Reducing Carbon Emission in Liquid Biofuel Production

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One of the main contributors to global warming is the emission of greenhouse gases from burning fossil fuels. In addition, petroleum-based fuels are a significant source of air pollutants, such as polycyclic aromatic hydrocarbons and NOx. Because of these shortcomings, renewable biofuel production has attracted considerable scientific and commercial interest. Currently, most biofuels are produced from microbial fermentation. This process also produces CO_2 as a by-product, which limits the overall reduction in CO_2 emission.

To solve this issue, we identified non-oxidative glycolysis (NOG) as a potential alternative metabolic pathway to reduce carbon emission because it converts glucose to acetyl-coenzyme A without carbon loss. After selecting suitable enzymes, constructing the pathway, and demonstrating its activity using a variety of assays, we also optimized its efficiency by debottlenecking the rate-limiting steps, knocking out competitive pathways, and evolving the engineered strain to overcome its growth defect. To evaluate the reduction in CO_2 emission, we designed, constructed, and validated a continuous CO_2 monitoring pipeline. Using the pipeline, we showed that the final engineered strain showed a 70% reduction in CO_2 emission compared to the wild-type control strain.

We then optimized the biofuel production in the engineered strain. Using a secondary substrate showed a synergistic effect and increased lipid titer by about 2-fold. Using computational simulations, we showed that such effects can be attributed to the balance of carbon source and energy supply, which enables rational designs of substrate co-feeding schemes.

Overall, this thesis is a concrete step towards zero-carbon biofuel production. It demonstrated the reduction of CO_2 during fermentation, developed a CO_2 monitoring system, and provided directions for the design of substrate co-feeding schemes.

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