversed one of the most efficient of all metabolic pathways -- the beta oxidation cycle -- to engineer bacteria that make biofuels at a breakneck pace. Credit: Jeff Fitlow/Rice University

In a biotechnological tour de force, Rice University engineering researchers this week unveiled a new method for rapidly converting simple glucose into biofuels and petrochemical substitutes. In a paper published online in *Nature*, Rice's team described how it reversed one of the most efficient of all metabolic pathways -- the beta oxidation cycle -- to engineer bacteria that produce biofuel at a breakneck pace.

Just how fast are Rice's single-celled chemical factories? On a cell-per-cell basis, the bacteria produced the butanol, a biofuel that can be substituted for gasoline in most engines, about 10 times faster than any

previously reported organism.

"That's really not even a fair comparison because the other organisms used an expensive, enriched feedstock, and we used the cheapest thing you can imagine, just glucose and mineral salts," said Ramon Gonzalez, associate professor of chemical and biomolecular engineering at Rice and lead co-author of the Nature study.

Gonzalez's laboratory is in a race with hundreds of labs around the world to find green methods for producing chemicals like butanol that have historically come from petroleum.

"We call these 'drop-in' fuels and chemicals, because their structure and properties are very similar, sometimes identical, to petroleum-based products," he said. "That means they can be 'dropped in,' or substituted, for products that are produced today by the petrochemical industry."

Butanol is a relatively short molecule, with a backbone of just four carbon atoms. Molecules with longer carbon chains have been even more troublesome for biotech producers to make, particularly molecules with chains of 10 or more carbon atoms. Gonzalez said that's partly because researchers have focused on ramping up the natural metabolic processes that cells use to build long-chain fatty acids. Gonzalez and students Clementina Dellomonaco, James Clomburg and Elliot Miller took a completely different approach.

"Rather than going with the process nature uses to build fatty acids, we reversed the process that it uses to break them apart," Gonzalez said. "It's definitely unconventional, but it makes sense because the routes nature has selected to build fatty acids are very inefficient compared with the reversal of the route it uses to break them apart."

The beta oxidation process is one of biology's most fundamental,

Gonzalez said. Species ranging from single-celled bacteria to human beings use beta oxidation to break down fatty acids and generate energy.

In the Nature study, Gonzalez's team reversed the beta oxidation cycle by selectively manipulating about a dozen genes in the bacteria Escherichia coli. They also showed that selective manipulations of particular genes could be used to produce fatty acids of particular lengths, including long-chain molecules like stearic acid and palmitic acid, which have chains of more than a dozen carbon atoms.

"This is not a one-trick pony," Gonzalez said. "We can make many kinds of specialized molecules for many different markets. We can also do this in any organism. Some producers prefer to use industrial organisms other than E. coli, like algae or yeast. That's another advantage of using reverse-beta oxidation, because the pathway is present in almost every organism."

Provided by Rice University