Supplying sustainably sourced biomaterial building blocks from plant feedstocks

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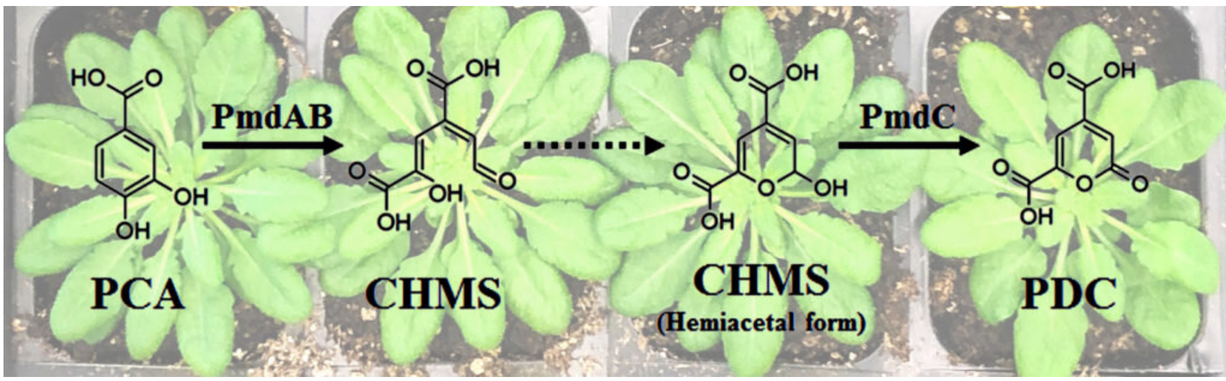

Credit: Joint BioEnergy Institute

One challenge in the production of bioproducts (chemicals and materials made from living organisms) is supplying large amounts of cheap and sustainably sourced building blocks from which these products can be made. The Joint Bioenergy Institute (JBEI) is addressing this challenge by developing sustainable methods to produce these bioproduct building blocks. Most recently, JBEI scientists in the Feedstocks Division figured out how to produce large amounts of a promising building block, 2-pyrone-4,6-dicarboxylic acid (PDC), in plants.

PDC is not normally produced by plants like the one used in this study, Arabidopsis thaliana. Rather, PDC is typically synthesized in nature by soil bacteria that degrade a component of plants called lignin (a tough, difficult-to-utilize plant component). The lead researcher on this project, Dr. Aymerick Eudes, explained that his team successfully "introduced a novel capability into plants to turn precursors for lignin into PDC." Specifically, Dr. Eudes's team engineered A. thaliana plants to produce enzymes, which come from soil bacteria (Corynebacterium glutamicum and Comamonas testosteroni), that can convert lignin into PDC.

The accumulation of non-biodegradable plastics has become a huge environmental issue. The Department of Energy (DOE) has recently launched the Plastics Innovations Challenge to dramatically reduce plastic waste by 2030. PDC is an attractive bioproduct that can be converted into various consumer products, including biodegradable plastics, helping to address the issue of plastic waste. Historically, there hasn't been a sustainable way to make PDC, until bacteria were recently engineered to synthesize it.

In this study, researchers engineered the first-ever plant-based production route for PDC. Pioneering the production of PDC in plants will allow bioplastics to be produced more cheaply and sustainably. Specifically, for growth, these engineered plants utilize free and "green" resources, atmospheric carbon dioxide and solar energy, while synthesizing PDC.

Current plastic production methods utilize fossil fuels such as petroleum and result in non-biodegradable plastics that are frequently not recycled and can accumulate in, and damage natural environments. This new method of producing PDC will help environmentally friendly bioplastics (that are biodegradable and renewably sourced) compete with traditional plastics by lowering the cost of producing them.

In this study, researchers genetically engineered a plant to produce PDC, a promising bioproduct building block. PDC production in the engineered A. thaliana plant had no negative impact on its growth and significantly reduced the amount of lignin present in the plant. This is likely due to the fact that the PDC-production process diverts resources away from lignin formation. In the context of growing plants to use in the production of biofuels, this decreased lignin content is actually beneficial. Specifically, reducing the amount of lignin in plants allows enzymes to more efficiently break down a component of plants called cellulose (a tough fiber made of chains of sugars) into valuable sugars, which microbes can consume to produce biofuels.

Dr. Chien-Yuan Lin, project scientist at JBEI and the first author of the study, notes that this is a "unique "win-win" strategy to promote both biofuel and bioproduct production from plants. The PDC production technology developed at JBEI has the potential to be transferred from A. thaliana (a plant species not commonly grown outside of laboratory settings) to bioenergy crops and could improve the economic viability, and sustainability, of producing bioplastics and biofuels" in these crops. In fact, Dr. Lin said that "the findings from this study have motivated us to investigate the effect of PDC production in engineered sorghum, an attractive bioenergy crop promoted by the DOE." Dr. Lin said that he looked forward to determining if PDC-producing sorghum exhibited "the same beneficial traits" observed in PDC-producing A. thaliana plants through testing of the engineered sorghum in the field.

More information: Chien-Yuan Lin et al, In-planta production of the biodegradable polyester precursor 2-pyrone-4,6-dicarboxylic acid (PDC): Stacking reduced biomass recalcitrance with value-added co-product, *Metabolic Engineering* (2021). DOI: 10.1016/j.ymben.2021.04.011

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