A metabolic pathway in cyanobacteria could yield better biofuels and bioproducts from photosynthesis

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An image of Cyanobacteria, Tolypothrix. Credit: Wikipedia / CC BY-SA 3.0

Scientists from the Energy Department's National Renewable Energy Laboratory (NREL) have discovered that a metabolic pathway previously only suggested to be functional in photosynthetic organisms is actually a major pathway and can enable efficient conversion of carbon dioxide to organic compounds.

The discovery shines new light on the complex metabolic network for carbon utilization in cyanobacteria, while opening the door to better ways of producing chemicals from carbon dioxide or plant biomass, rather than deriving them from petroleum.

The discovery was led by NREL senior scientist Jianping Yu and Wei Xiong, an NREL Director's Postdoc Fellow. The findings were published in the online edition of *Nature Plants*.

The latest NREL discovery followed on the heels of recent work involving cyanobacteria, commonly known as blue-green algae. NREL scientists engineered a cyanobacterium, Synechocystis, that is unable to store carbon as glycogen into a strain that could metabolize xylose (a main sugar component of cellulosic biomass), thus turning xylose and carbon dioxide into pyruvate and 2-oxoglutarate, organic chemicals that can be used to produce a variety of bio-based chemicals and biofuels. While testing this mutant strain under multiple growth conditions, the scientists discovered, unexpectedly, that it excreted large amounts of acetic acid.

"It was a big surprise," said Yu.

Acetic acid is a chemical produced in high volumes for a wide variety of purposes. The chemical industry produces more than 12 million tons per year of acetic acid, primarily from methanol, which in turn is mainly produced from natural gas. The potential to produce acetic acid from photosynthesis could reduce the nation's reliance on natural gas.

While the potential applications are promising, the researchers were mainly intrigued that they couldn't explain the production of acetic acid from known pathways. Traditional pathways involving pyruvate dehydrogenase didn't quite fit the facts. They knew that an enzyme called phosphoketolase could be involved, as it had previously been suggested to be active in cyanobacteria.

That's when the real detective work began. Starting from a previously studied phosphoketolase, the researchers were able to identify the gene slr0453 as the likely source of the phosphoketolase in Synechocystis. The researchers were zeroing in on their quarry.

The next step in the detective work was to disable the gene and see what happened. Disabling it in both the wild and mutant strains of Synechocystis slowed the growth in sunlight-that is, conditions dependent only on CO2 assimilation by photosynthesis-demonstrating that the gene played a role in photosynthetic carbon metabolism. The strains with the disabled gene did not excrete acetic acid in the light in the presence of xylose.

The clincher was that Synechocystis was able to produce acetic acid in the dark when fed with sugars, but the strains with the disabled gene could not. The researchers found that the phosphoketolase pathway was solely responsible for the production of acetic acid in the dark and also contributed significantly to carbon metabolism in the light when xylose was supplied.

"From a basic science point of view, this is a major pathway that has a potentially important function in regulating photosynthetic energy conversion," said Yu. "We didn't start with the hypothesis that there was an additional pathway actively involved in carbon metabolism; we just followed our own findings and made this discovery."

Xiong then quantified the contribution of the newly discovered pathway by using carbon isotopes to track how xylose and carbon dioxide were converted into other organic chemicals. The results showed that the phosphoketolase pathway actually carried a significant proportion of central carbon metabolism.

"It turns out that the phosphoketolase pathway is a major pathway under our experimental conditions," said Yu. "And because it avoids the carbon loss associated with traditional pathways, a wide variety of bioproducts and biofuels can be made more efficiently using this pathway."

"There are two aspects that are important in this discovery," Yu said. "One is that it is an important native metabolic pathway in the cyanobacterium whose role was not studied previously. Second is that this pathway is more efficient than the traditional pathways, so it can be exploited to increase photosynthetic productivity."

More information: Wei Xiong et al. Phosphoketolase pathway contributes to carbon metabolism in cyanobacteria, *Nature Plants* (2015). DOI: 10.1038/nplants.2015.187

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