NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hydrogen & Fuel Cell
Technical Highlights

A Significant Increase in Hydrogen Photoproduction Rates and Yields by Wild-Type Algae is Detected at High Photobioreactor Gas Phase Volume

Project: Biological Systems for Hydrogen Photoproduction

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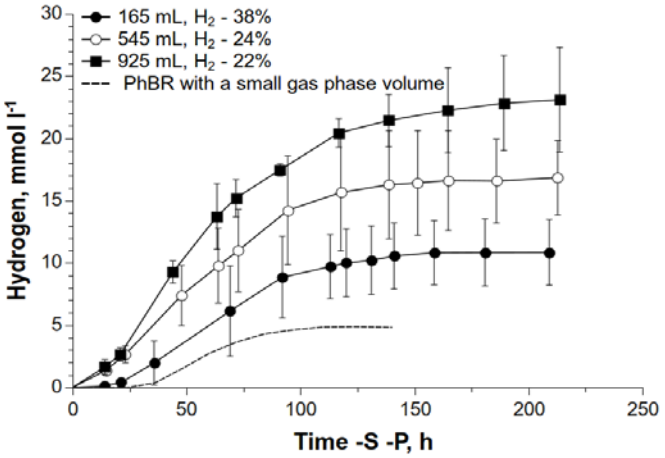
Accomplishment: Researchers found that hydrogen (H_2) photoproduction activity in algal cultures can be improved dramatically by increasing the gas-phase to liquid-phase volume ratio ($V_{g.p.}$ / $V_{l.p.}$) of the photobioreactor (PhBR). NREL, in partnership with subcontractors from the Institute of Basic Biological Problems (Pushchino, Russia), demonstrated that the H_2 photoproduction rate in algal cultures always decreases exponentially with increasing H_2 partial pressure above the culture. The inhibitory effect of high H_2 concentrations in the PhBR gas phase on H_2 photoproduction by algae is significant and comparable to the effect observed with some anaerobic bacteria. In suspension cultures (see figure for details), a 4x increase in $V_{g.p.}$ / $V_{l.p.}$ (from ~0.5 to ~2) results in a 2x increase (from 10.8 to 23.1 mmol L^{-1} or 264 to 565 mL L^{-1}) in the total yield of H_2 gas. Remarkably, 565 mL of H_2 gas per liter of the suspension culture is the highest yield ever reported for a wild-type strain in a time period of less than 180 hours. In contrast, a control PhBR with a historically small gas phase volume of ~5–10 mL L^{-1} of culture only produced up to 120 mL L^{-1} of H_2 gas. A similar effect was obtained for algal cultures immobilized in thin alginate films.

Context: The effect of H_2 partial pressure on H_2 gas production has been known for a long time and has been well studied in some anaerobic bacteria that perform dark fermentation. However, a short-term increase in the rate of H_2 production in algae after increasing the PhBR gas phase volume or purging the culture with argon (see Greenbaum et al., 2001, *J. Phys. Chem. B* 105, 3605-09 for details) had always been attributed to the effective dilution of O_2 in algal cultures. The investigation of the direct effect of H_2 on H_2 photoproduction by algal cultures has demonstrated that H_2 photoproduction in nutrient-deprived algae depends more on H_2 rather than O_2 in the PhBR gas phase.



Hydrogen photoproduction by 500 mL of sulfur/phosphorus-deprived (-S -P) algal cultures placed in PhBRs with different headspace volumes (165–925 mL). The final percentages of H_2 gas in the gas phase of the PhBRs are indicated in the figure inset; the Y-axis reports actual amounts of H_2 produced. The yield of H_2 gas in the PhBR with a historically small gas phase volume is shown as a dotted line.

Applicable DOE Technical Target: Systems engineering of photolytic H_2 production from water in order to more quickly reach the programmatic incident light conversion efficiency target.

Significance of Accomplishment: The results from this study have direct practical consequences. Much higher H_2 photoproduction rates and yields in PhBRs with H_2-producing algae are possible if H_2 is efficiently removed from cell cultures by increasing the gas phase volume. In practice, the H_2 concentration in a PhBR should not exceed 5%. This could be achieved, for instance, by continuous removal of dilute H_2 out of the gas phase by electrochemical pumping for concentration and storage or by using the gas to directly run a fuel cell. This approach will contribute to an increase in the incident light conversion efficiency of H_2 photoproduced by algae.

Publication: Kosourov, S.N., et al. (2012). "Maximizing the hydrogen photoproduction yields in *Chlamydomonas reinhardtii* cultures: The effect of the H_2 partial pressure." *International Journal of Hydrogen Energy*, 37:8850-8858.

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