CABBI
CENTER FOR ADVANCED BIOENERGY AND BIOPRODUCTS INNOVATION

A Unifying Equation for Fermentation Sustainability Across the Titer-Rate-Yield Landscape

Background/Objective

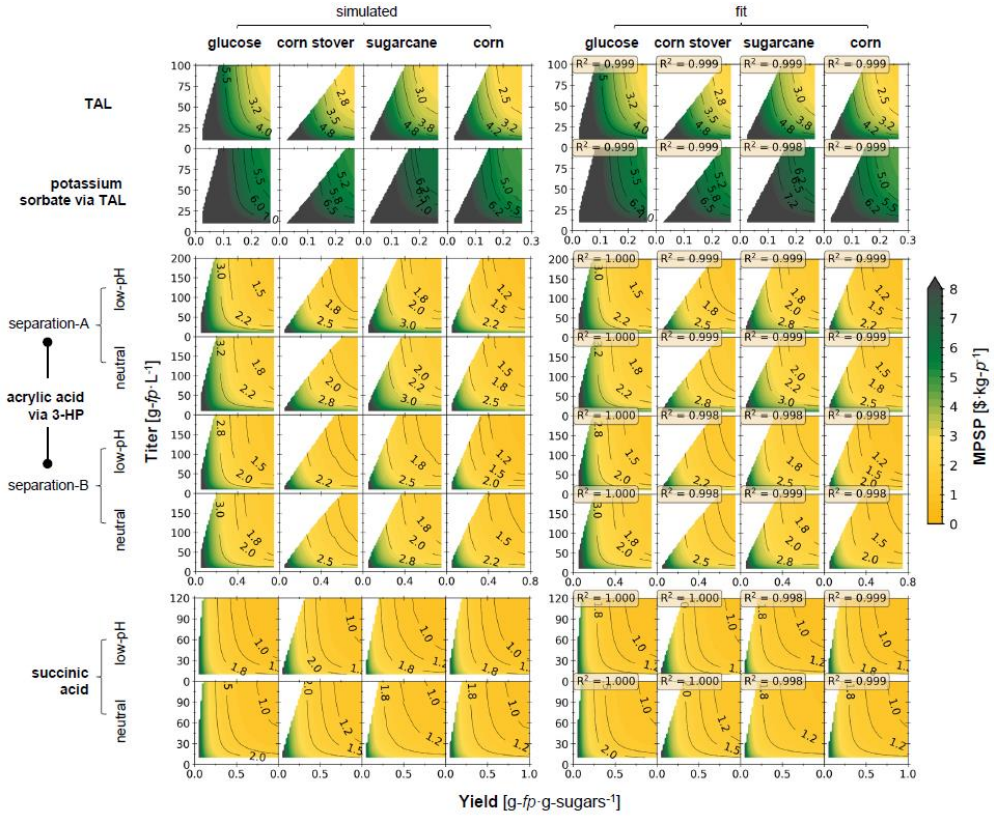
Industrial fermentation is central to the production of fuels, products, and chemicals, but commercial viability of emerging technologies depends on improving fermentation titer, rate, and yield (TRY). How these metrics impact system cost remains difficult to generalize due to complex interactions among different system component processes. This work addresses this gap by providing generalizable mathematical insights into how microbial fermentation interacts with the rest of the biomanufacturing facility to influence system cost under uncertainty.

Approach

Researchers systematically mapped theoretical performance spaces for 32 diverse representative biomanufacturing facility designs by simulating and evaluating them via techno-economic analysis (TEA) under uncertainty (600,000 Monte Carlo simulations) and across TRY combinations (7,500 TRY combinations for each of 32 configurations). From this, they derived a generalized mathematical equation to robustly capture the relationships between fermentation performance and the minimum product selling price (MPSP, $\$\cdot kg^{-1}$) from TEA.

Results

Across this wide design and thermodynamic simulation space, they found that the relationship between fermentation TRY and system cost could be captured by a simple, generalizable, physically interpretable mathematical equation which can be used to elucidate key drivers shaping cost sensitivity to fermentation performance.



MPSP of the main biomanufacturing facility product across fermentation yields and titers at baseline productivity values.

Significance/Impacts

By demonstrating a unifying relationship governing the impact of fermentation on biomanufacturing economics, this work establishes a foundation for agile, holistically predictive, resource-efficient strategies to prioritize fermentation research and development needs and accelerate commercialization of emerging biomanufacturing technologies.

Bhagwat et al. 2026. "A Unifying Equation for Fermentation Sustainability Across the Titer-Rate-Yield Landscape." *Nature Communications*. DOI: 10.1038/s41467-026-75285-1.