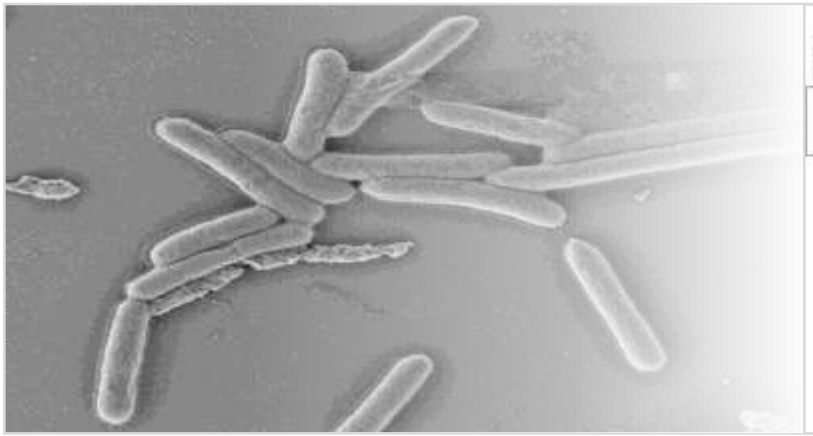
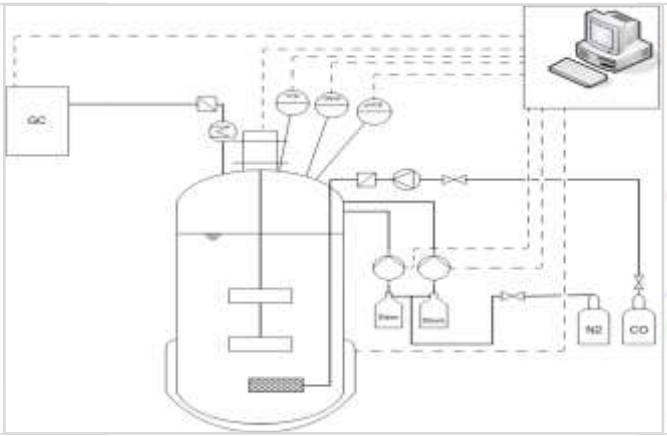
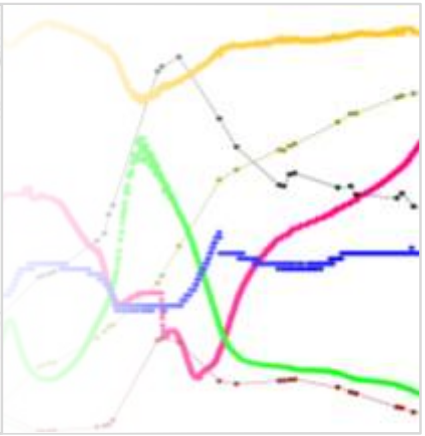
Karlsruhe Institute of Technology

Anaerobic biotechnology

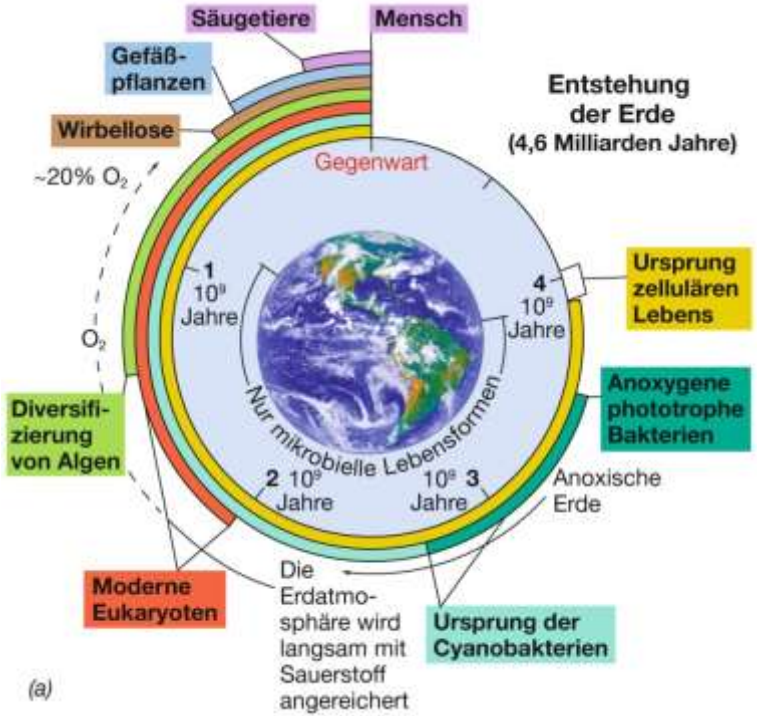
Syngas fermentation @ KIT-Tebi and KIT-IKFT







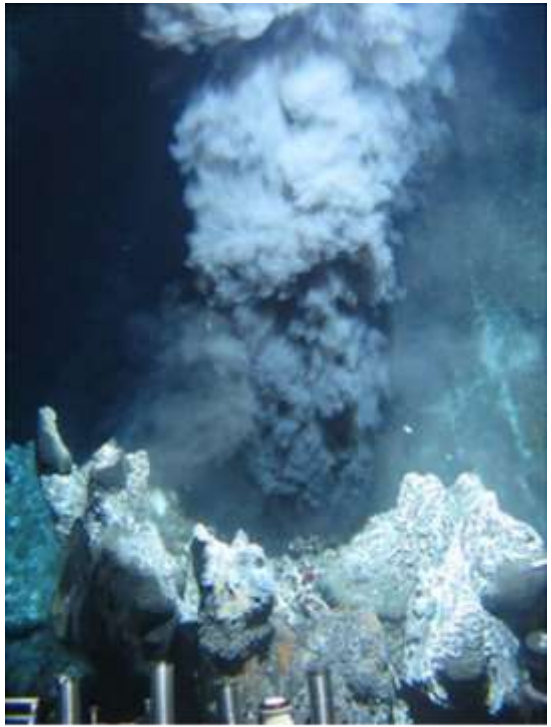
Anaerobic Biotechnology



A look back into earths history:

- For about 2 billion years the Earth was anoxic.
- C1 compounds served as carbon source.

How to grow and thrive without air?



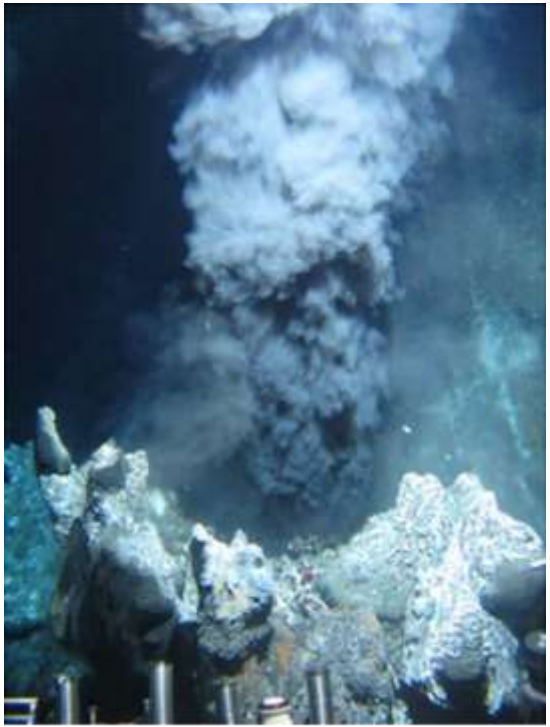
https://upload.wikimedia.org/wikipedia/commons/6/6f/High_Rise_black_smoker.jpg

Nutrients in hot hydrothermal water:

- H_2
- CO HCO_3^-
- CH_3SH H_2S
- NH_4 CN^-

- C1 compounds serve as carbon source!

How to grow and thrive without air?



https://upload.wikimedia.org/wikipedia/commons/6/6f/High_Rise_black_smoker.jpg

Acetogenese (Bacteria)

$$4\ H_2 + 2\ CO_2 \rightarrow\ CH_3COO^- + H^+ + 2\ H_2O$$

$$\Delta G°´ = -\ 95\ kJmol^{-1}$$

$$4\ CO + 2\ H_2O \rightarrow\ CH_3COO^- + H^+ + 2\ CO_2$$

$$\Delta G°´ = -\ 175\ kJmol^{-1}$$

Methanogenese (Archaea)

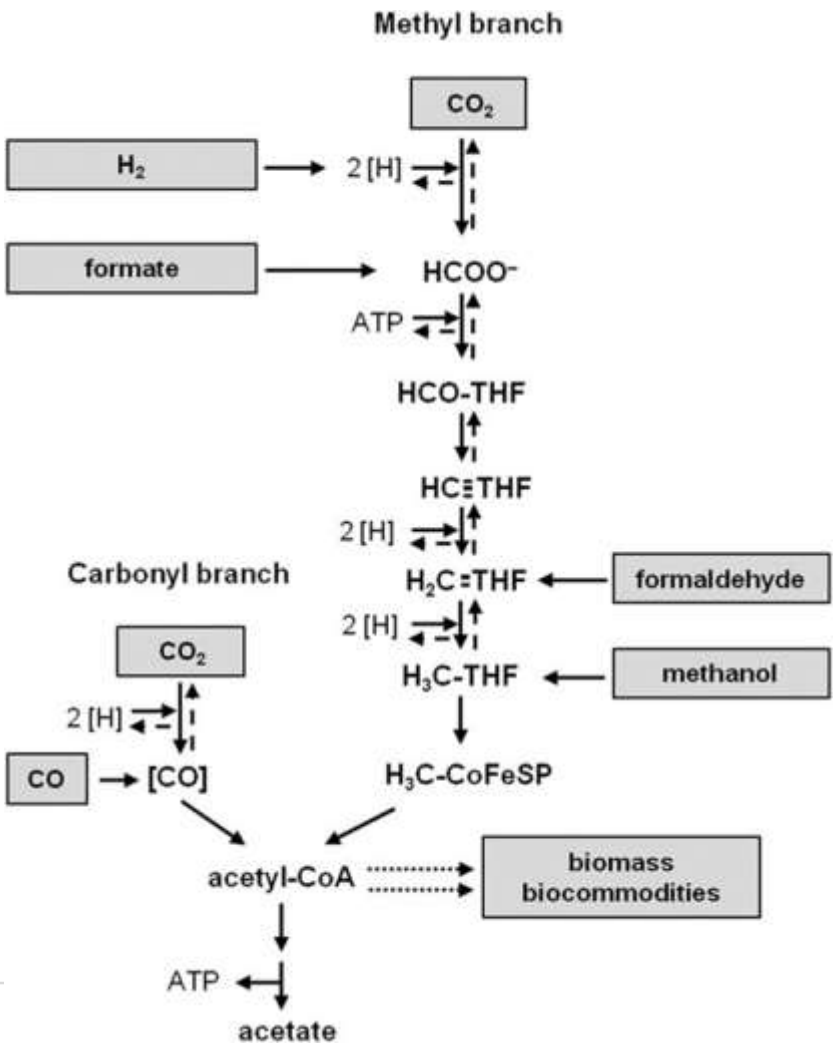
$$4\ H_2 + CO_2 \rightarrow\ CH_4 + 2\ H_2O$$

$$\Delta G°´ = -\ 131 kJ\ mol^{-1}$$

C1-substrates for acetogenes

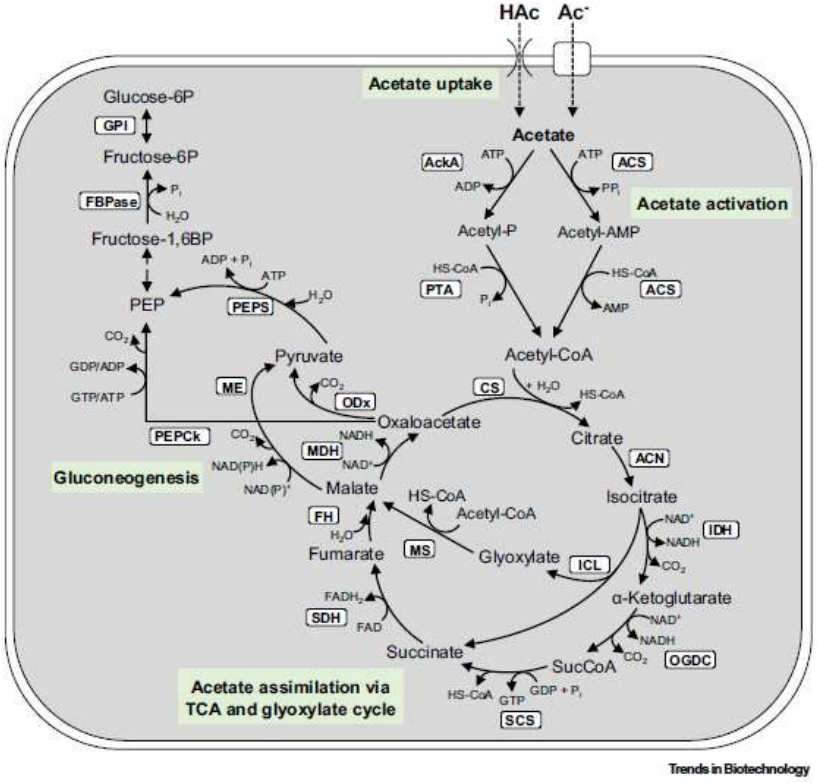
Acetate can be formed from:

- Carbondioxid - CO_2
- Carbomonoxide -CO
- Formate $HCOO^-$
- Formaldehyde CH_2O
- Methanol CH_3OH



Katsyv A, Müller V. Overcoming Energetic Barriers in Acetogenic C1 Conversion. *Front Bioeng Biotechnol*. 2020;8:621166.

What to do with acetate?



- Acetate is a central substrate able to substitute glucose in all biotechnological fermentations.

Dirk Kiefer, Manuel Merkel, Lars Lilge, Marius Henkel, Rudolf Hausmann, Trends in Biotechnology,Volume 39, Issue 4, 2021, https://doi.org/10.1016/j.tibtech.2020.09.004.

Typical composition of crude syngas

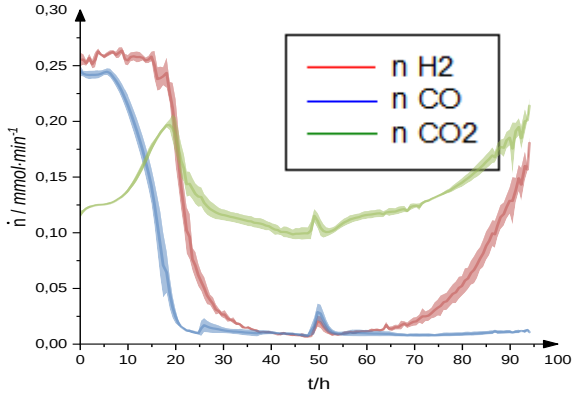
Table 1. Typical biosyngas composition for gasification of wood (15% moisture) at 850°C in an atmospheric air-blown CFB gasifier.[2]

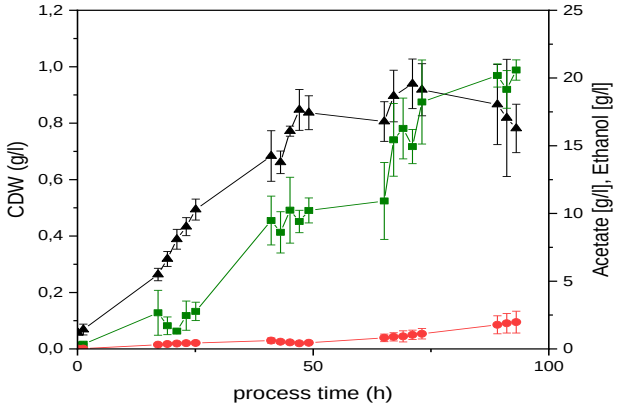
Main Constituents	[vol%, dry]	[LHV%]	Impurities	[mg/m$_n^3$]
CO	18	27.8	NH_3	2200
H_2	16	21.1	HCl	130
CO_2	16	-	H_2S	150
H_2O (relative to dry gas)	13	-	all COS, CS_2, HCN, HBr	< 25
N_2	42	-	dust, soot, ash	2000
CH_4	5.5	24.1		
C_2H_2 (acetylene)	0.05	0.4	**Tar classes** [9]	[mg/m$_n^3$]
C_2H_4 (ethene)	1.7	12.4	class 2 (hetero atoms)	350
C_2H_6 (ethane)	0.1	0.8	- *phenol*	*160*
benzene	0.42	7.9	class 3 (1-ring, excl. BTX)	370
toluene (BTX)	0.07	1.6	class 4 (2,3-ring)	5300
xylenes	0.04	1.0	- *naphthalene*	*2250*
sum of tars	0.12	2.8	class 5 (≥4-ring)	650
TOTAL	*100*	*100*	class 1 (unidentified)	330

standard 18 ml/min; 16% CO_2;
syngas 32.5% CO; 32.5% H_2

bioliq 18 ml/min; 2,8% CO_2;
syngas 30,4% CO; 32.5% H_2

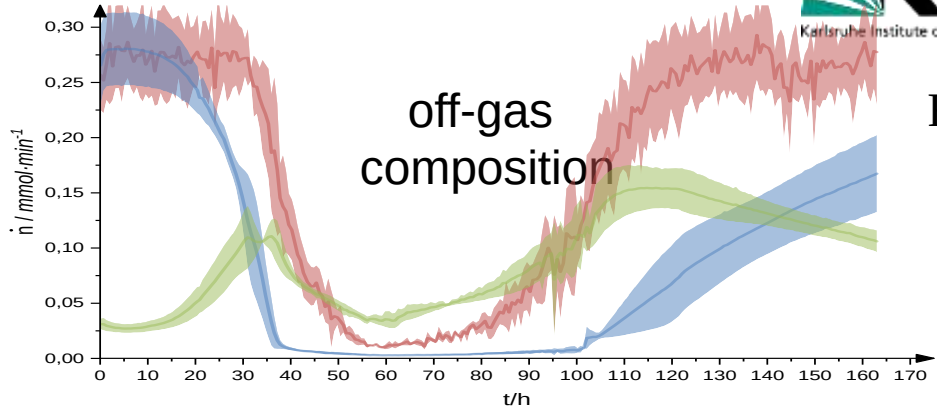
F2

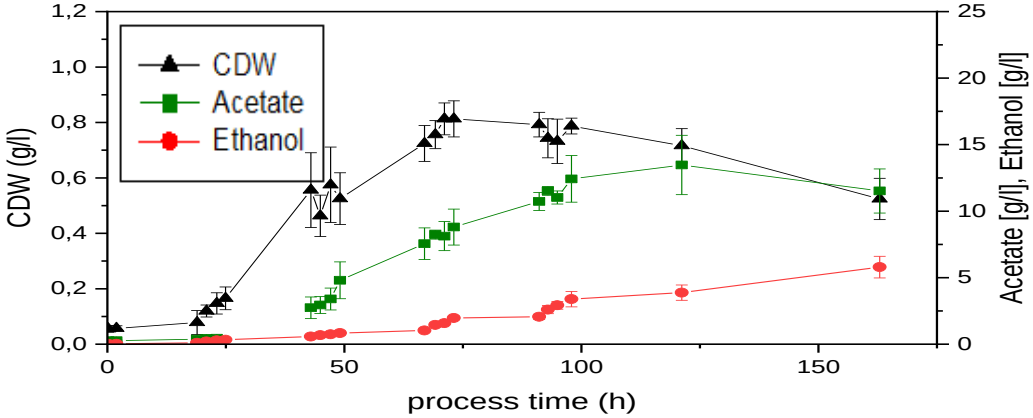




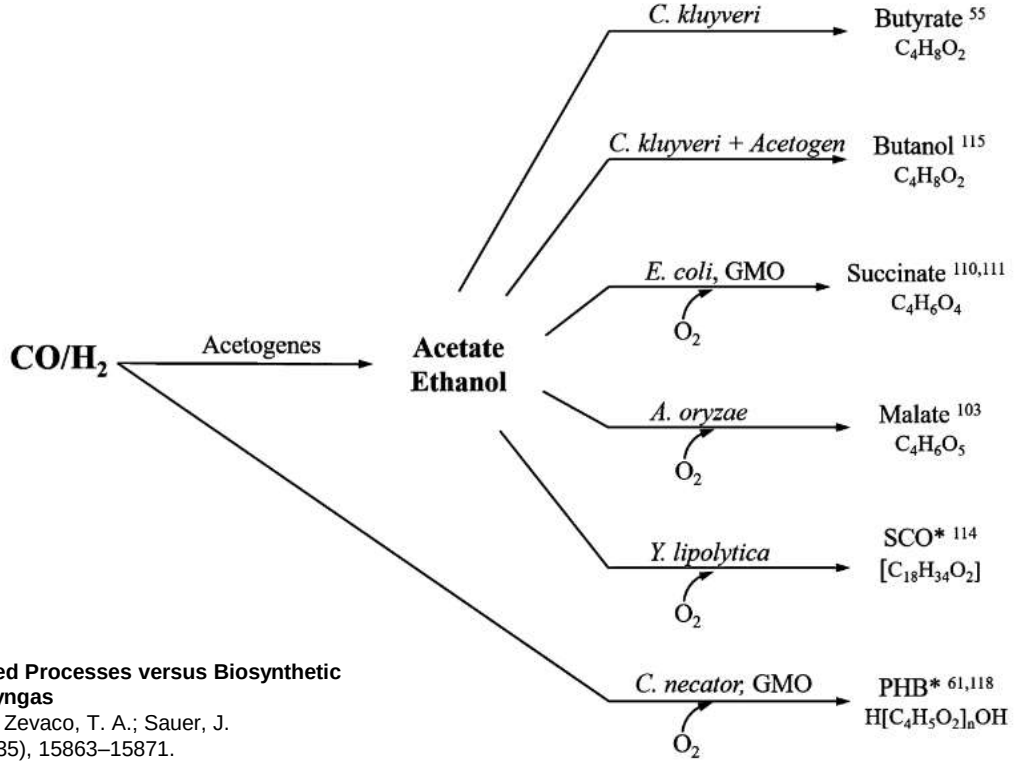
off-gas composition

F10





Reported High-Yield Microbial Synthesis of C4 Compounds from Syngas



The Complex Way to Sustainability: Petroleum-Based Processes versus Biosynthetic Pathways in the Formation of C4 Chemicals from Syngas
Stoll, I. K.; Boukis, N.; Neumann, A.; Ochsenreither, K.; Zevaco, T. A.; Sauer, J.
2019. Industrial & engineering chemistry research, 58 (35), 15863–15871.
doi:10.1021/acs.iecr.9b01123

Syngas fermentation @ KIT-Tebi and KIT-IKFT

- Continuous high pressure fermentation with cell retention for higher productivity.
- Design of the reaction system and optimization of the feed steams, product spectrum and yield.

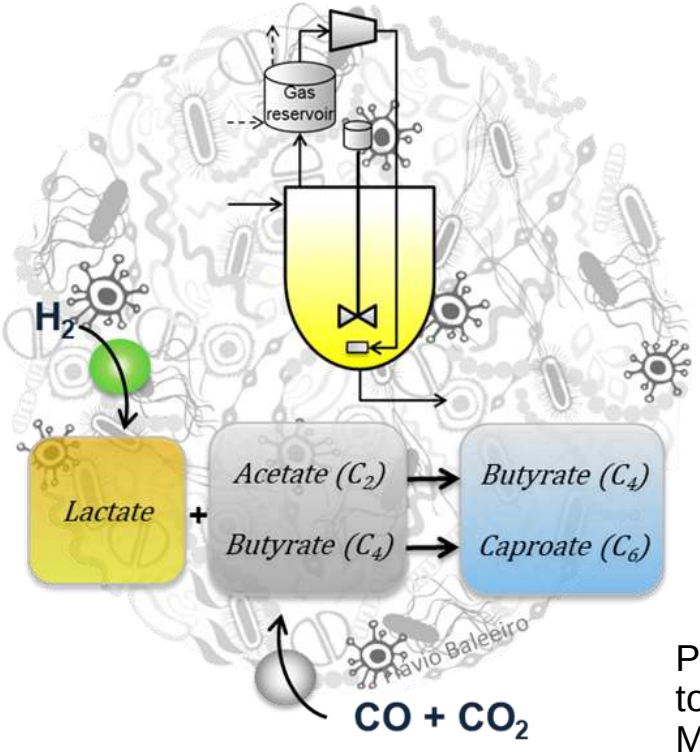
High pressure syngas reactor
with level probe @ KIT-IKTF

Syngas fermentation @ KIT-Tebi and KIT-IKFT

- Thermophilic mixed cultures for pure acetate production
- Use of biomass or plastic waste derived pyrolysis gas plus aqueous condensates as substrates
- Two stage continuous fermentation for the production of a range of products from ethanol to single cell protein using acetate as intermediate substrate

One of three bench top bioreactor for continuous (termophilic) syngas fermentation @ KIT-Tebi

Syngas fermentation @ KIT-Tebi and UFZ-Leipzig



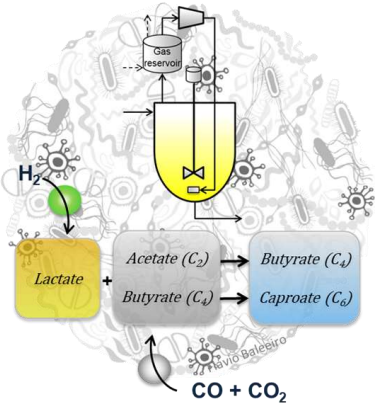
- **Chain elongation** (up to caproate C6) by simultaneous syngas and biomass fermentation with mixed cultures

PhD-work of Flavió Baleeiro
together with UFZ - Working Group
Microbiology of Anaerobic Systems

Kontakt

High pressure syngas fermentation
KIT-IKFT
Jörg Sauer
Nikolaos Boukis
Lukas Perret
https://www.ikft.kit.edu/index.php

Syngas fermentation
raw syngas - two stage - termophilic mixed cultures
KIT-Tebi
Anke Neumann
Alberto Robazza
https://tebi.blt.kit.edu/mitarbeiter_neumann.php



Chain elongation
UFZ – Microbiology of Anaerobic Systems
Sabine Kleinsteuber
Heike Sträuber
Flavió Baleerio
https://www.ufz.de/index.php?en=38431