# Fermentative Hydrogen Production:

## Strain Selection and Reactor Operation

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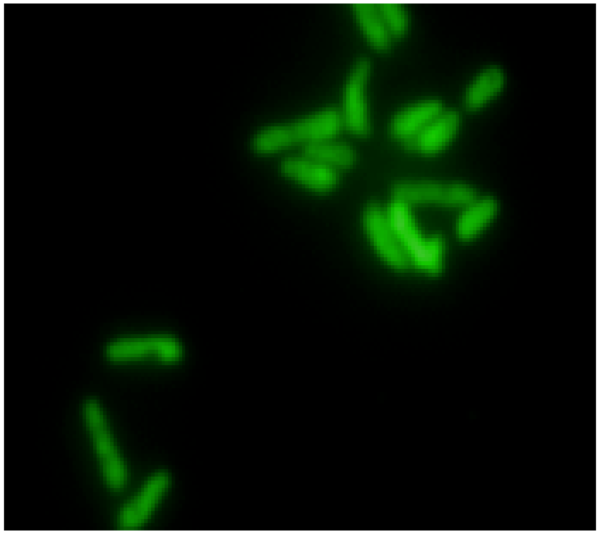
# Fermentative production of $H_2$ from sugars



- Full oxidation of glucose to $H_2$:

$$C_6H_{12}O_6 + 6\ H_2O \rightarrow 12\ H_2 + 6\ CO_2$$

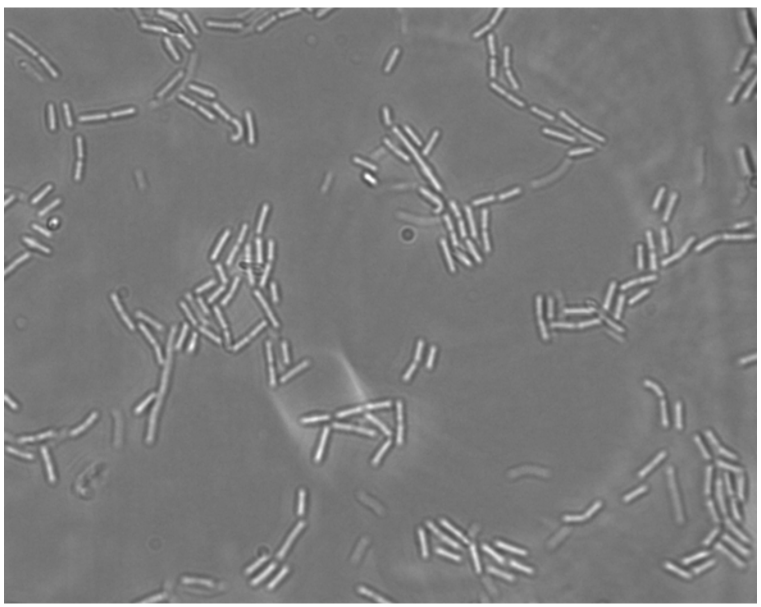
- Known pathways:

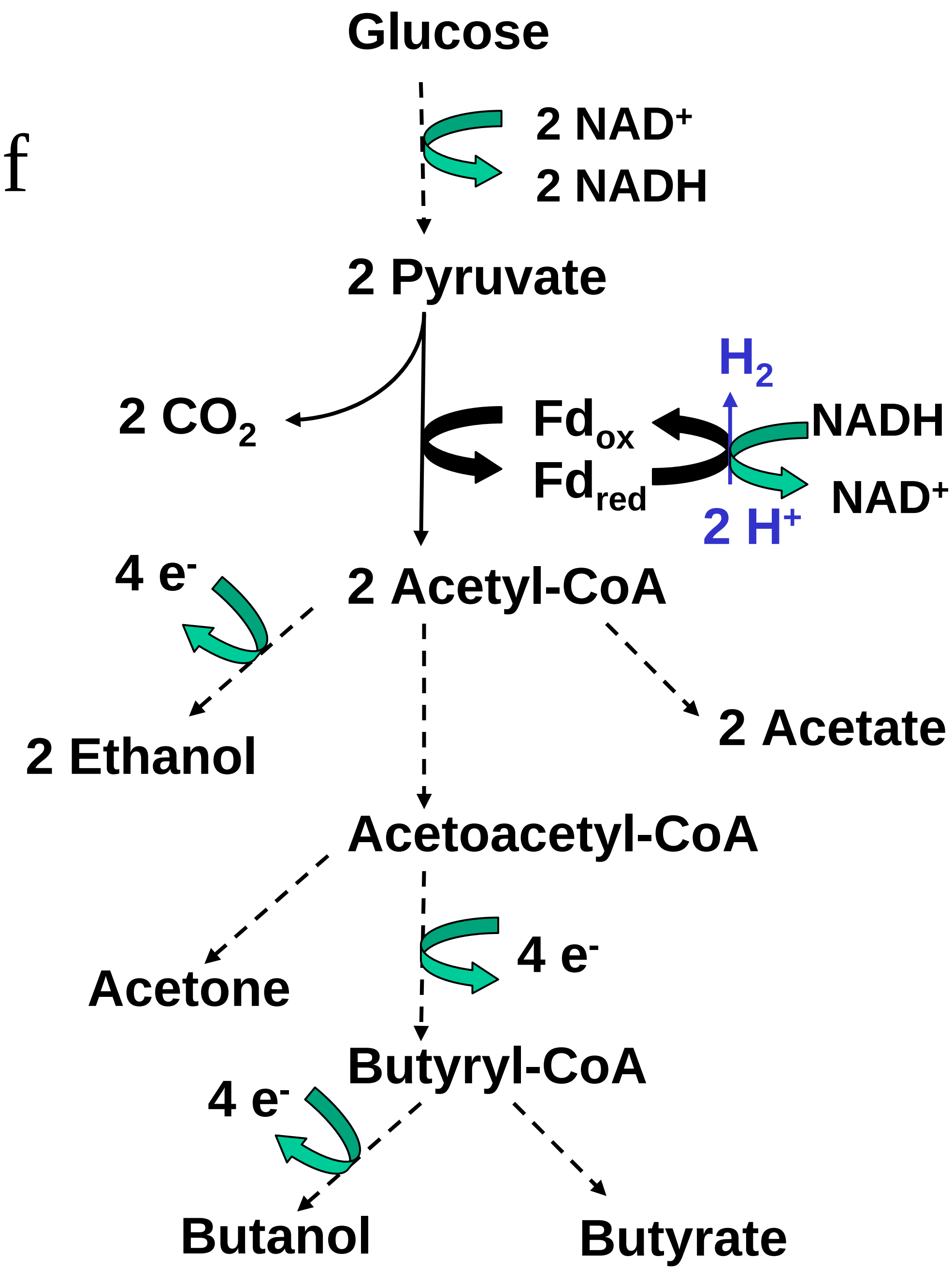
$$C_6H_{12}O_6 + 2\ H_2O \rightarrow 4\ H_2 + 2\ C_2H_4O_2 + 2\ CO_2$$

$$C_6H_{12}O_6 \rightarrow 2\ H_2 + C_4H_8O_2 + 2\ CO_2$$

- Typical yield < 2 mol $H_2$/mol glucose

# Central Metabolism of *Clostridium acetobutylicum* 824





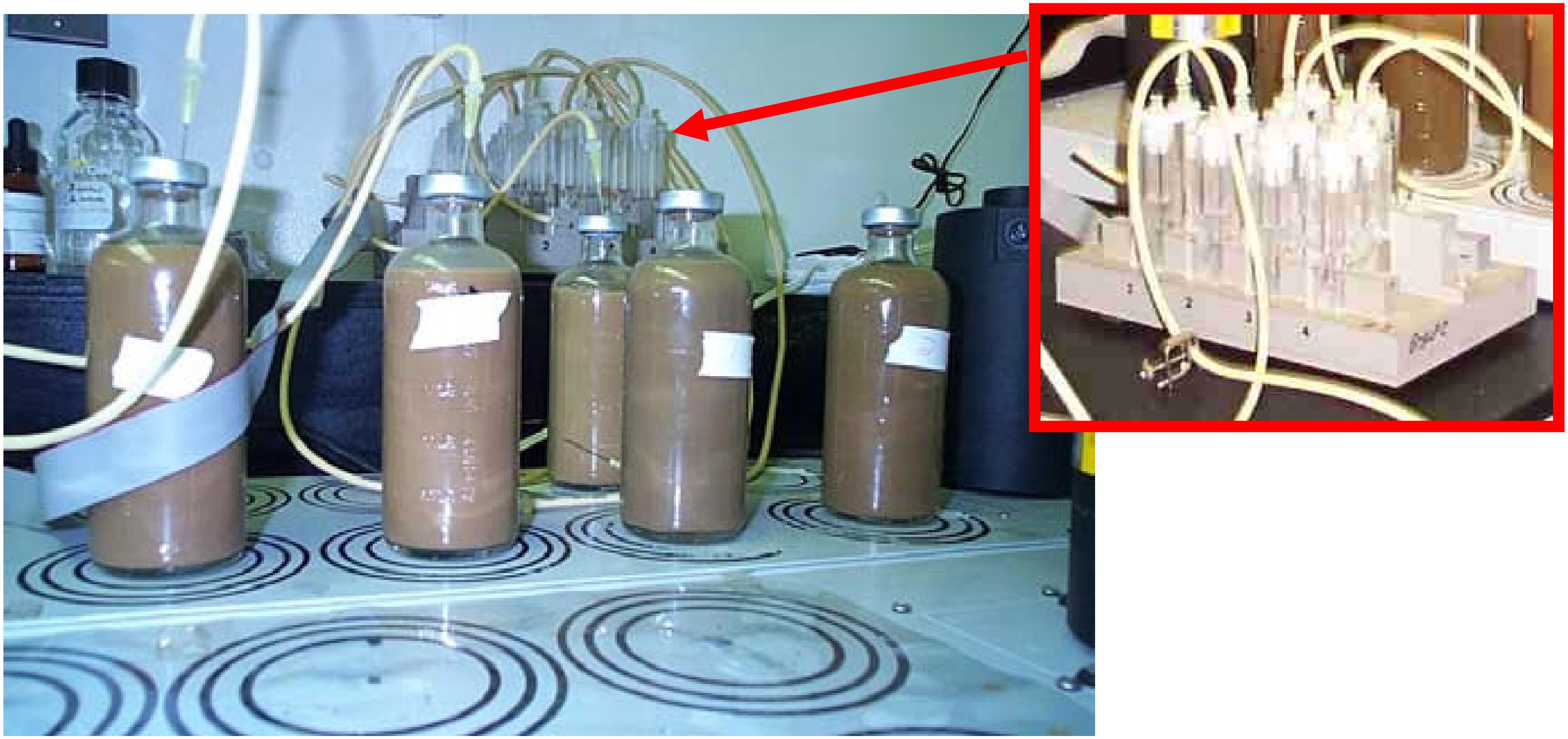
# Strategies to Increase Fermentative $H_2$ Yields

- Reactor configurations
  - Continuous gas release in batch systems
  - Chemostat reactors

- Uncouple hydrogen consumption (methanogenesis/homoacetogenesis)

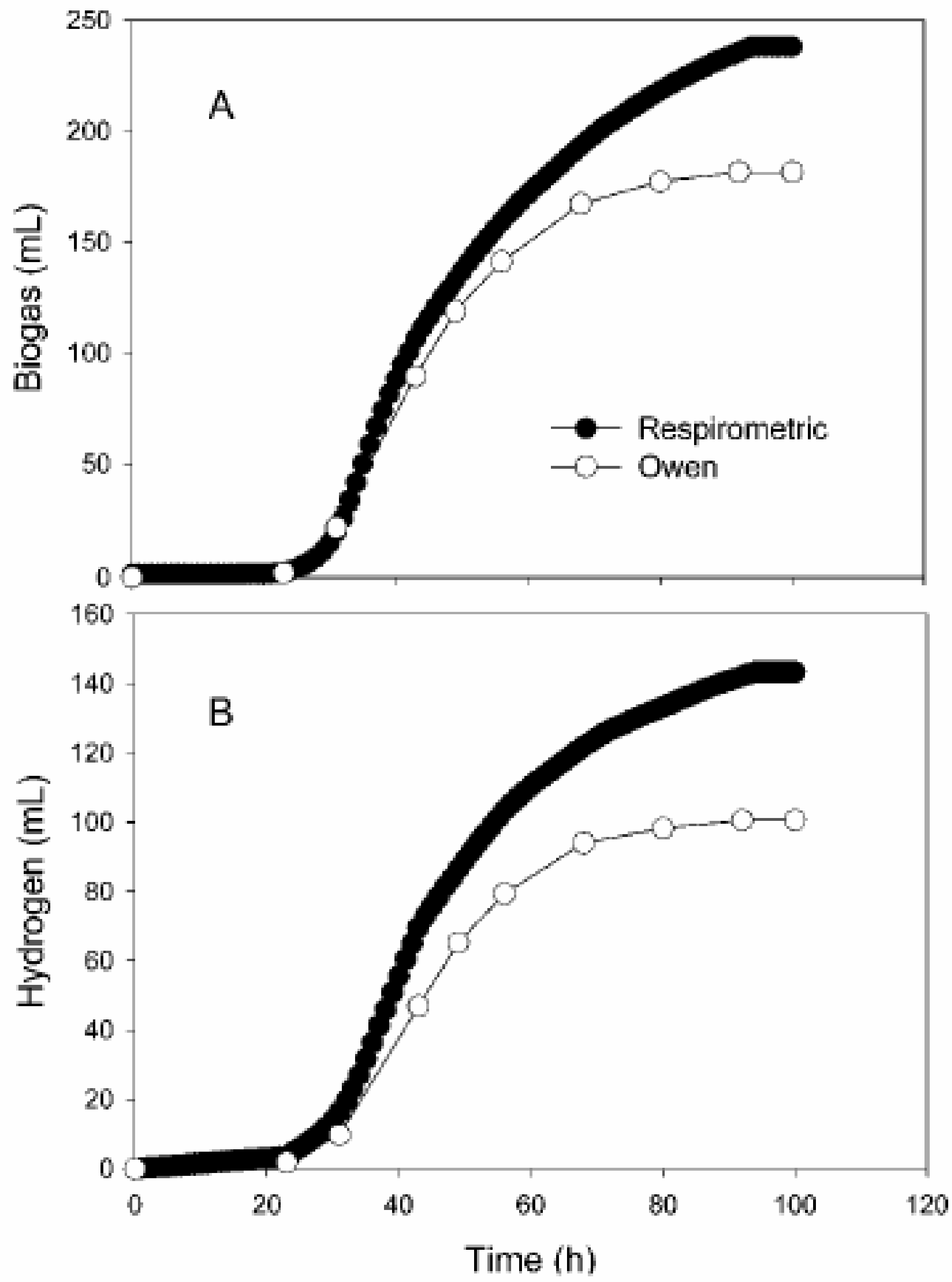
- Strain selection

# Continuous gas release system
# (respirometer)



Continuous gas release in batch cultures

43% increased $H_2$ production




Logan et al. (2002) *Environ. Sci. Tech*., 36, 2530.

# $H_2$ production is higher in CSTR than in batch

Batch Tests: Overall conversion efficiency of 26% (8.7%)

CSTR Tests: Overall conversion efficiency of 44% (15%)

Reasons: $H_2$ loss due to acetogenesis, shifts in community structure

# Strategies to Increase Fermentative H2 Yields

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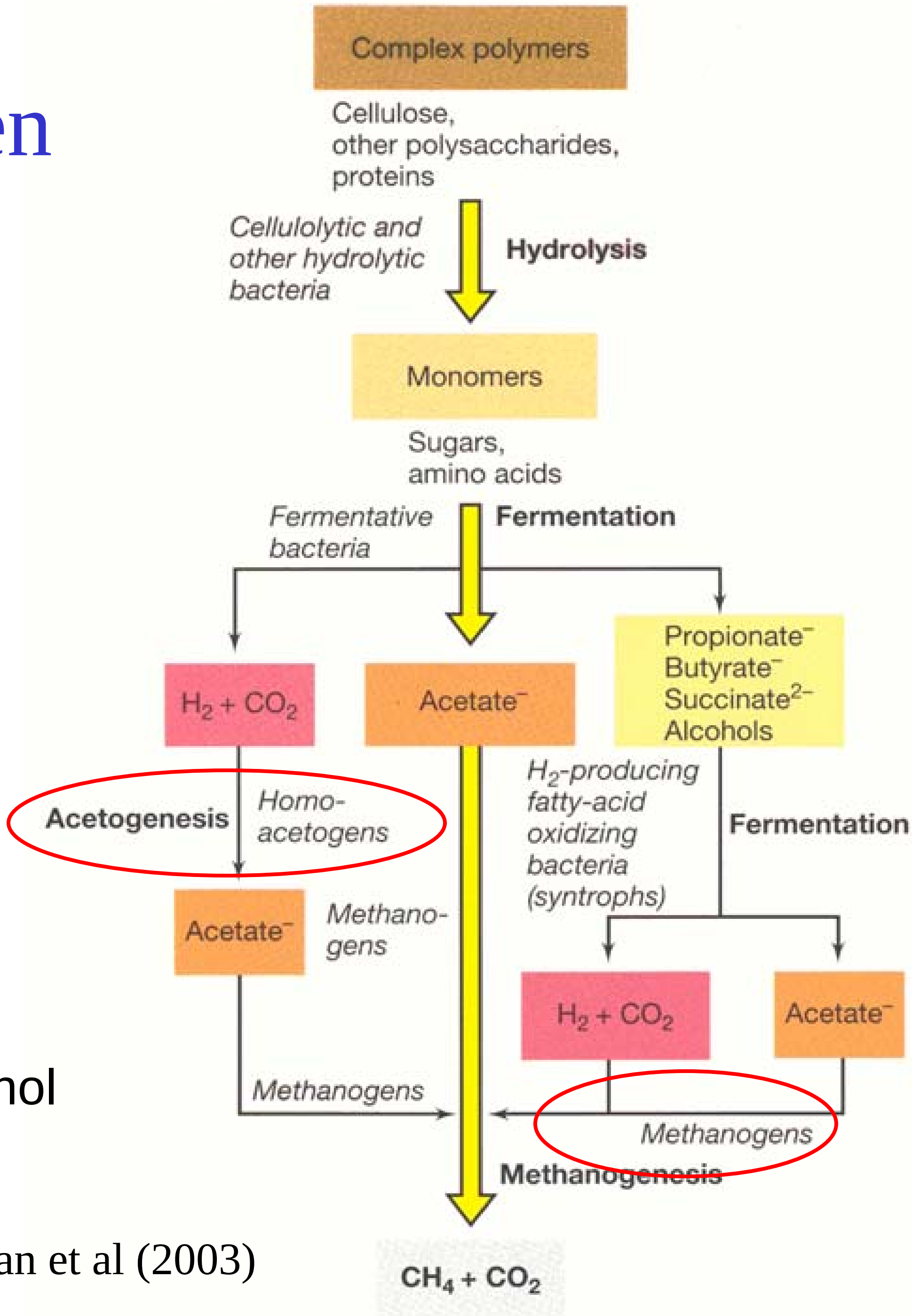
# Uncoupling Hydrogen *Consumption*

- Anaerobic food chain involves interspecies $H_2$ transfer
- $H_2$ production requires preventing:
  - Hydrogenotrophic methanogenesis
  - Homoacetogenesis
  - $H_2$-oxidizing propionate/ethanol production




Madigan et al (2003)

# Limiting Methanogenic $H_2$ Consumption

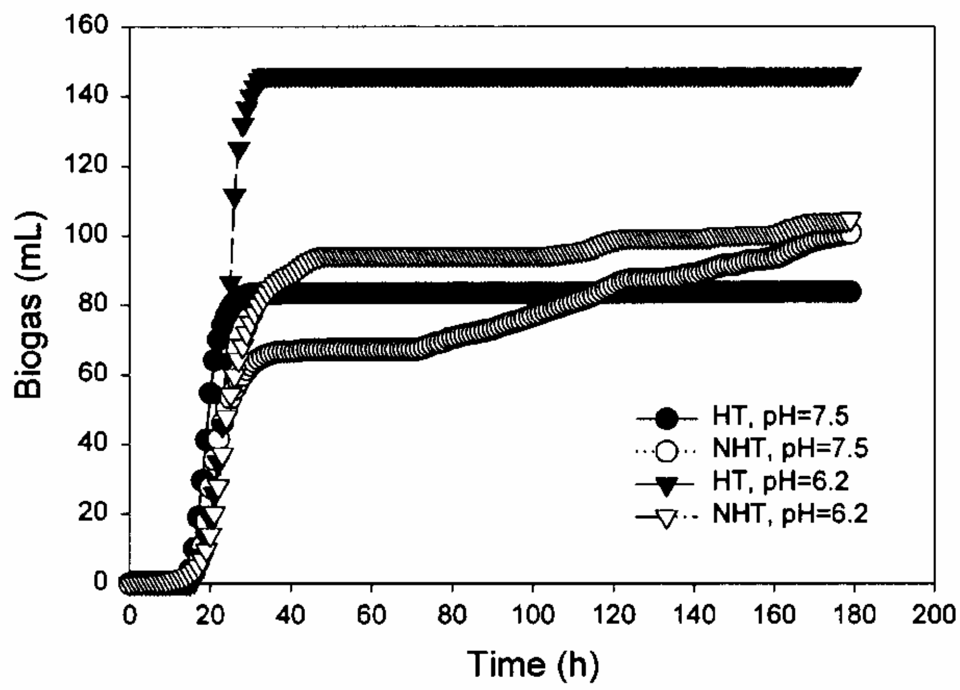
– Heat treatment of inoculum: kills non-spore forming bacteria such as methanogens that are hydrogen consumers

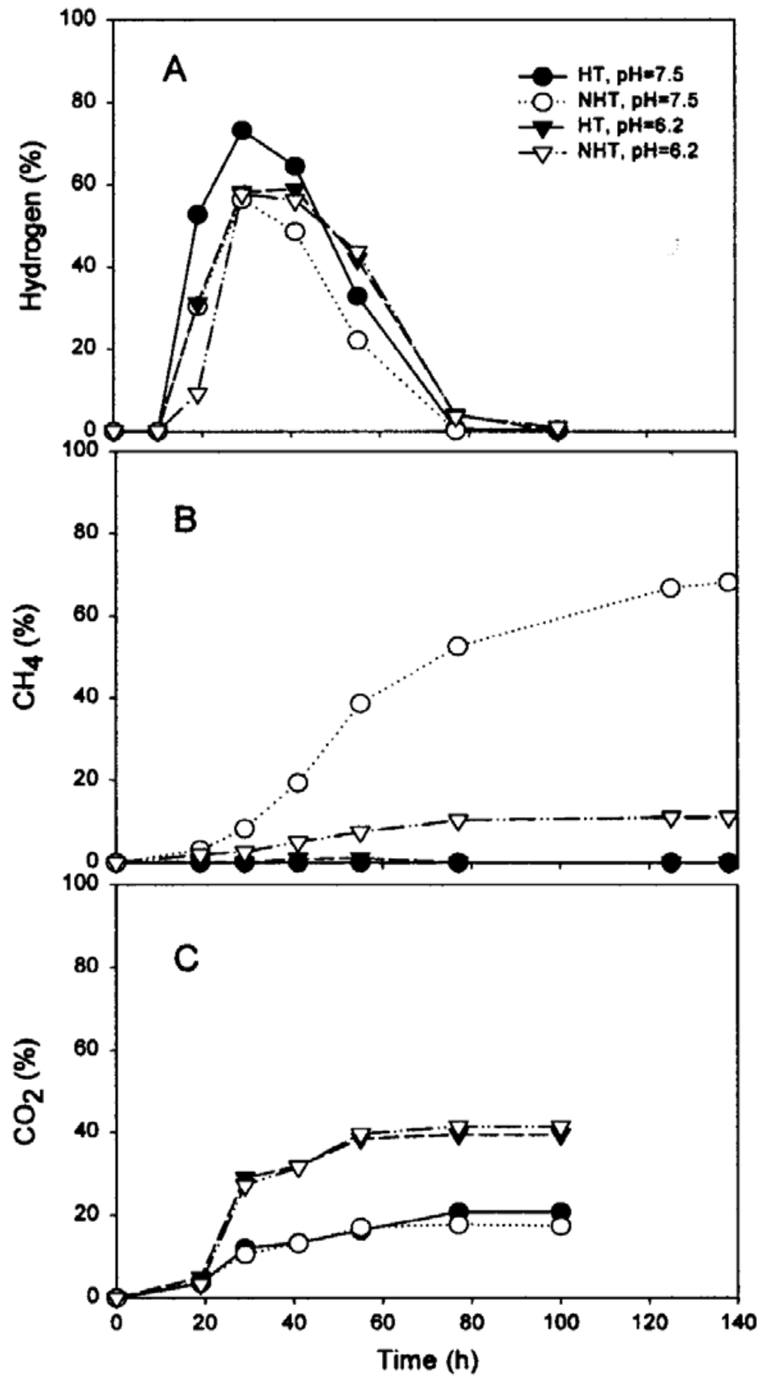
– Low pH (~6): limits methanogen growth

– Short SRT: methanogens grow too slowly

– Alkaline pretreatment [Cai et al (2004) Environ. Sci Technol.]

# $H_2$ production maximized with heat treatment to kill non spore formers and using a low pH




HT = heat treated

NHT = non heat treated

Oh et al. (2003) *Environ. Sci. Technol*

# Limiting Homoacetogenic $H_2$ Consumption

- Homoacetogenesis:

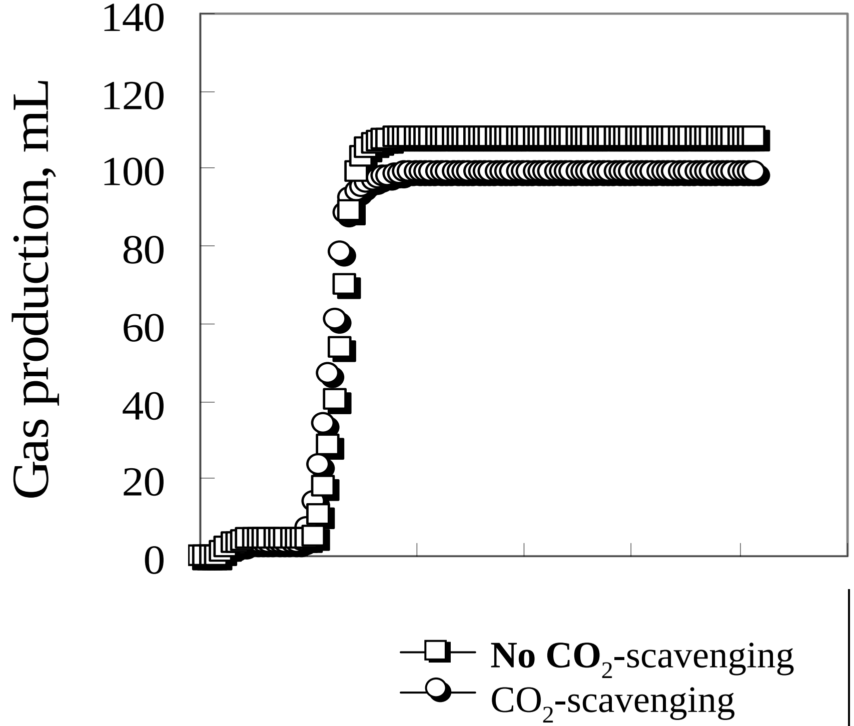
$$4\ H_2 + 2\ CO_2 \rightarrow CH_3COOH + 2\ H_2O$$

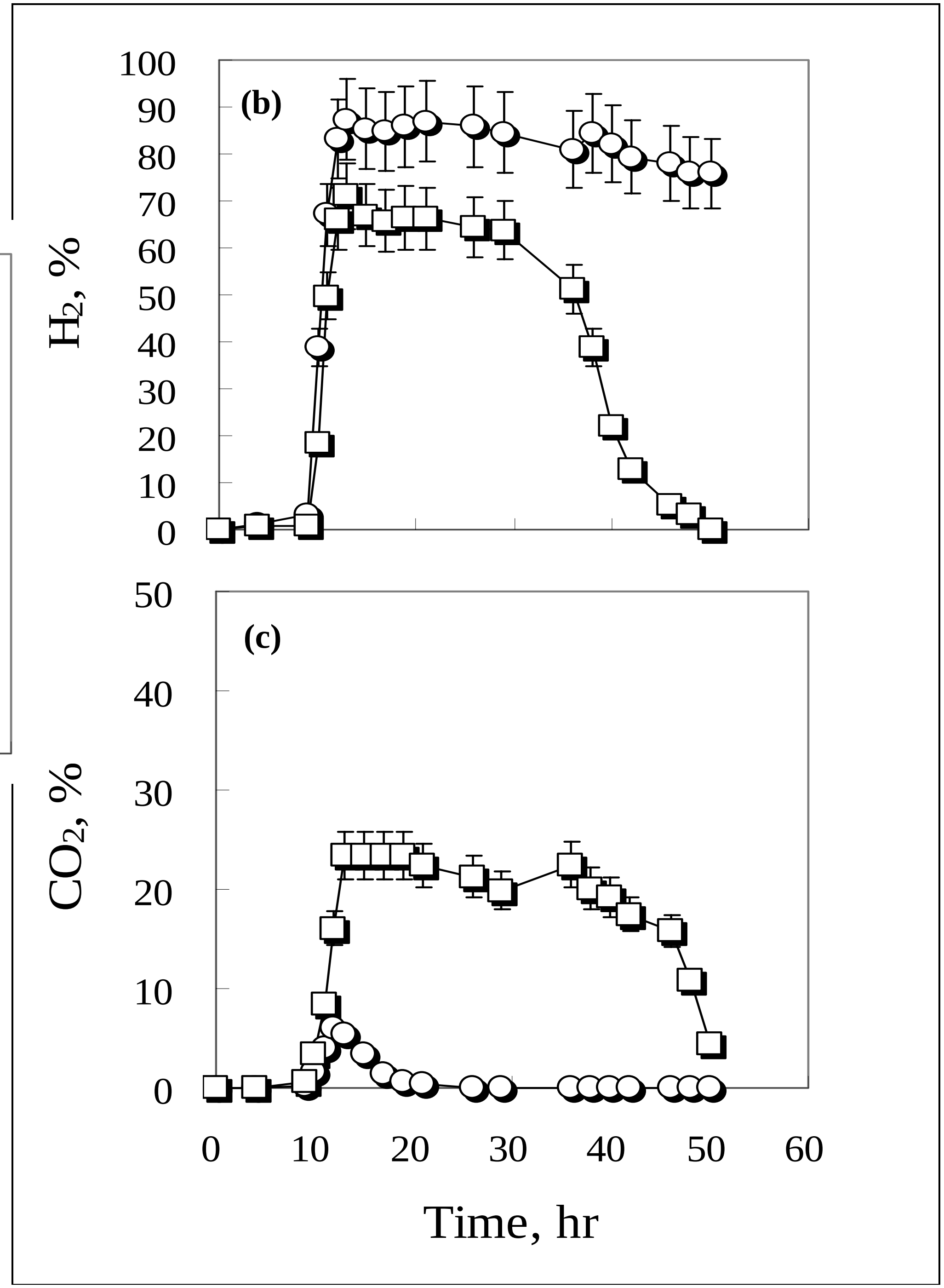
Solution:

- low $P_{H2}$ with continuous gas release
- $CO_2$ scavenging with KOH

Park et al (2005) Environ. Sci. Technol.

# Gas production



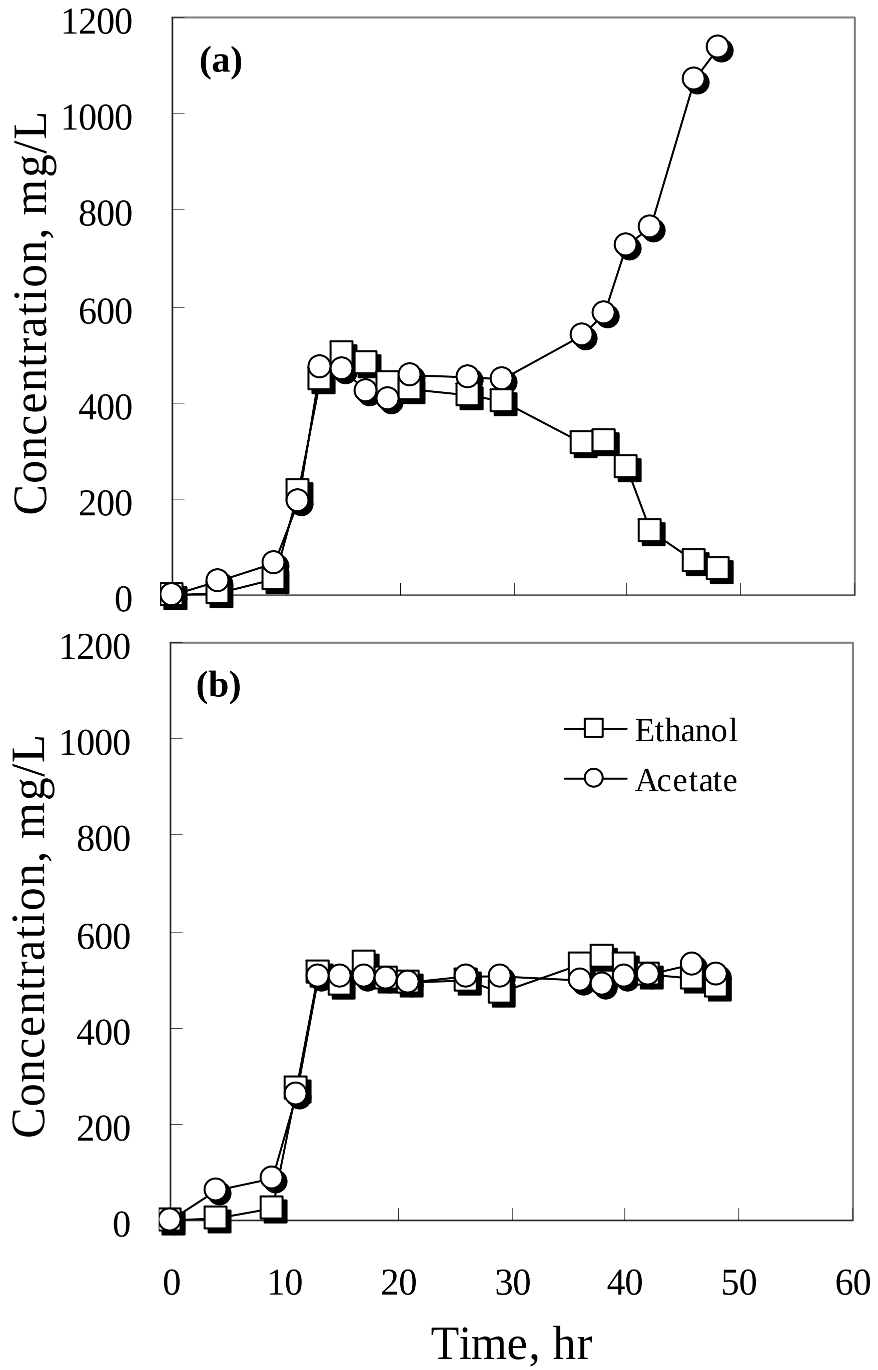

H2 Yield (mol/mol):

- 2.0 w/ scavenging
- 1.4 w/o

# Fermentation products

No $CO_2$ scavenging

With $CO_2$ scavenging



# Strategies to Increase Fermentative H2 Yields

- Reactor configurations
  - Continuous gas release in batch systems
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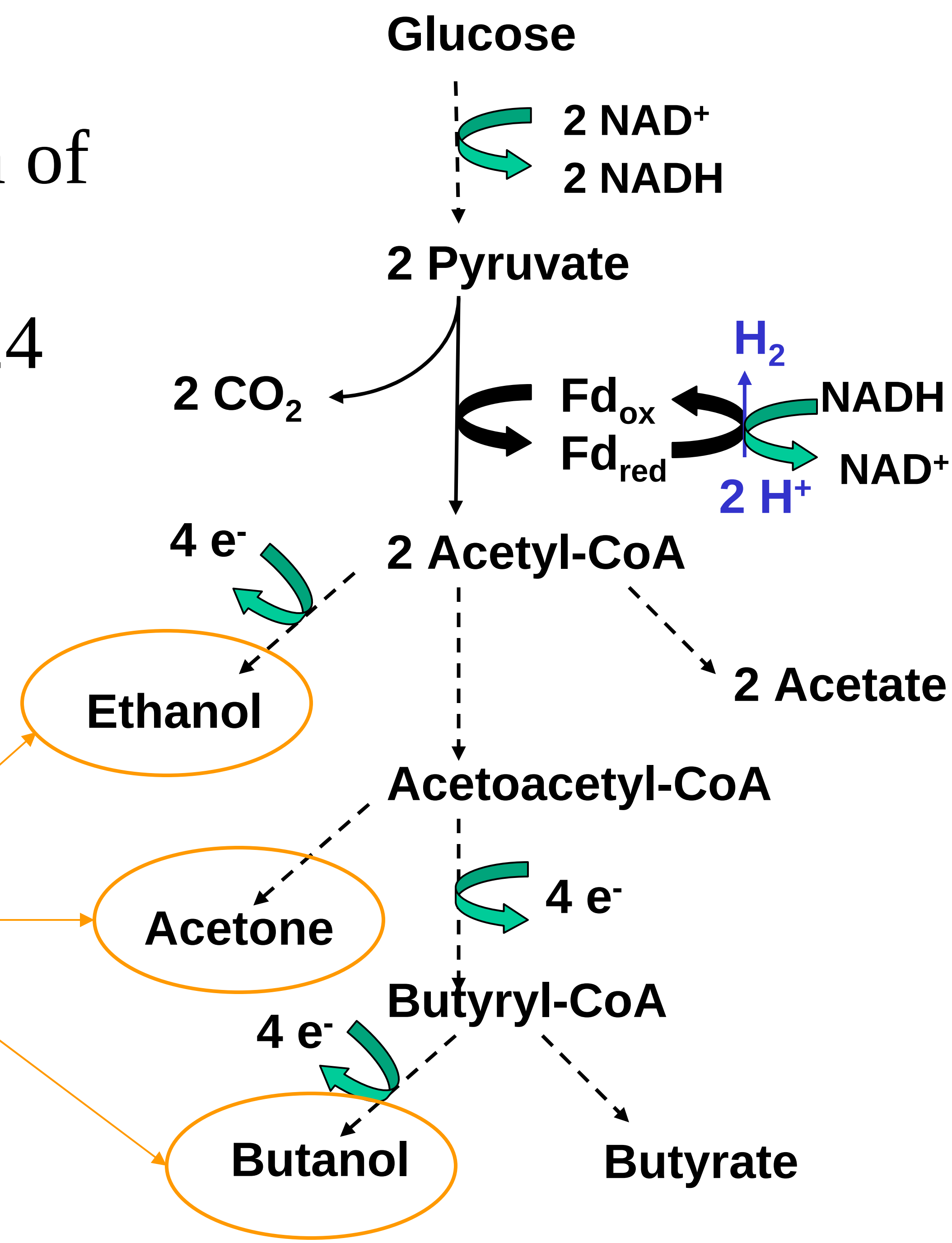
- Strain selection

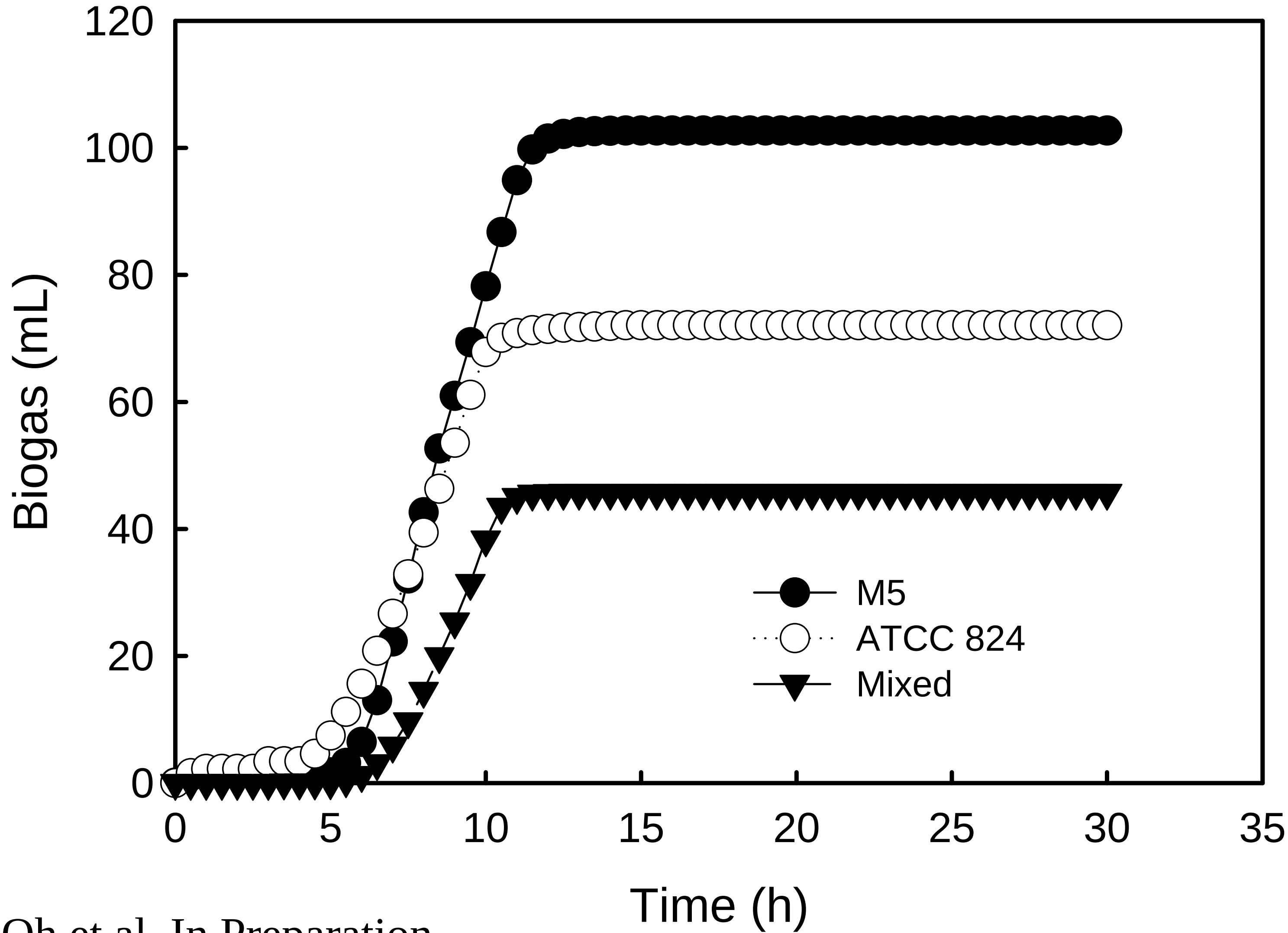
# Central Metabolism of *Clostridium acetobutylicum* 824

$H_2$ yield from megaplasmid-deficient strain M5?

Production decreased in megaplasmid-deficient strains

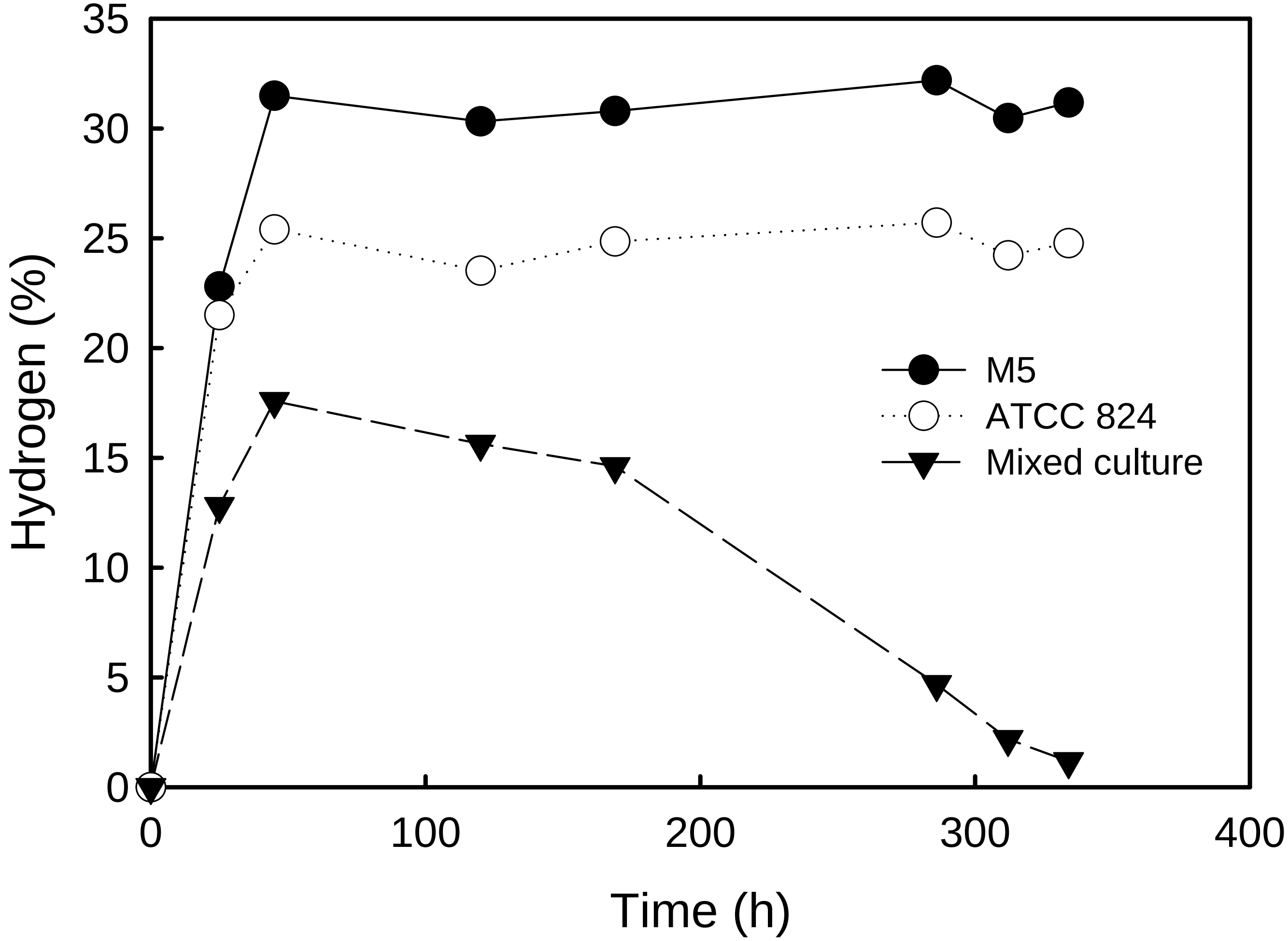


# Respirometric Results



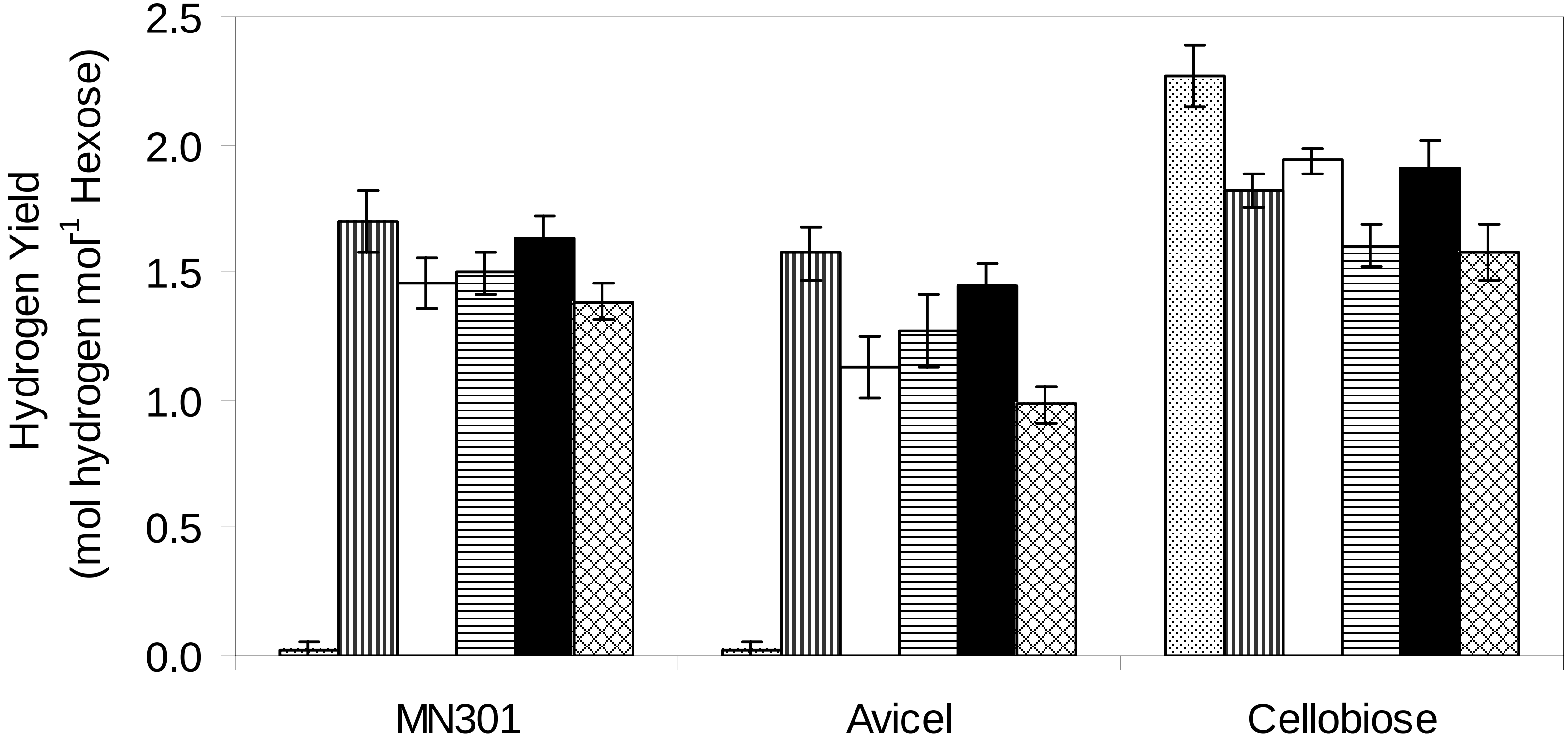

Oh et al, In Preparation

# Hydrogen Yield Results




| Yield ($mol\ H_2/mol$) |
| --- |
| **2.4** |
| **1.6** |
| **1.0** |

# Comparison of $H_2$ yield for *Clostridium* spp.



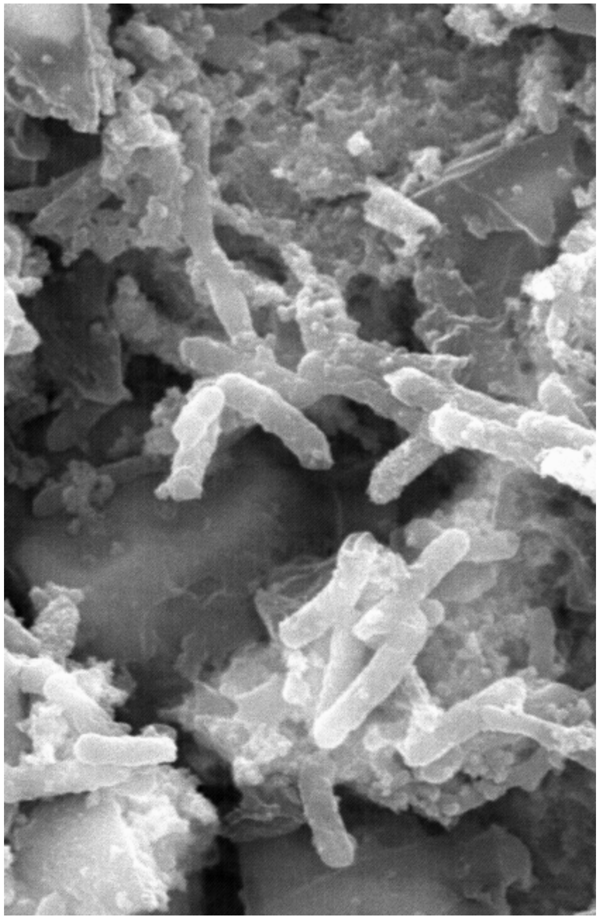

*Clostridium* species: *acetobutylicum*, *cellulolyticum*, *cellobioparum*
*celerecrescens*, *populeti*, *phytofermentans*

Ren, Ward, Logan, and Regan (2007) *J. Applied Microbiol.*

# Summary

Fermentative hydrogen yields can be increased by:

- Continuous release of $H_2$
- Continuous flow system
- Reducing $H_2$ consumption by methanogens and acetogens
- Using strains that divert more electrons to proton reduction than other products



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Funding:

USDA/DOE 2003 Biomass Research and Development Initiative

PENNSTATE

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