Microbial division of labor produces higher biofuel yields

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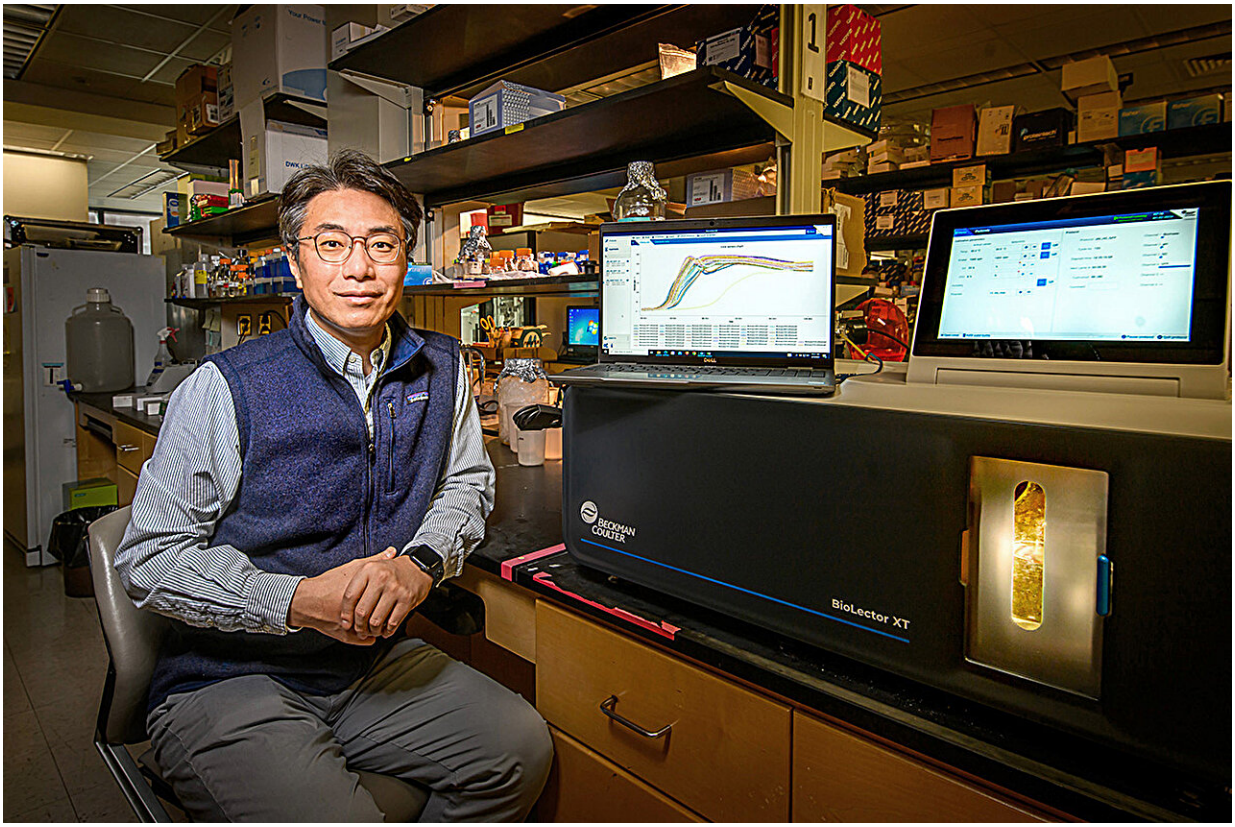

A research team co-led by food science and human nutrition professor Yong-Su Jin, pictured here, with bioengineering professor Ting Lu, not pictured, found a way to increase ethanol production from a mixture of sugars using a microbial division-of-labor approach and mathematical modeling. Credit: Fred Zwicky

Scientists have found a way to boost ethanol production via yeast

fermentation, a standard method for converting plant sugars into biofuels. Their approach, detailed in the journal *Nature Communications,* relies on careful timing and a tight division of labor among synthetic yeast strains to yield more ethanol per unit of plant sugars than previous approaches have achieved.

"We constructed an artificial microbial community consisting of two engineered yeast strains: a glucose specialist and a xylose specialist," said Yong-Su Jin, a professor of food science and human nutrition at the University of Illinois Urbana-Champaign, who co-led the new research with U. of I. bioengineering professor Ting Lu. "We investigated how the timing of mixing the two yeast populations and the ratios in which the two populations were mixed affected the production of cellulosic ethanol."

Postdoctoral researcher Jonghyeok Shin and Siqi Lao, a Ph.D. student in the Center for Biophysics and Quantitative Biology at the U. of I., carried out the work.

Glucose and xylose are the two most abundant sugars obtained from the breakdown of plant biomass such as agricultural wastes. The team was trying to overcome a common problem that occurs when using yeast to convert these plant sugars into ethanol. In the wild, the yeast strain of interest, Saccharomyces cerevisiae, prefers glucose and lacks the ability to metabolize xylose. Other scientists have used genetic engineering to alter the yeast so that it also consumes xylose, but these engineered strains still prefer glucose, reducing their overall efficiency in ethanol production.

Some scientists have pursued the idea that communities of microbes, each with its own special function, can operate more efficiently than a single, highly engineered strain.

"My group is dedicated to the design, analysis and engineering of synthetic microbial communities. Jin's lab specializes in yeast metabolic engineering and biofuel production," Lu said.

"Our complementary expertise enabled us to test whether a division-of-labor approach among yeast might work well in biofuels production."

The researchers conducted a series of experiments testing the use of their two specialist yeast strains. They altered the order in which the different strains were added to the sugar mixture and the timing of each addition.

"We also investigated the ratios at which the two populations were mixed to determine their effects on the rapid and efficient production of cellulosic ethanol," Jin said.

The team also developed a mathematical model that accurately predicts their yeasts' performance and ethanol yields.

"We used the data from the experiments to train our mathematical model so that it captures the characteristic ecosystem behaviors," Lu said. "The model was then used to predict optimal fermentation conditions, which were later validated by corresponding experiments."

The researchers discovered that adding the xylose-fermenting yeast specialist to the mixture first, followed 14 to 29 hours later by the glucose specialist, dramatically boosted ethanol production, more than doubling the yield.

"This study demonstrates the functional potential of division of labor in bioprocessing and provides insight into the rational design of engineered ecosystems for various applications," the authors wrote.

Yong-Su Jin and Ting Lu also are professors in the Biosystems Design theme in the Carl R. Woese Institute for Genomic Biology at the U. of I. Jonghyeok Shin is now a scientist at the Korea Research Institute of Bioscience and Biotechnology.

More information: Jonghyeok Shin et al, Compositional and temporal division of labor modulates mixed sugar fermentation by an engineered yeast consortium, *Nature Communications* (2024). DOI: 10.1038/s41467-024-45011-w

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