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

Team: Maria L. Ghirardi and Michael Seibert, NREL; Sergey N. Kosouro, Khorcheska A. Batyrova, Ekaterina P. Petushkova, and Anatoly A. Tsygankov, IBBP, Russian Academy of Sciences, Russia

Accomplishment: Researchers found that hydrogen (H₂) 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 H₂ photoproduction rate in algal cultures always decreases exponentially with increasing H₂ partial pressure above the culture. The inhibitory effect of high H₂ concentrations in the PhBR gas phase on H₂ 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 H₂ gas. Remarkably, 565 mL of H₂ 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 H₂ gas. A similar effect was obtained for algal cultures immobilized in thin alginate films.

Context: The effect of H₂ partial pressure on H₂ 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 H₂ 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 O₂ in algal cultures. The investigation of the direct effect of H₂ on H₂ photoproduction by algal cultures has demonstrated that H₂ photoproduction in nutrient-deprived algae depends more on H₂ rather than O₂ in the PhBR gas phase.

Applicable DOE Technical Target: Systems engineering of photolytic H₂ 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 H₂ photoproduction rates and yields in PhBRs with H₂-producing algae are possible if H₂ is efficiently removed from cell cultures by increasing the gas phase volume. In practice, the H₂ concentration in a PhBR should not exceed 5%. This could be achieved, for instance, by continuous removal of dilute H₂ 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 H₂ photoproduced by algae.