Scientists uncover last steps for benzoic acid creation in plants

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Natalia Dudareva.

(Phys.org)—Purdue University scientists have mapped the entire pathway plants use to create benzoic acid, a precursor to a number of important compounds.

Natalia Dudareva, Distinguished Professor of Horticulture, said plants use benzoic acid to create defensive compounds and growth regulators, and to attract pollinators. Drugs, such as the anticancer medication Taxol, also require benzoic acid for formation. The plants make benzoic acid by modifying the chemical structure of cinnamic acid the same way many organisms break down fatty acids.

"There's a lot of potential. It opens the door to allow scientists to engineer plants for increased benzoic acid production," said Purdue postdoctoral researcher Joshua Widhalm, one of the authors of the findings. "If you want to modify the amount of compounds that attract pollinators, or improve plant defense, it would be important to understand this pathway."

Dudareva, Widhalm and former Purdue postdoctoral researcher Anthony Qualley published their results in the Proceedings of the National Academy of Sciences. They used petunias as a model.

"This completes our understanding of the steps required to create benzoic acid," Dudareva said. "Now, we can put it in textbooks."

The chemical structure of cinnamic acid is a ring with a three-carbon chain coming off the side. The findings show that four enzymes work to remove two of those carbon molecules, resulting in benzoic acid.

Dudareva said when she saw the complete puzzle, she realized that the process for creating benzoic acid will be quite familiar to some scientists.

"In plants and animals, the process already exists in fatty acid oxidation," Dudareva said. "In that process, you break off two carbon units in the acids. This is the same."

Widhalm said the finding showed the ability of plants to take a common process and adapt it for their survival.

"Plants have taken it a step further by using this existing process to create beneficial compounds," Widhalm said. "There is a finite number of chemistries that can occur in plants, and they find combinations of these chemistries to make different products."

More information: Completion of the Core b-oxidative Pathway of Benzoic Acid Biosynthesis in Plants, *PNAS*, 2012.

Abstract:
Despite the importance of benzoic acid (BA) as a precursor for a wide array of primary and secondary metabolites, its biosynthesis in plants has not been fully elucidated. BA formation from phenylala-nine requires shortening of the C3 side chain by two carbon units, which can occur by a non–β-oxidative route and/or a β-oxidative pathway analogous to the catabolism of fatty acids. Enzymes responsible for the first and last reactions of the core BA β-oxidative pathway (cinnamic acid → cinnamoyl-CoA → 3-hydroxy-3-phenyl- propanoyl-CoA → 3-oxo-3-phenylpropanoyl-CoA → BA-CoA) have previously been characterized in petunia, a plant with flowers rich in phenylpropanoid/benzenoid volatile compounds. Using a functional genomics approach, we have identified a petunia gene encoding cinnamoyl-CoA hydratase-dehydrogenase (PhCHD), a bi-functional peroxisomal enzyme responsible for two consecutively occurring unexplored intermediate steps in the core BA β-oxidative pathway. PhCHD spatially, developmentally, and temporally co-expresses with known genes in the BA β-oxidative pathway, and correlates with emission of benzenoid volatiles. Kinetic analysis of recombinant PhCHD

revealed it most efficiently converts cinna- moyl-CoA to 3-oxo-3-phenylpropanoyl-CoA, thus forming the substrate for the final step in the pathway. Down-regulation of PhCHD expression in petunia flowers resulted in reduced CHD enzyme activity, as well as decreased formation of BA-CoA, BA and their derived volatiles. Moreover, transgenic lines accumulated the PhCHD substrate cinnamoyl-CoA and the upstream pathway intermediate cinnamic acid. Discovery of PhCHD completes the elucidation of the core BA β-oxidative route in plants, and together with the previously characterized CoA-ligase and thiolase enzymes, provides evidence that the whole pathway occurs in peroxisomes.

Provided by Purdue University

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