Syngas fermentation - biochemical challenges and opportunities

Torbjørn Ølshøj Jensen
Center for Biosustainability
Historical highlights

- 4000 mil  Origin of life
1932  Acetogenesis reported in $\text{H}_2 + \text{CO}_2 \rightarrow \text{acetate}$
1936  First organisms isolated
1938  First organisms lost
1942  Isolation of a thermophilic acetogen
       3 acetate from 1 glucose
1945-52  Acetate from $^{14}\text{CO}_2$ or $^{13}\text{CO}_2$
2004  -  Demonstration and commercialization
       (Lanzatech, Coskata, INEOS Bio)
$4 \text{H}_2 + 2 \text{CO}_2 \rightarrow \text{acetate} + 0.5 \text{ATP}$
Butyrate, Lactate, Ethanol, Acetone, Butanol, Propanol

[^CH_3]-[Co-Protein] → HSCoA → Acetyl-CoA

*Phosphotrans-acetylase*

CO

CH_3C-SCoA → Assimilation into cellular carbon

CH_3COO-PO_4^{2-} → Acetate kinase

ADP + P_i → ATP

CH_3COOH

Butyrate, Lactate

Ethanol, Acetone, Butanol, Propanol

Product Inhibition
Biological gas conversion

Gas-fermentation

CONDESATION

Butyrate fermentation

In situ esterification

Butylbutyrate
Biological gas conversion

**Gas-fermentation**

CO₂ — H₂ — CO — H₂ — CO₂

**Butyrate fermentation**

H₂ — CO — H₂ — CO₂

**In situ esterification**

Butylbutyrate
Gas fermentation

- Identifying thermophilic acetogen
- Characterizing the strain
- Optimizing growth (media, conditions etc.)
- Establishing genetic tools
- Finding genes responsible for production of butanol
- Characterizing the proteins (thermostability)
- Integrating the pathway into the selected strain
Cultivation optimization of *M thermoacetica* resulted increased growth and postponed sporulation.

4x increase in OD and 3x increase in acetate concentration
Tool development

Genetic reporter system
Anaerobe/aerobic marker system was developed. It is working a temperatures from 37-60°C in a broad range of organisms.

Published in AMB express 2017
Identifying butyrate producing acetogens

Characterize and benchmark the strains

Optimizing growth and productivity (media, conditions etc.) on gases

Assess different gas compositions effect on the fermenting organism

Assess new esterases

Optimize enzymatic esterification
Assess the influence of inhibitors on the fermenting organisms
Esterification

- Develop methods for measuring the production
- Screen different lipases
- Optimize enzymatic esterification
- Perform the esterification in the fermentation broth, *in situ*
- Evaluate the detoxifying effect
Future challenges

Adaption of strains
Expressing the butanol pathway in the themophilic host
Process integration
Scale up
Acknowledgement
Thanks for your attention