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Photosystem I-Hydrogenase Chimeras and Processes for Biohydrogen Production

With increased demand for energy, particularly from inexpensive, renewable, and environmentally friendly sources, Hydrogen (H₂) is an attractive target product, with over 60 million tons produced globally. Unfortunately, around 95% of hydrogen is produced from steam reformation of fossil fuels, contributing to rising atmospheric CO₂. Reengineering fundamental processes in photosynthetic organisms can provide a platform for solar powered bio-factories that can generate high-energy product molecules, such as hydrogen. One such photosynthetic organism that shows promise in this space is algae, because of their photosynthetic capabilities and unique hydrogenase enzymes. However, despite various attempts to improve hydrogen production in algae, inactivation of hydrogenase by oxygen and competition for reductant with other processes have hindered efforts.

Researchers at Arizona State University have developed novel processes for creating engineered photosynthetic cells having altered electron flow for greater biohydrogen production, as well as specific chimeras from this process. By capturing some of the reducing power and redirecting it from carbon fixation to proton reduction, the energy storage molecule can be changed from carbohydrate to molecular hydrogen.

Chlamydomonas reinhardtii, a green algae, was used as an experimental system for testing out these processes and creating these chimeras. In one process, an in vivo fusion of photosystem I (PSI) and an algal hydrogenase was created. In another process, an in vivo fusion of PSI and a bacterial hydrogenase was created. Cells expressing these chimeras direct electron flow away from CO₂ fixation towards proton reduction and biohydrogen production, which can be sustained over many days while maintaining cell viability.

These chimeras, using only the sun and water, provide the foundation for a cheap and renewable platform for creating bio-factories capable of driving difficult redox transformations.

Potential Applications

- Photosynthetic production of hydrogen (H₂)

Benefits and Advantages

- Environmentally friendly and renewable
- Efficient – 2.7 mmol H₂ h⁻¹ per g dry weight of cells (could perform well even on a cloudy day)
- Long-term H₂ production – H₂ was produced continuously for 5 days at an average rate of 14.0 ±1.7 μmol H₂ h⁻¹
- Scalable and economically feasible
- O₂ evolution is constrained from PSII, preserving hydrogenase activity for sustained H₂ production over many days
 - Eliminates the need to use nutrient deprivation, PSII inhibitors or mutations
- Preserves the proton pumping and ATP production carried out by the PETC, maintaining cell viability
- The PSI-bacterial hydrogenase chimeras are relatively O₂ tolerant, exhibiting a ~10-fold lower O₂ inactivation rate compared to algal hydrogenases
- The PSI-bacterial hydrogenase chimeras may have more optimized long term H₂ production

For more information about this opportunity, please see

[Kanygin et al – Int. J. Hydrog. Energy - 2022](#)

[Kanygin – Dissertation - 2022](#)

[Kanygin et al – Energy Environ Sci - 2020](#)

For more information about the inventor(s) and their research, please see

[Dr. Redding's departmental webpage](#)