Electron bifurcation mechanism and homoacetogenesis explain product yields in mixed culture anaerobic fermentations

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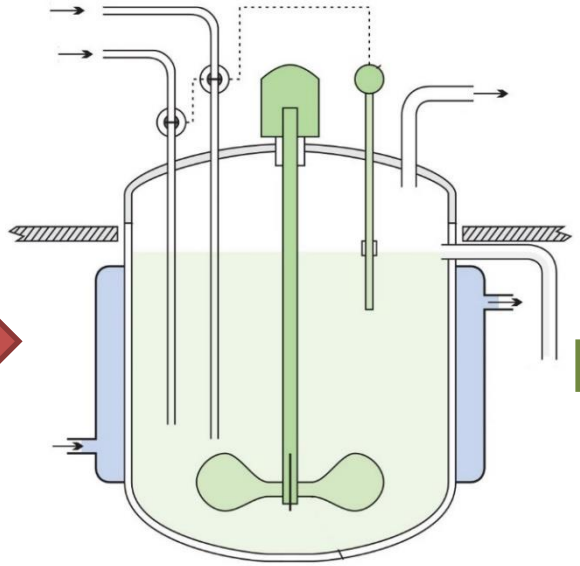
Mixed culture fermentations for a circular economy



Wastes

Products with value

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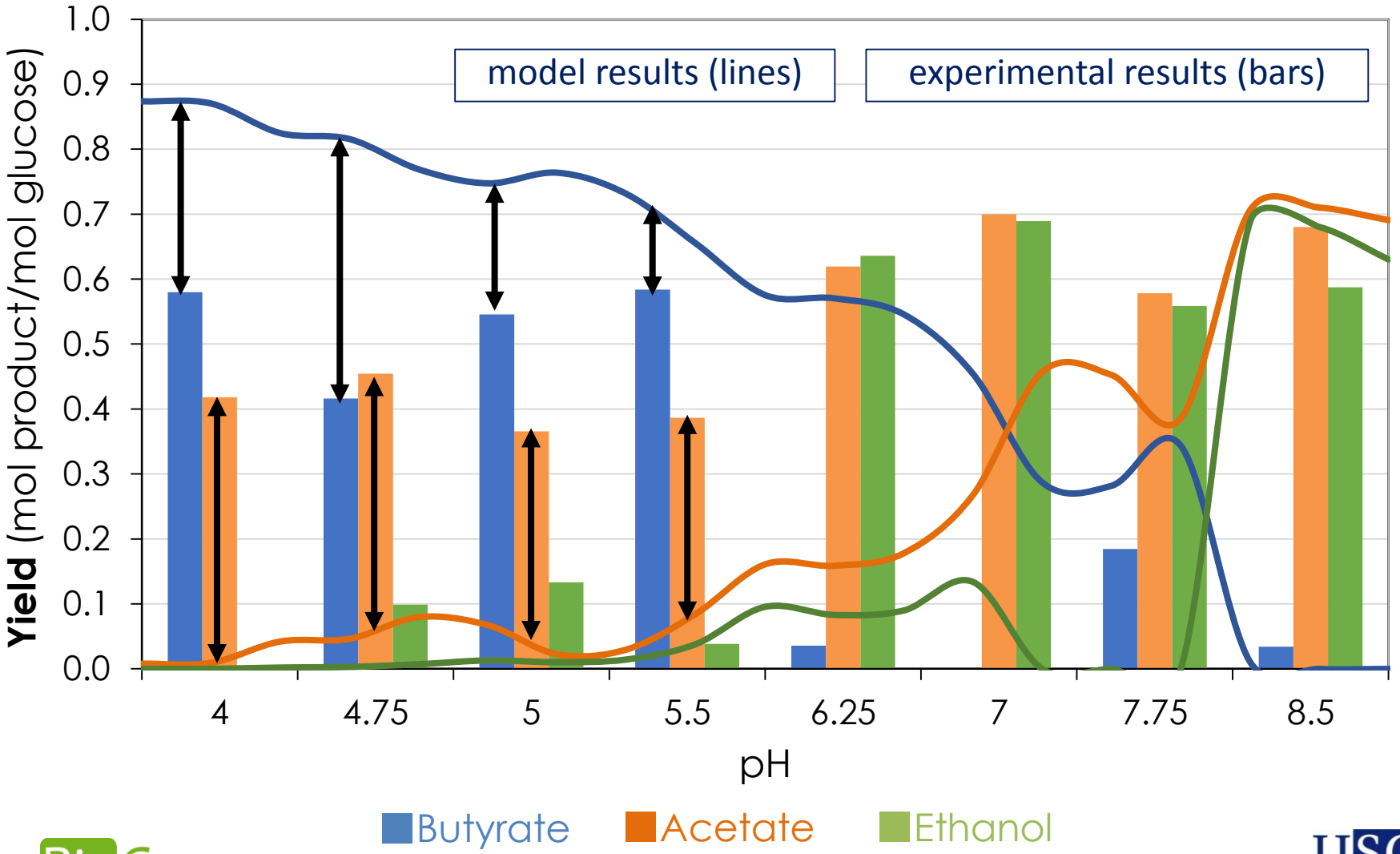
Product yield changes with pH

Model results: González-Cabaleiro et al. (2015). PLoS ONE
Experimental results: Temudo et al. (2007). Biotechnol. Bioeng.



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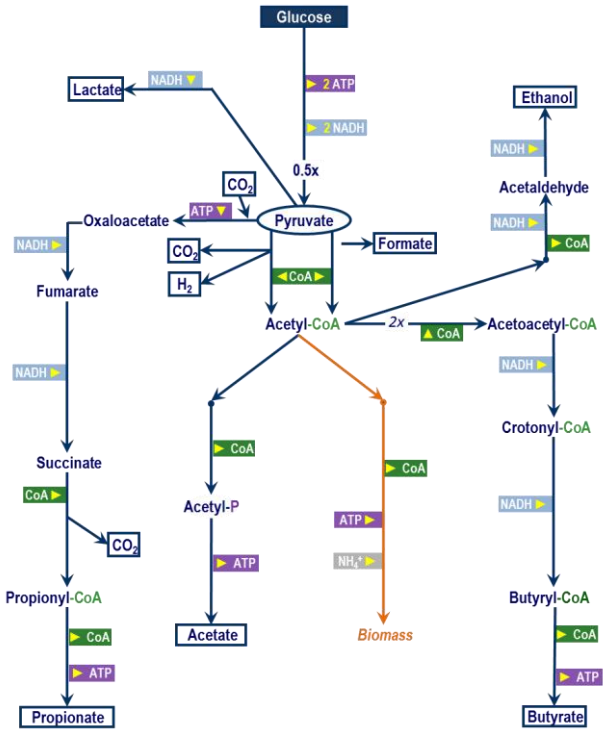
Maybe… the metabolic network is incorrect?

How can we test the metabolic network?

Experimental yields of products *(Acetate, Propionate, Butyrate, Ethanol)*

Info In



NADH balance

H_2 yield

CO_2 yield

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Metabolic network

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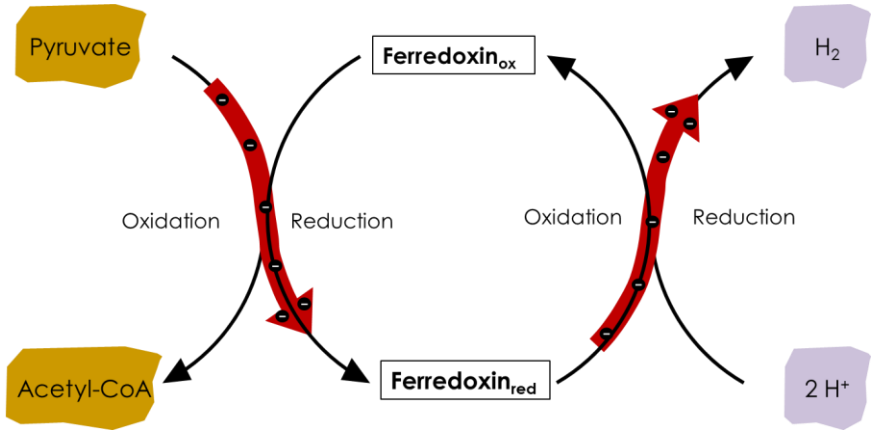
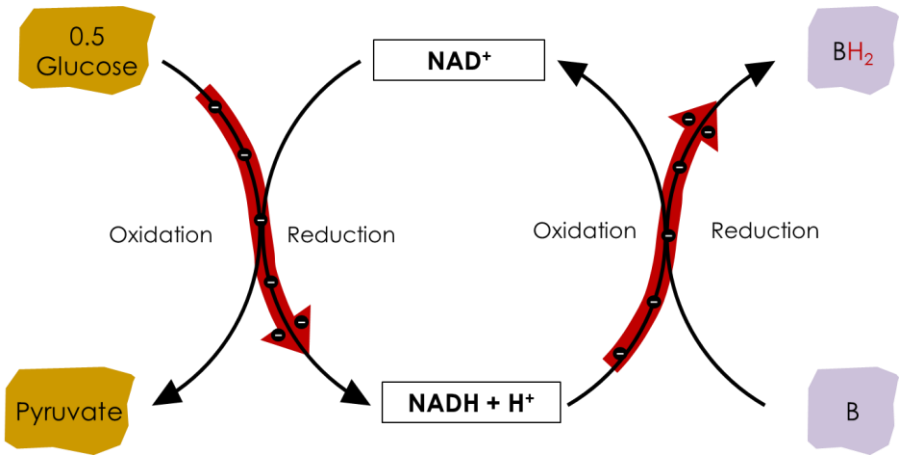
The electron carriers considered

Ferredoxin



E°' ≈ -400 mV

NADH/NAD$^+$



E°' ≈ -320 mV

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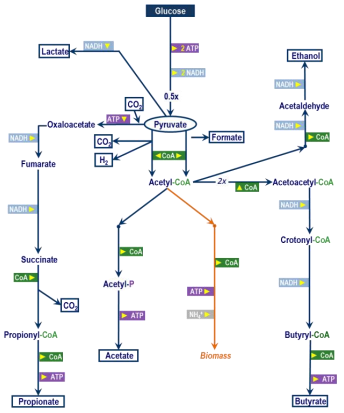
Why performing NADH balances?

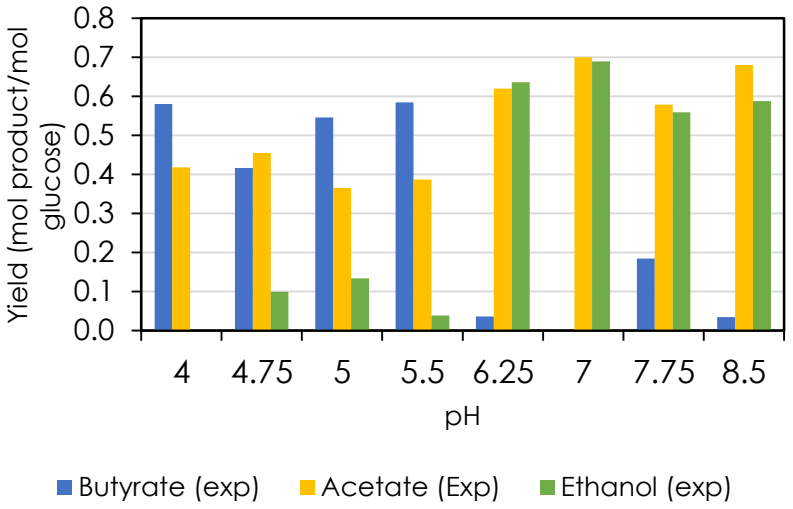
- An accurate network will result in a neutral NADH balance:

$$\sum_{i=products} \vartheta_{NADH,i} \cdot y_i = 0$$

Stoichiometric coeffs.

Experimental yields





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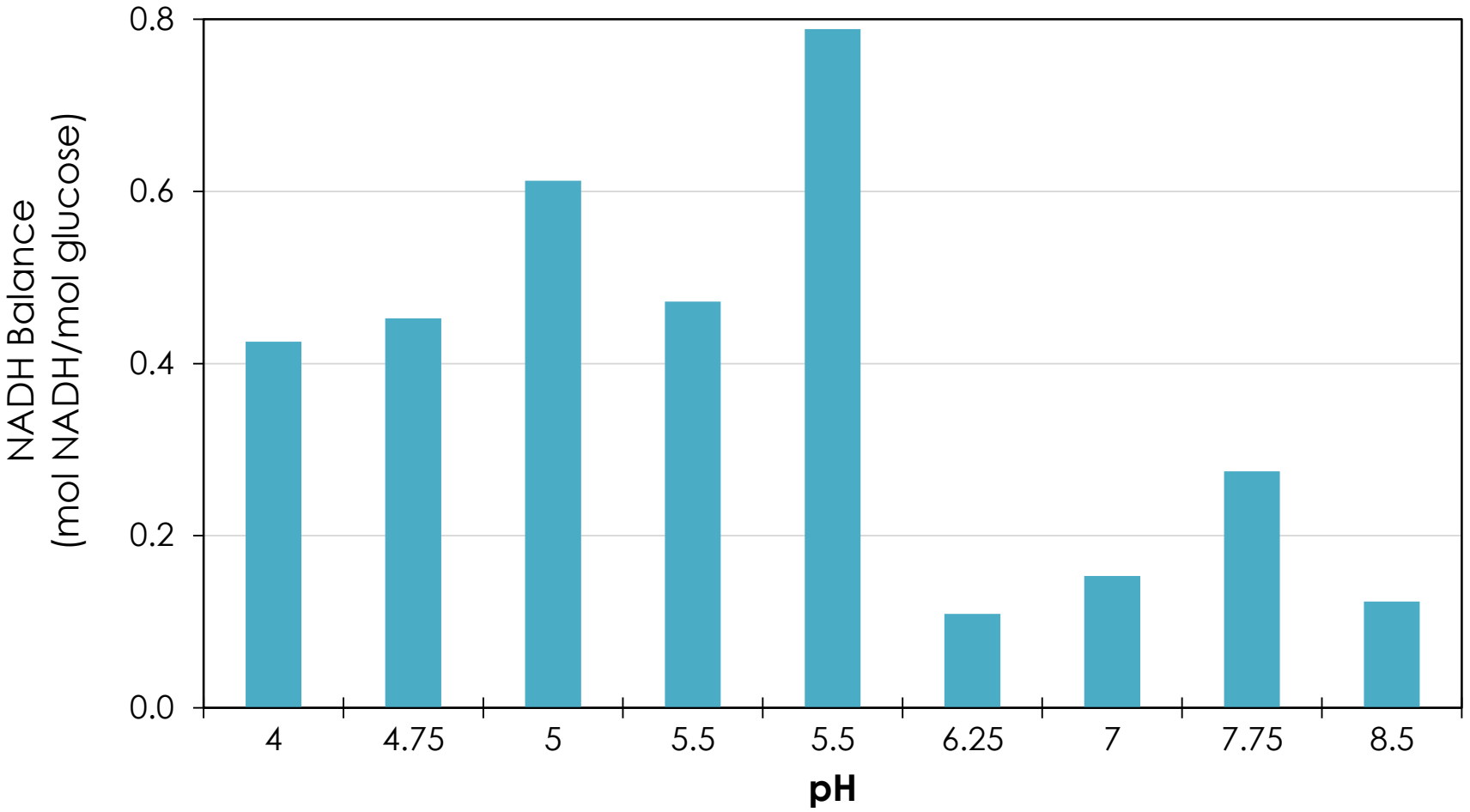
NADH is not conserved



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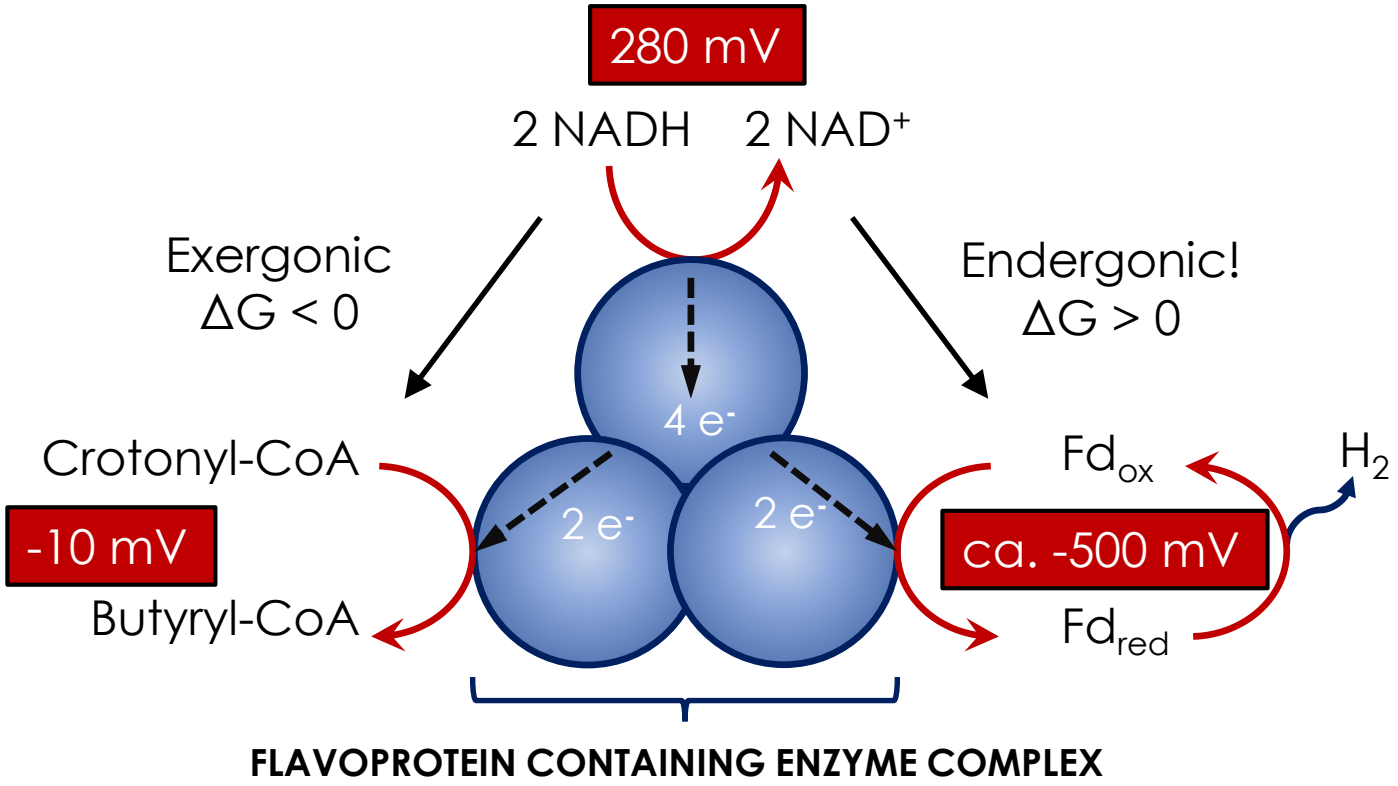
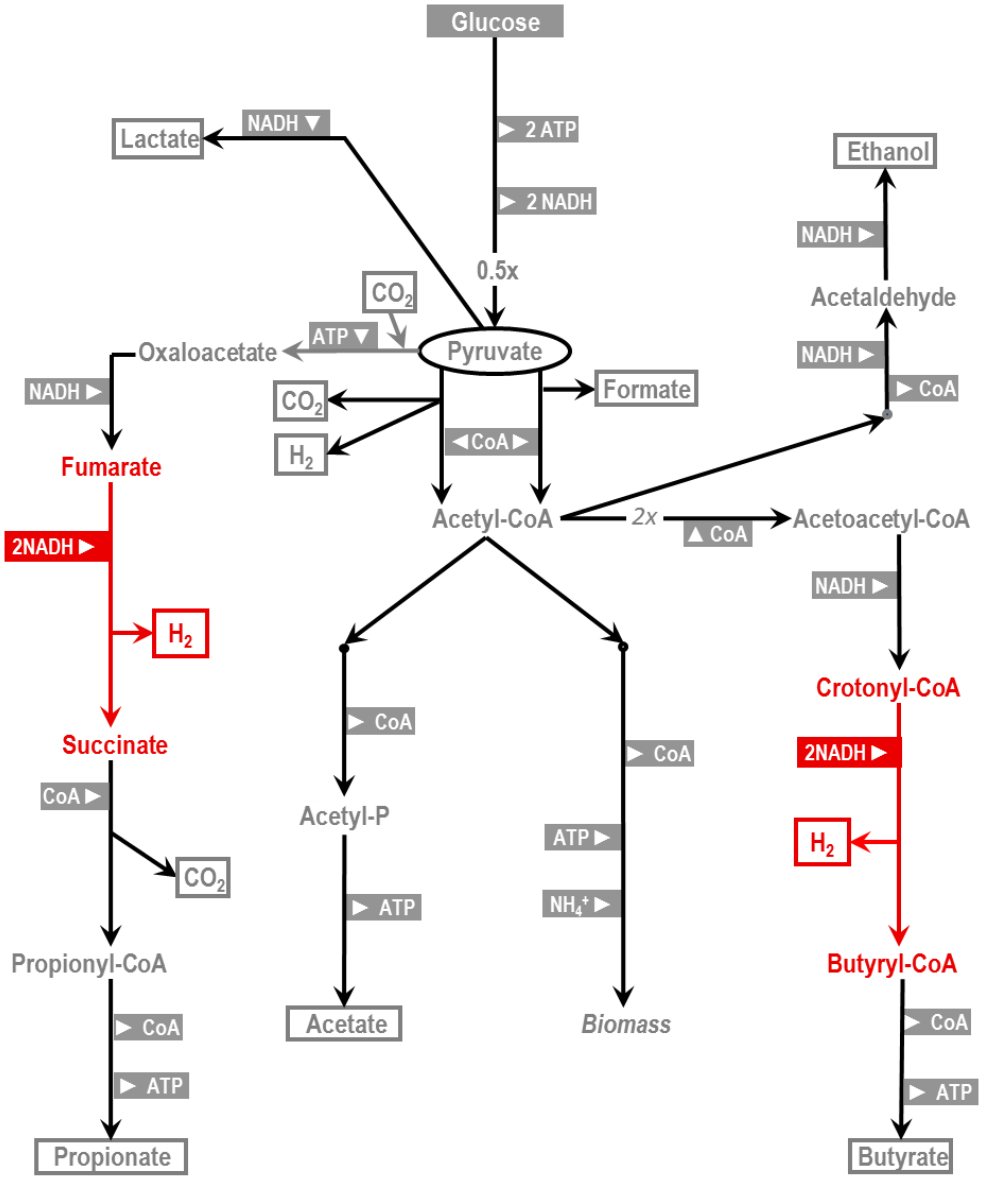
Electron bifurcation: a novel biochemical mechanism

- Only observed *in vitro* (*Clostridium pasteurianum*)



Bucket and Thauer (2013). Biochimica et Biophysica Acta

Electron bifurcation changes the stoichiometry



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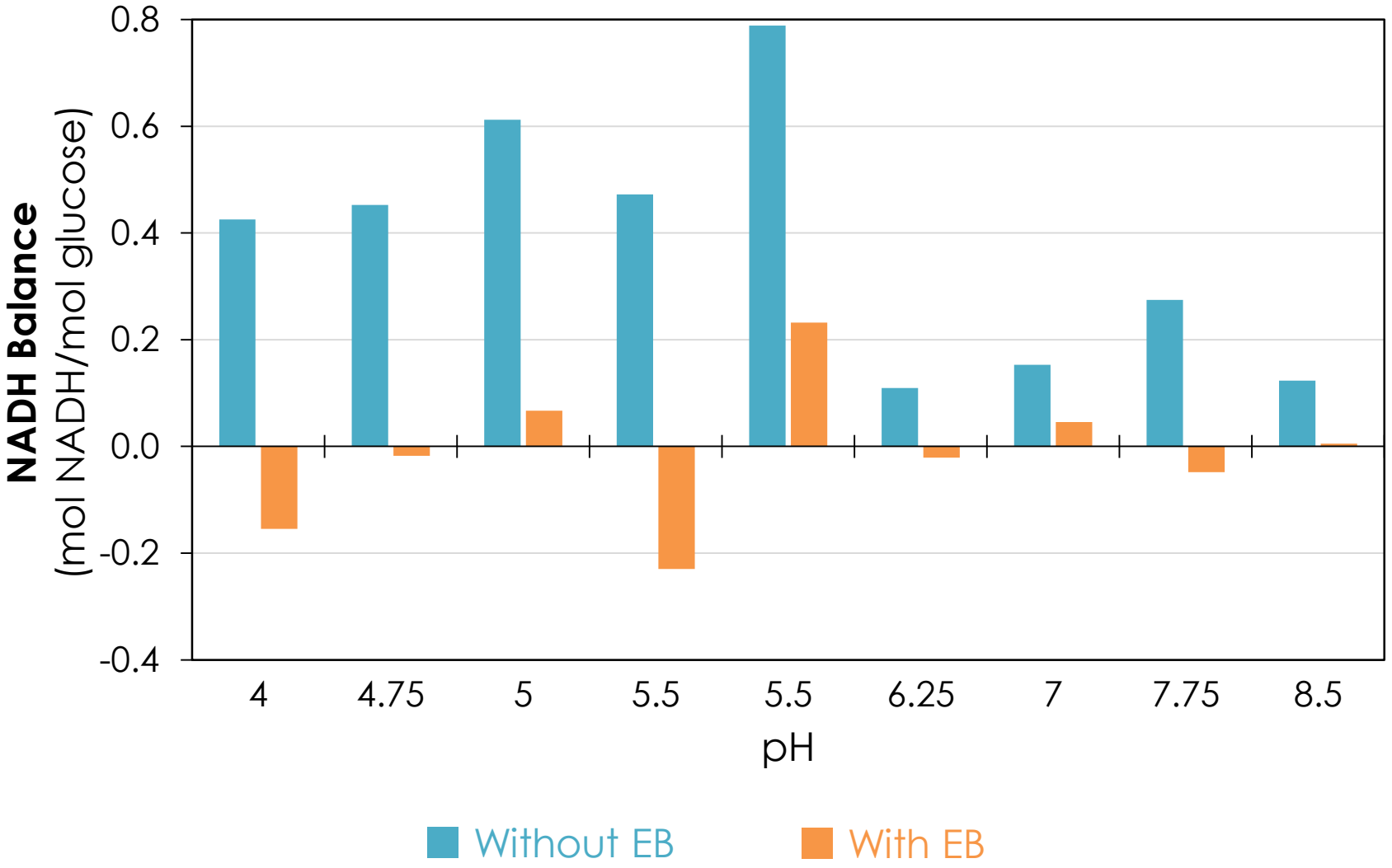
Electron bifurcation reduces the error in the e^- balances



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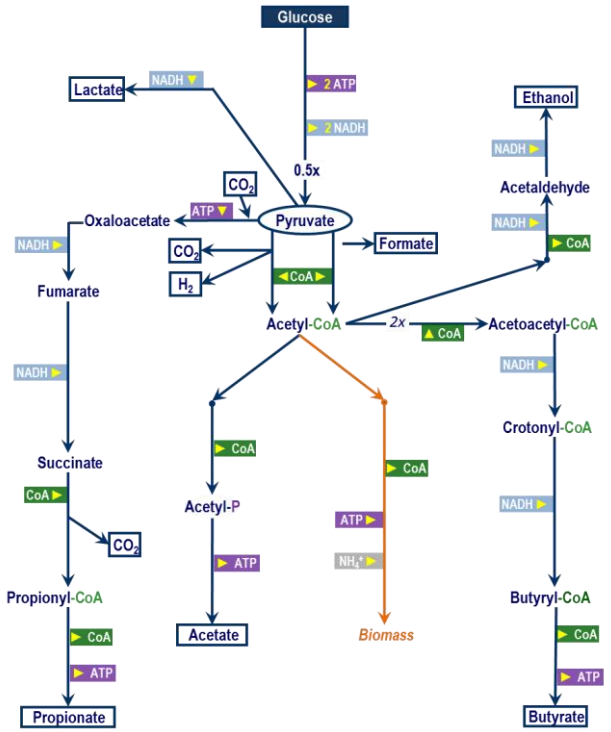
How can we test the stoichiometry?

Experimental yields of products *(Acetate, Propionate, Butyrate, Ethanol)*

Info In



NADH balance ✓

H_2 yield

CO_2 yield

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Stoichiometry

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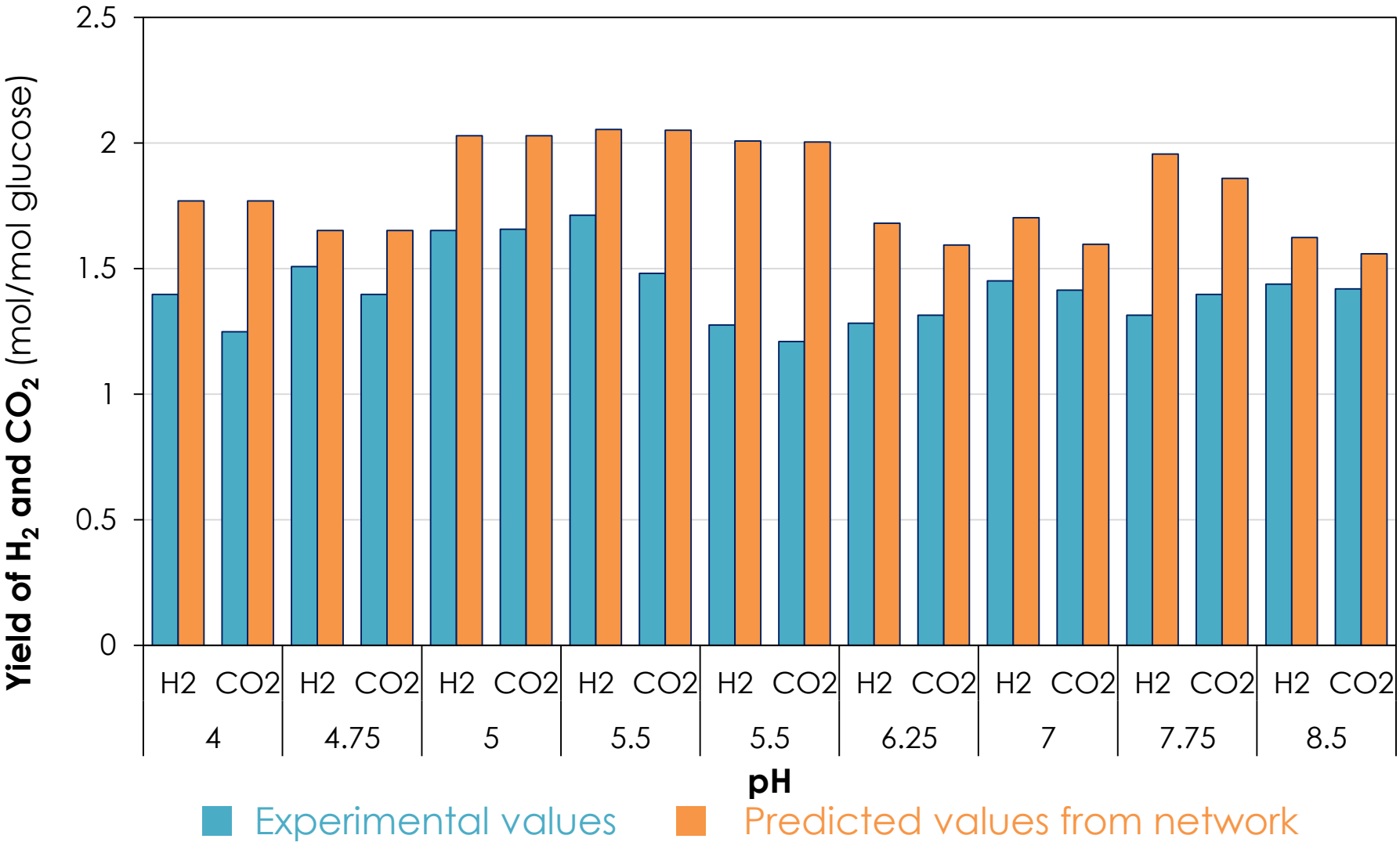
H_2 and CO_2 yields do not fit either



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Temudo et al. (2007). Biotechnol. Bioeng.

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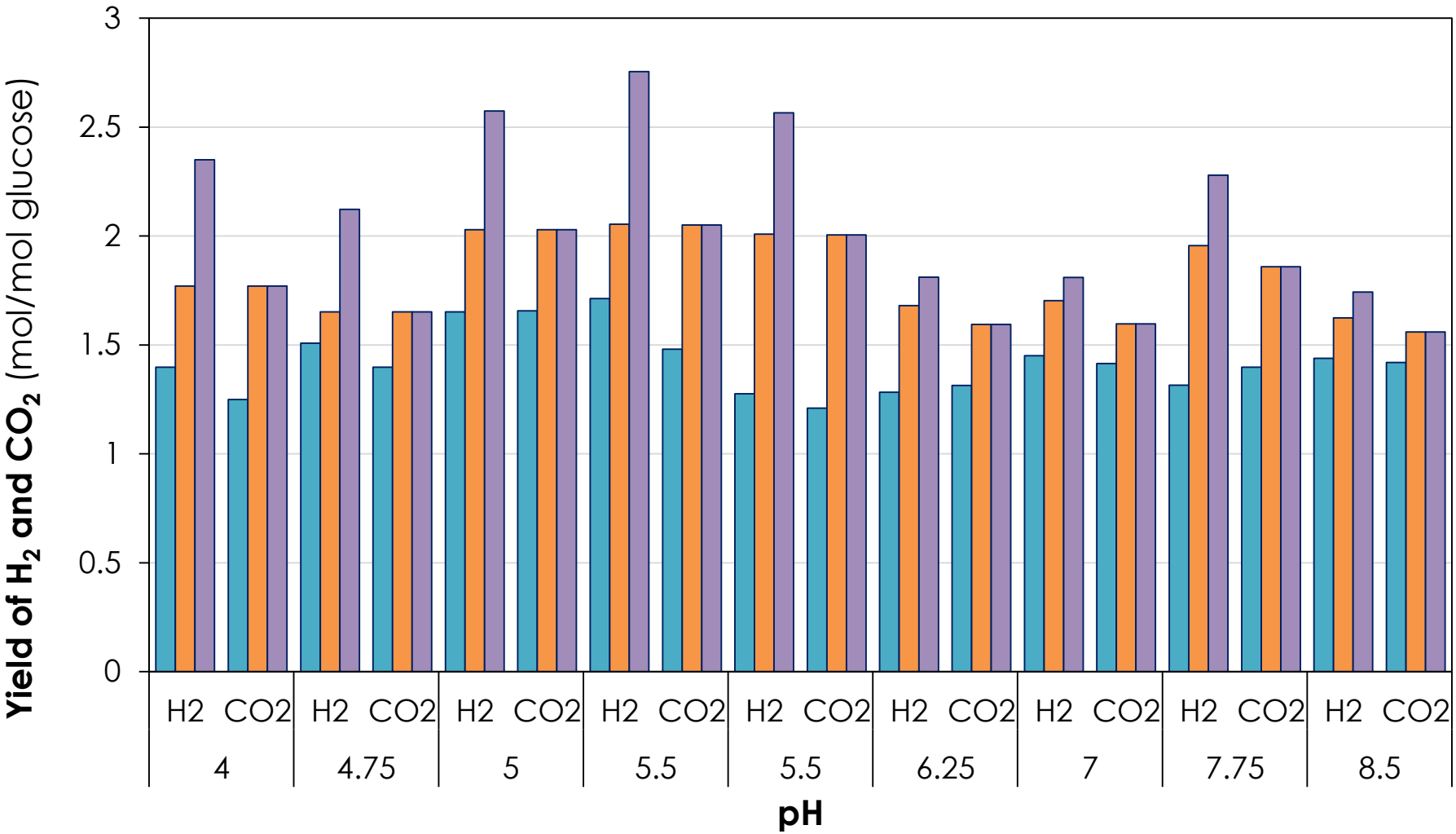
Electron Bifurcation does not solve the problem



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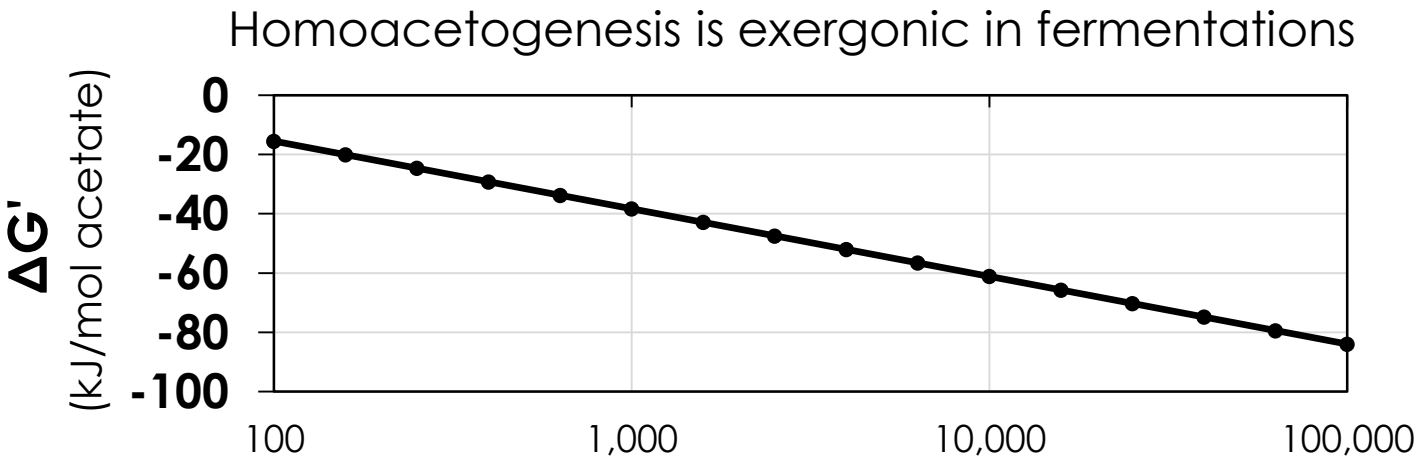
Temudo et al. (2007). Biotechnol. Bioeng.

Possibilities to explain the H_2 and CO_2 yields observed

- Reduced Ferredoxin does not yield H_2
    - Could be oxidized in highly endergonic reactions in the anabolic process.
    - Could participate in other catabolic reactions as electron donor instead of NADH

- Homoacetogenesis $4H_2 + 2HCO_3^- + H^+ \rightarrow \text{Acetate} + 4H_2O$



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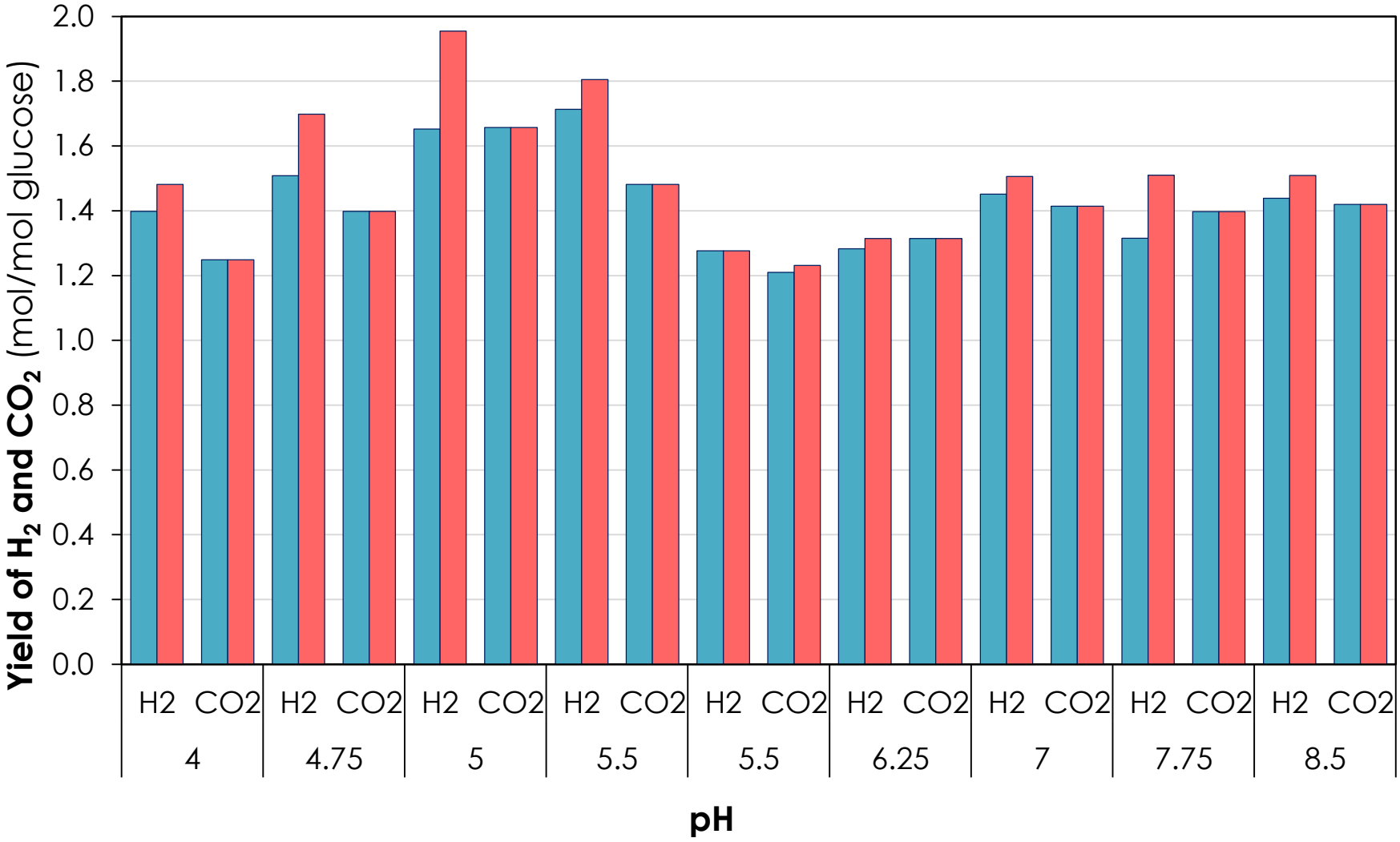
Homoacetogenesis explains the H_2 and CO_2 yields observed



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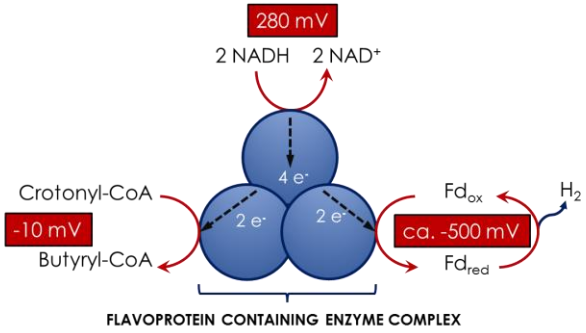
Temudo et al. (2007). Biotechnol. Bioeng.

Conclusions

- Electron Bifurcation is likely a mechanisms commonly used by fermenters
- Homoacetogenesis could possibly occur and explain the H_2 and CO_2 yields observed
- The new network will help to improve model predictions and bioprocess design.



$$4H_2 + 2HCO_3^- + H^+ \rightarrow Acetate + 4H_2O$$

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