Feasibility of Biological Hydrogen Production from Biomass for utilization in fuel cells

P.A.M. Claassen *), J.W. van Groenestijn, A.J.H. Janssen, E.W.J. van Niel, R.H. Wijffels

Aim

Hydrogen production from biomass by a two step fermentation process (Fig. 1) according to the following reactions:

glucose ? $4\ H_2 + 2\ CO_2 + 2$ acetate (1)

2 acetate ? $8\ H_2 + 4\ CO_2$ (2)

(1) With thermophiles *Thermotoga elfii* or *Caldicellulosiruptor saccharolyticus*

(2) With photoheterotroph *Rhodopseudomonas* spp.

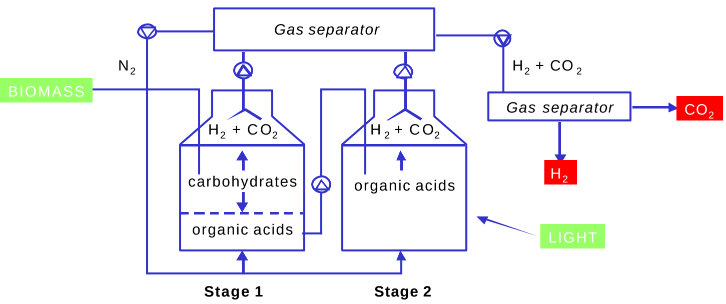

Fig. 1 Production of hydrogen in a 2 step fermentation.

Results

Thermotoga elfii, growing at 65 °C in a chemostat, produced 4 mole of H_2 and 2 mole of acetate per mole of glucose consumed (Fig. 2). The highest productivity rates obtained with the thermophiles and photoheterotrophs were 0.01 and 0.006 g H_2/L.h, respectively.

Technical and economical details were calculated for an industrial, small-scale process. The production rate was set at 500 m^3 H_2/h which is equivalent to 39 kg H_2/h. To meet this production, approximately 1000 kg biomass/h is needed. Pretreatment of the biomass was done using extrusion.

Table 1. Specifications of the fermentation processes for production of 500 m^3 H_2/h from biomass.

Specifications	Thermophilic fermentation	Photofermentation
Reactor size (m^3)	95	300
Temperature (°C)	80 – 90	30
Critical pH_2 (Pa)	10^4	10^5
Special features	elaborate H_2 removal	sunlight collector light penetration

Table 2. Cost prices for hydrogen produced in small-scale installations at 100 – 1000 m^3 H_2/h

Technology	Costs (EURO ct /m^3 H_2)	CO_2-emission (kg /m^3 H_2)
Steam-reforming of natural gas	32	0.8
Electrolysis with conventional electricity	23	1.8
Electrolysis with CO_2-lean electricity	27-36	0
Biological hydrogen production from biomass (estimate)	21	0
Steam-reforming of biomethane	32	0
Electrolysis with wind energy	25	0
Electrolysis with photovoltaic cells	295	0

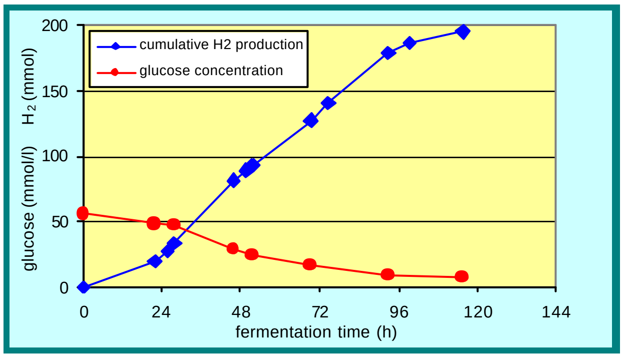

Figure 2: Hydrogen production during growth of *Thermotoga elfii* on glucose

Conclusions

Hydrogen production by bacteria from biomass in decentralized small-scale production facilities seems a realistic approach to provide fuel which is suited for utilization in fuel cells.

References

Claassen P.A.M., J.B. van Lier, A.M. López Contreras, E.W.J. van Niel, L. Sijtsma, A.J.M. Stams, S.S. de Vries & R.A. Weusthuis (1999). Utilisation of biomass for the supply of energy carriers. Appl Microbiol Biotechnol 52:741-755

Future research

?? Pretreatment of biomass
?? Increase of thermophilic productivity by a factor of 10
?? Increase of photofermentative productivity by a factor of 15
?? Prevention of feedback inhibition by hydrogen or acetate
?? Increase of efficiency of light distribution
?? Integration of whole process

Acknowledgements

This research project was supported by the Dutch EET program. The partners were ATO-DLO, Wageningen Agricultural University, TNO-MEP and Paques Biosystems B.V. Additional funding was from the EU: Biohydrogen QLK5-01267 with ATO (coordinator), WAU, NTUA, TUB, JADE/BRC and Air Liquide. Corresponding author: P.A.M.Claassen@ato.wag-ur.nl
More information at: www.biohydrogen.nl

ATO Instituut voor Agrotechnologisch Onderzoek
Bornsesteeg 59
Postbus 17
6700 AA Wageningen
Tel.: (+31) 0317-475024
Fax. : (+31) 0317-475347
e-mail: info@ato.wag-ur.nl
Internet: http://www.ato.wageningen-ur.nl