Applications of a biological water-gas shift reaction using unique photosynthetic bacteria

P.-C. Maness*, K. Magrini, S. Smolinski, A. Dillon, M. Heben, P. F. Weaver
National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, Colorado, 80401 USA
Fax: 303-384-6150; pinching_maness@nrel.gov

Photosynthetic bacteria are versatile in their modes of H_2 metabolism. They have four terminal enzymes mediating the metabolism of H_2: nitrogenase, uptake hydrogenase, fermentative hydrogenase, and CO-linked hydrogenase. Among them, the most unique is the CO-linked hydrogenase enzyme. It was first reported by Uffen [1] in two strains of photosynthetic bacteria that shift CO and H_2O into H_2 and CO_2 according to the net reaction:

$$CO + H_2O \longrightarrow H_2 + CO_2$$

We have isolated about 450 strains of photosynthetic bacteria from environment using CO as the sole carbon source. Figure 1 shows the kinetics of CO uptake and the concomitant production of H_2 in darkness of a typical photosynthetic isolate exposed to 16% CO in N_2. Water-gas shift rates in light are similar, but much of the evolved H_2 and CO_2 are photo-assimilated into new cell mass.

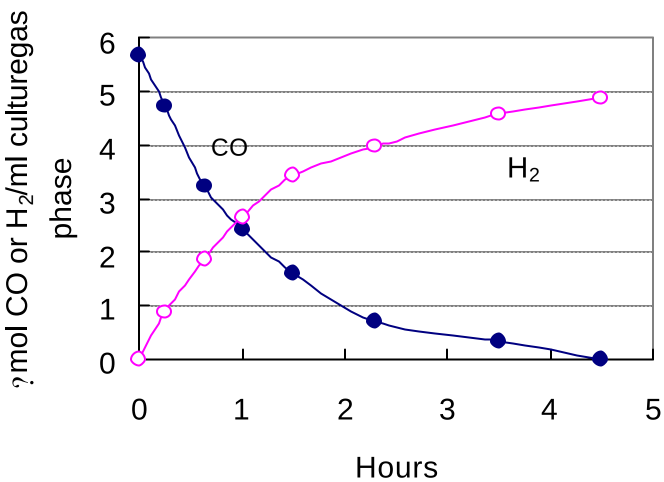


Fig. 1 Anaerobic shift of CO and H_2O into H_2 and CO_2 by *Rx. gelatinosus* CBS in darkness

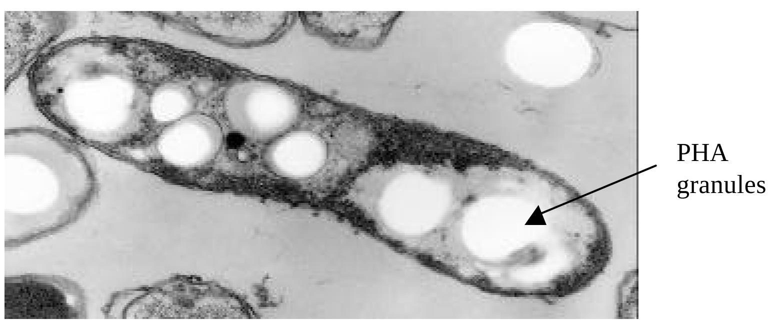
Based on measurements of activity, durability, and competitiveness, a new isolate, *Rubrivivax gelatinosus* CBS, has the best potential for scale-up applications. The terminal step of the shift pathway is a CO-inducible, membrane-bound hydrogenase. This hydrogenase is relatively O_2 tolerant, retaining 50% of its activity when whole cells of CBS were stirred in full air for 21 hrs. By suspending whole cells in D_2O under an atmosphere of H_2, we detected a hydrogen-deuterium (H-D) exchange activity. Using a capillary mass spectrometer to measure H-D exchange activity kinetically, we have determined that this hydrogenase is functional even in the presence of 3% O_2, with the activity proceeding at a linear rate for the duration of the 10-min assay. Until our recent work, no H_2-producing enzyme had been described that would function for any appreciable period of time in the presence of more than a small concentration of O_2 [2]. This hydrogenase may be suitable for genetic transfer into an oxygenic host where photosynthetic water-splitting reactions provide the reducing equivalents for H_2 photo-production.

Potential Applications

Since these bacteria catalyze the shift reaction at high rates and efficiency at near ambient temperature and pressure, the reaction equilibrium favors the almost complete consumption of CO into H_2. One logical source of CO is from gasified biomass. Gasification serves to inexpensively convert very heterogeneous biomass materials into relatively homogeneous gaseous products that specific bacteria can easily metabolized. About 5 quadrillion BTUs of energy are available from yearly biomass wastes in the US, and much of this is suitable for thermal conversion into fuel gases with subsequent bacterial conditioning into additional H_2 and free of residual CO.

Besides producing H_2, *Rx. gelatinosus* CBS can also produce other high-value, bio-based chemicals using gasified biomass. Most photosynthetic bacteria fix N_2. When atmospheric N_2 was provided as the sole source of nitrogen nutrient, *Rx. gelatinosus* CBS carried out the N_2-fixation reaction while photosynthetically assimilating CO as the sole carbon substrate. The resulting cell mass had a composition of 65% protein containing all essential amino acids and most vitamins and neutraceuticals. NREL currently holds a patent for converting gasified biomass into single cell protein to use as animal feed and human food supplement [3]. Under nutrient unbalanced conditions, photosynthetic bacteria are known to accumulate polyhydroxyalkanoate (PHA) polymers. PHAs are biodegradable thermoplastics. We have demonstrated that CBS can photosynthetically accumulate PHA when cultured with CO as the sole carbon substrate [4] as shown in Fig. 2. NREL holds a patent for the production of PHA polymers using gasified biomass [5]. These results clearly demonstrate that certain photosynthetic bacteria can convert gasified biomass into either additional H_2 as a clean fuel or into other high-value commodity chemicals such as biodegradable thermoplastics or single-cell protein. We will present and discuss most recent data on the biological use of fuel gases and its potential applications at the Conference.

Fig. 2. The photoproduction of PHA from CO in *Rx. gelatinosus* CBS



References

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