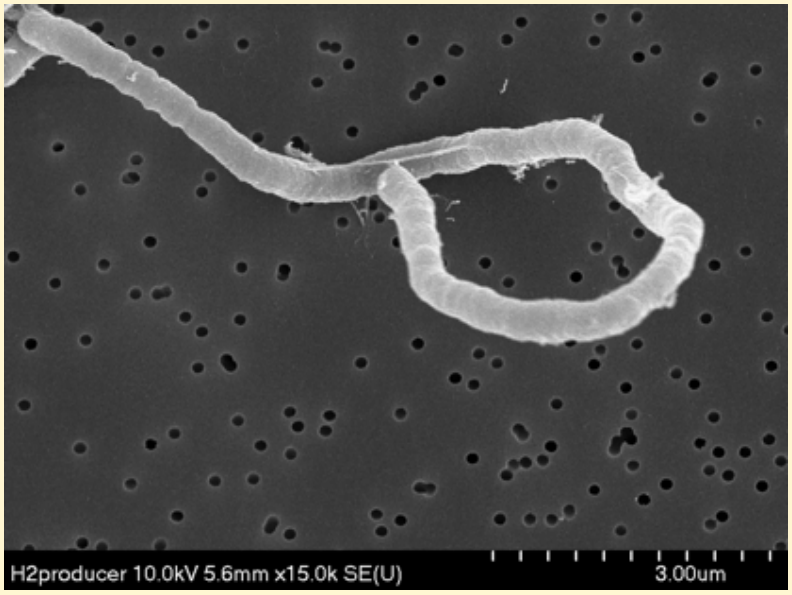
Bacterial Fermentative Hydrogen Production



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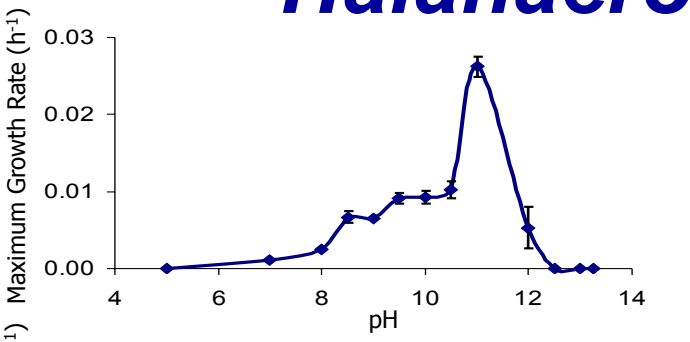
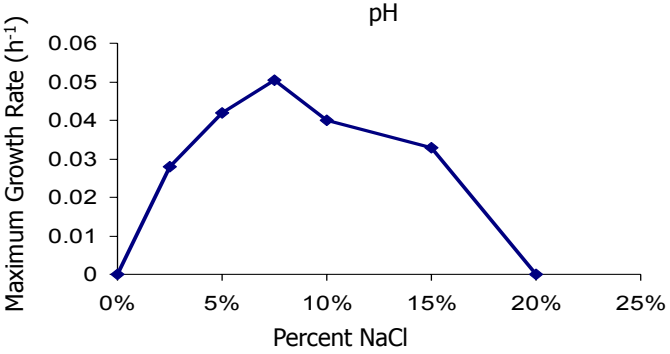
Lignocellulosic Pretreatment

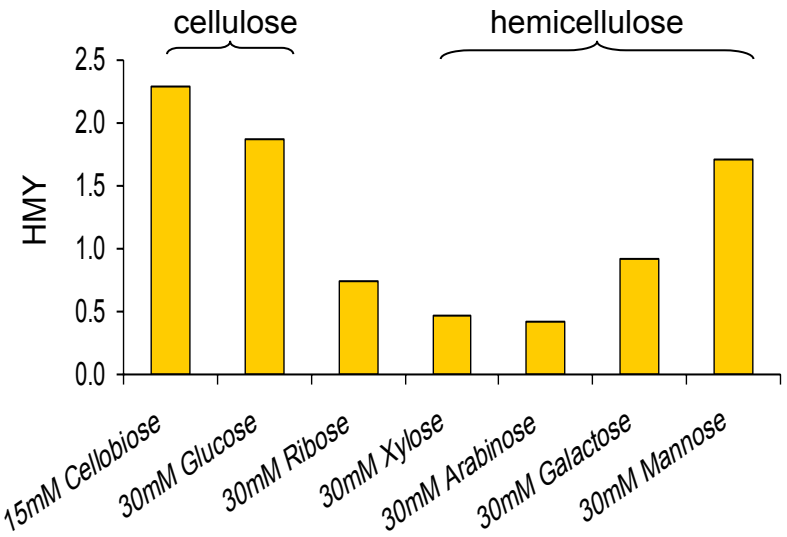
- Pretreatment separates & degrades soluble lignin/ hemicellulose from insoluble cellulose

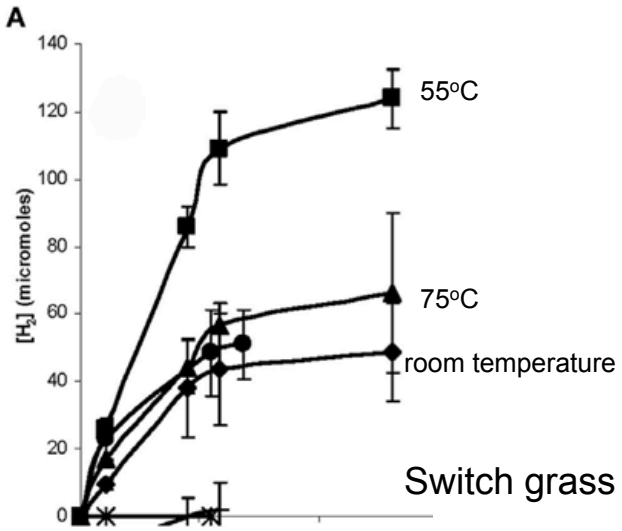
1. Steam blasting (steam explosion)
   - Fossil fuel dependent step.
   - Releases furans (phenols, carboxylic acids, salts -inhibit fermentation).
   - Detoxification best with alkaline treatment; ($Ca(OH)_2$ "over-liming").
2. Acidic treatment (H_2SO_4, SO_2)
   - Phenols, phenol aldehydes released.
3. Alkaline treatment ("ammonia freeze explosion/wet oxidation"; NaOH, NH_3, Na_2CO_3)
   - Shown to result in highest ethanol yield with yeast from straw.
   - Phenols, but lower than with acid.
   - *Issue with traditional microorganisms; Neutralization needed*.

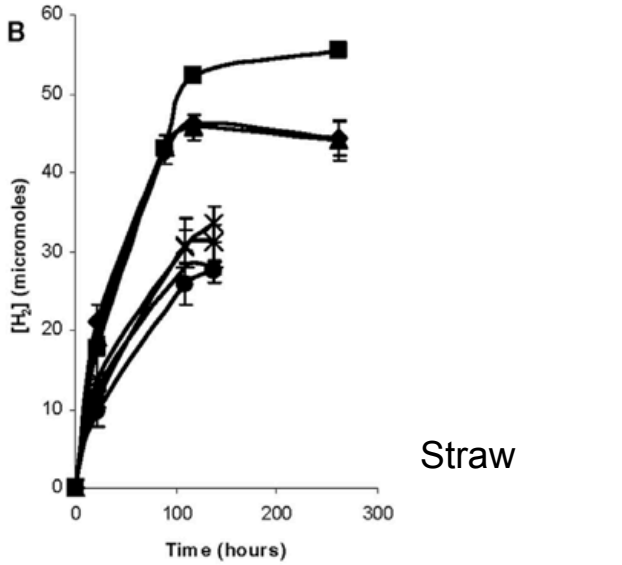
Halanaerobium hydrogeniformans











Matthew Begemann, Dylan Courtney, Dwayne Elias, Daniel Roush, Oliver Sitton, Judy Wall

Current Status of Bacterial Fermentation Hydrogen Production

Limitation of metabolic conversion is 4 moles H_2/1 mole glucose

This theoretical yield is not achieved

Inoculum	Substrate	Reactor Type	Maximum H_2 yield
Clostridium acetobutylicum	Glucose	Batch	2 mol/mol of glucose
Clostridium pasteurianum CH_4	Sucrose	Batch	2.07 mol/mol hexose
Clostridium thermolaticum	Lactose	Continuous	3.0 mol/mol lactose
Enterobacter aerogens E 82005	Molasses	Continuous	3.5 mol/mol sugar
Thermoanaerobacterium thermosaccharolyticum	Glucose	Batch	2.4 mol/mol glucose
Enterobacter cloacae DM11	Glucose	Batch	3.31 mol/mol glucose

Sinha, P., and Pandey, A. 2011. An evaluative report and challenges for fermentative biohydrogen production. International Journal of Hydrogen Energy, 36:7460-7478.

Major Issues, Barriers and Challenges

Increased substrate conversion

- Need to reach metabolic level and beyond
- Is it possible for a biological system to extract all 12 hydrogen atoms from glucose?

Bioreactor designs

- Continuous stirred-tank reactor – commonly used
- Better reactor systems?

Cost of raw materials

- Not only cost of raw materials but pre-treatment options
- What steps are required to provide optimal conditions for fermentations?

Important Developments in Progress
Key Research Needs

Easiest to hardest?

Improve reactor configurations

Optimization of bioprocess parameters

Decrease H_2 partial pressure

Microbial consortia

- Pure culture or mixed culture?
- Use of extremophiles?

Genetic modification of bacteria to channel metabolism towards

- towards enhanced H_2 production

Enhance activity of hydrogenases

What is needed to achieve 12 mole H_2/1 mole glucose?

- Metabolic engineering of new metabolic pathways?
- Use of hybrid two-stage systems