Bioprocess for hydrogen production from biomass

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To meet the expected increase in demand for hydrogen as fuel for fuel cells, renewable resources (wind, sun, hydropower, geothermics and biomass) will need to be used for hydrogen production in order to adhere to the Kyoto agreement. These technologies have all their specific advantages and disadvantages in terms of potential, efficiency, scale and foreseen production cost. Most technologies for the production of renewable hydrogen are still in the R&D stage and world-wide subject of increased research efforts.

At present, there are two strategies for the production of hydrogen from biomass: the thermochemical technology, such as gasification or supercritical water gasification, and the biological production technology using micro-organisms. Biological hydrogen production delivers clean hydrogen with an elegant and simple technology and is more suited for the conversion of wet biomass in small-scale applications as compared to the other thermochemical processes.

Many micro-organisms are able to produce hydrogen from mono- and disaccharides, starch and (hemi)cellulose under anaerobic conditions. The anaerobic production of hydrogen is a common phenomenon, occurring during the process of anaerobic digestion. Here, hydrogen producing micro-organisms are in syntrophy with methanogenic bacteria which consume the hydrogen as soon as it is produced. Unfortunately, in this natural process, hydrogen production remains obscure and methane is the end-product. By uncoupling hydrogen production from methane production, it becomes possible to harvest hydrogen instead of methane. However, the by-products arising from anaerobic hydrogen production from carbohydrates are carbon dioxide and organic acids. For maximal hydrogen production oxidation to acetic acid is preferred. To achieve this, thermophilic bacteria have been selected. In contrast to mesophilic bacteria, which posses branched pathways leading to more reduced by-products, most thermophilic bacteria oxidize carbohydrates to acetic acid as the final by-product (Van Niel et al 2003). For achieving full gain of all chemical energy preserved in the biomass, further conversion of acetic acid to carbon dioxide is required. This conversion is performed by photosynthetic bacteria, which obtain energy from light to combat the thermodynamic barrier of anaerobic acetic acid oxidation (Akkerman et al 2003). Thus, a two-stage fermentation is created which provides a highly efficient conversion of biomass to hydrogen and carbon dioxide.

Biomass for hydrogen production ranges from domestic organic waste to more defined agro-industrial residues and finally to well-defined produce from energy crops. Several examples have been tested with respect to applicability for biological hydrogen production (Claassen et al 2002). This far, most experiments have been successful, even with the limited number of thermophilic strains used. Lignocellulosic feedstock is generally favored because it is cheap and abundant. However, for obtaining high efficiencies, pretreatment for mobilization of fermentable sugars in hydrolysates is required (De Vrije et al 2002).

References

Akkerman I., M. Janssen, J.M.S. Rocha, J.H. Reith and R.H. Wijffels. Photobiological hydrogen production: Photochemical efficiency and bioreactor design. *In*: Reith J.H., Wijffels R.H., Barten H. Bio-methane & Bio-hydrogen: status and perspectives of biological methane and hydrogen production. Novem, pp. 124-145. ISBN: 90-9017165-7.

Claassen P.A.M., M.A.W. Budde, F.J. van der Wal, Zs. Kádár, G. E. van Noorden and T. de Vrije . Biological hydrogen production from biomass by thermophilic bacteria. Proceedings of 12th European

Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection, 17-21 June 2002, Amsterdam.

De Vrije T., G.G. De Haas, G.B. Tan, E.R.P Keijsers and P.A.M. Claassen. Pretreatment of *Miscanthus* for hydrogen production by *Thermotoga elfii*. Int J Hydrogen Energy 27 (2002): 1381-1391

Van Niel E.W.J., P.A.M. Claassen and A.J.M. Stams. Substrate and product inhibition of hydrogen production by the extreme thermophile, *Caldicellulosiruptor saccharolyticus*
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