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Syngas co-digestion with manure: kinetic modelling in a novel framework

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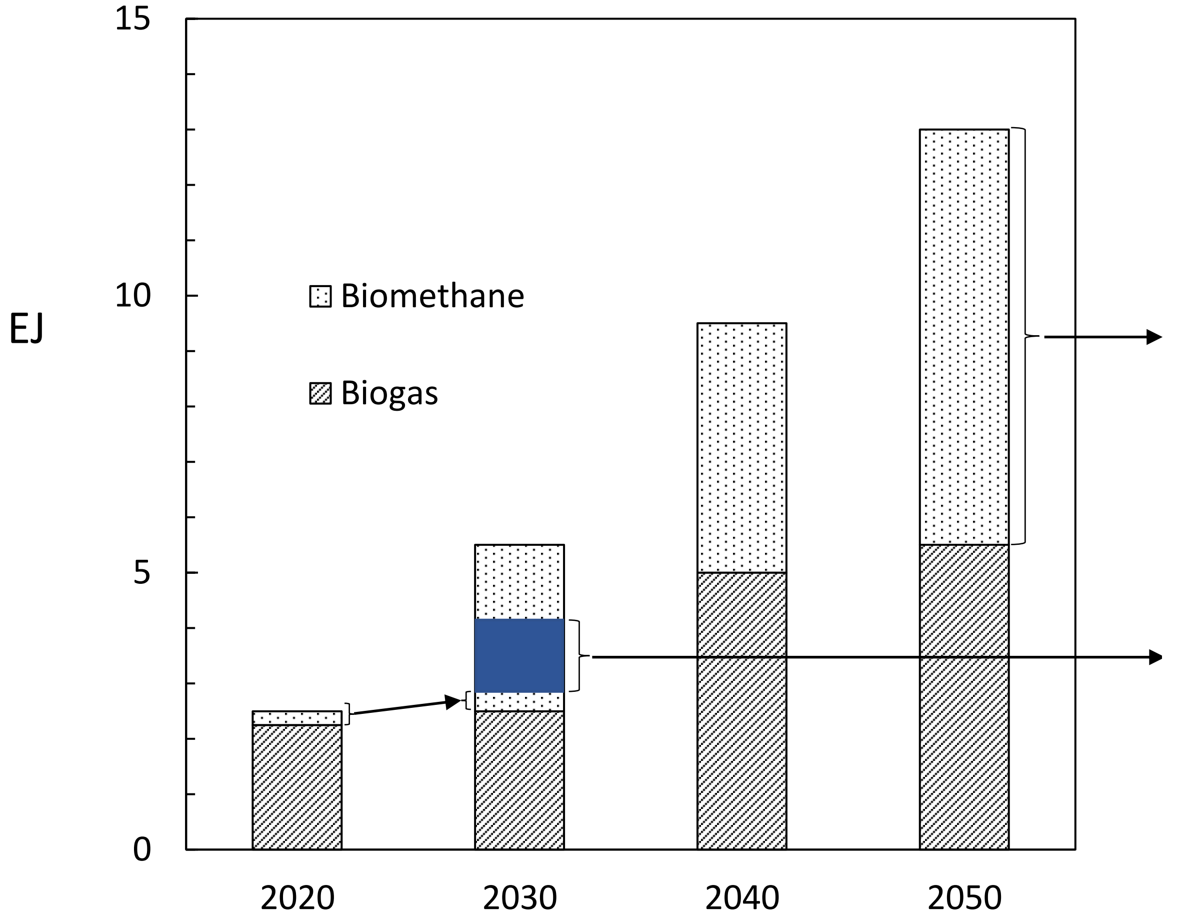
June 22, 2023

The future of biomethane and biohydrogen production in NZE scenario

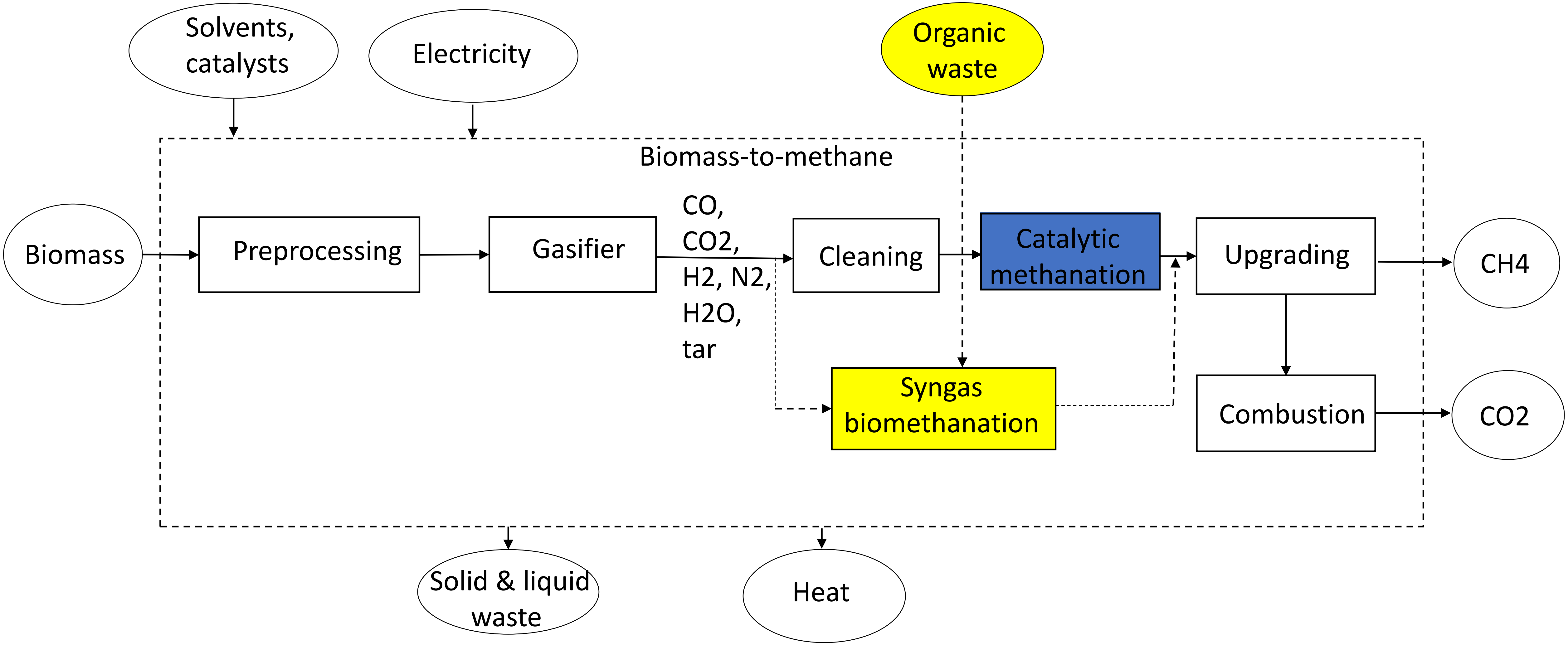


Biomethane:
20 % of supplied gas in grid worldwide

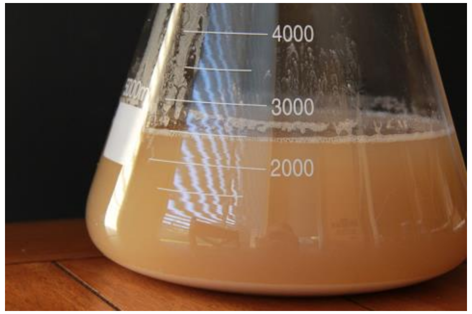
European Commission

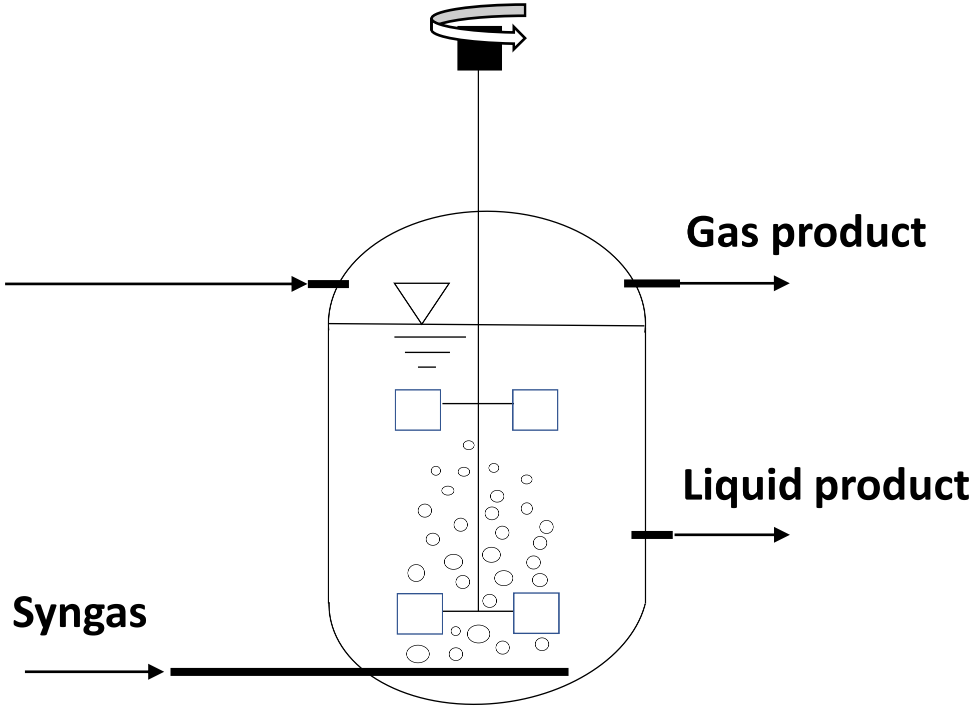
35 bcm biomethane/year
by 2030

Biomass-to-methane generic process flowsheet



Brewery spent yeast (BSY)






ELSEVIER
Biochemical Engineering Journal
Volume 193, April 2023, 108863

Syngas biomethanation by co-digestion with brewery spent yeast in a lab-scale reactor

Pietro Postacchini [a], Lorenzo Menin [a], Stefano Piazzi [a], Antonio Grimalt-Alemany [b], Francesco Patuzzi [a], Marco Baratieri [a]

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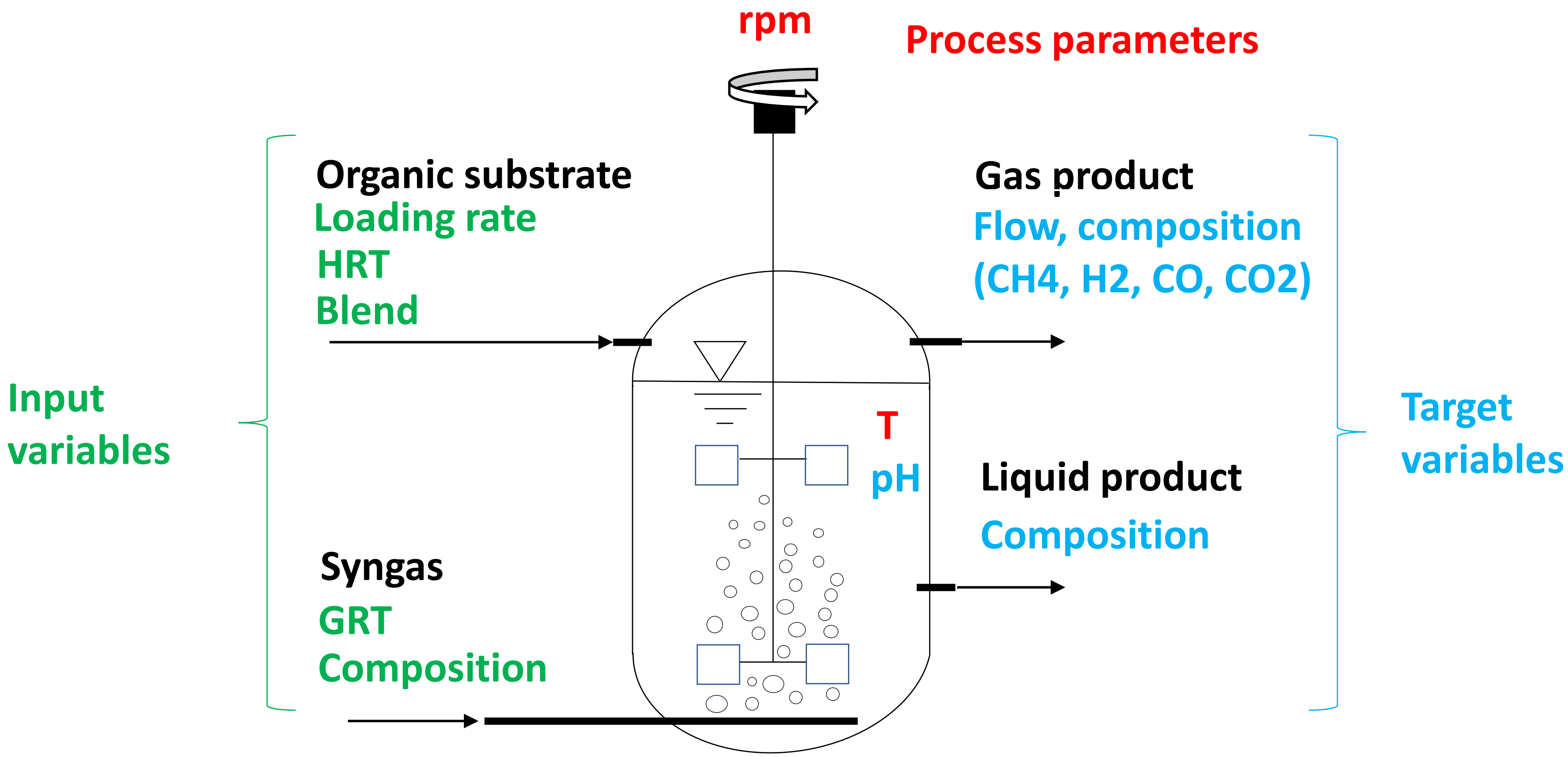
1. Culture adaptation to syngas biomethanation in presence of BSY as co-substrate
2. Continuos operation of CSTR for syngas co-digestion with BSY provided overstoichiometric methane production with respect to converted syngas moles
3. Process stability and performance should be optimized by appropriate nutrients management
4. Diversified community carrying out syngas co-digestion with BSY

Reserach objective: kinetic model syngas co-digestion with organic waste (e.g., manure) to optimize performance

1. Define generalizable, open-source version of Biomodel in Python
2. Estimate CO-inhibition parameters
3. Model calibration and validation on continuous CSTR operation

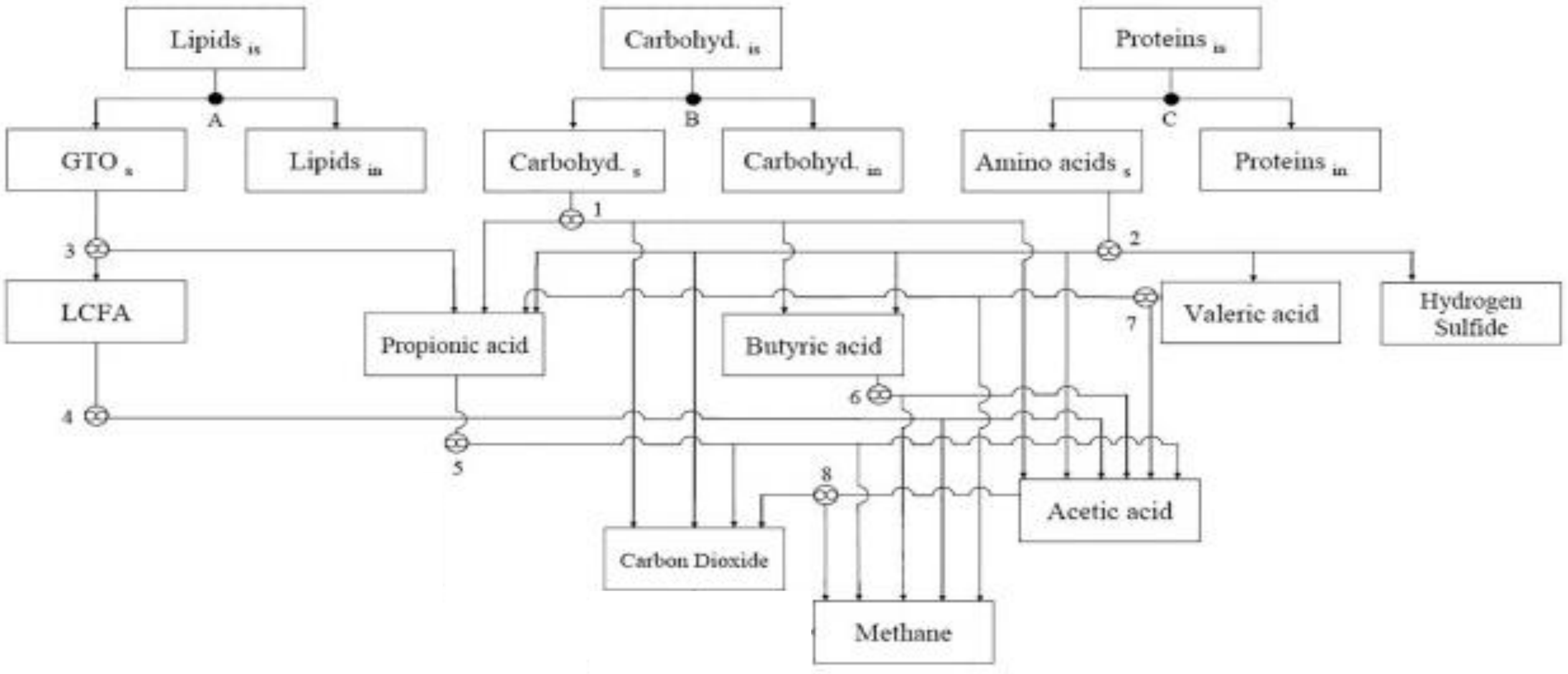


Biomodel structure:

$$\frac{dS_i}{dt} = S_{\text{in},\,i}\,\frac{q_{\text{in}}}{V_{\text{Liquid}}} - S_i\,\frac{q_{\text{out}}}{V_{\text{out}}} + \sum_j Y_{j,\,i}\,u_j$$

- S_i: Concentration of compound
- q: Volume flow
- $Y_{j,i}$: Stoichiometric coefficient of compound *i* in process *j*
- u_j: Kinetic rate equation for process *j* (microbiological or physicochemical)

Biochemical processes in the most recent biomodel version:



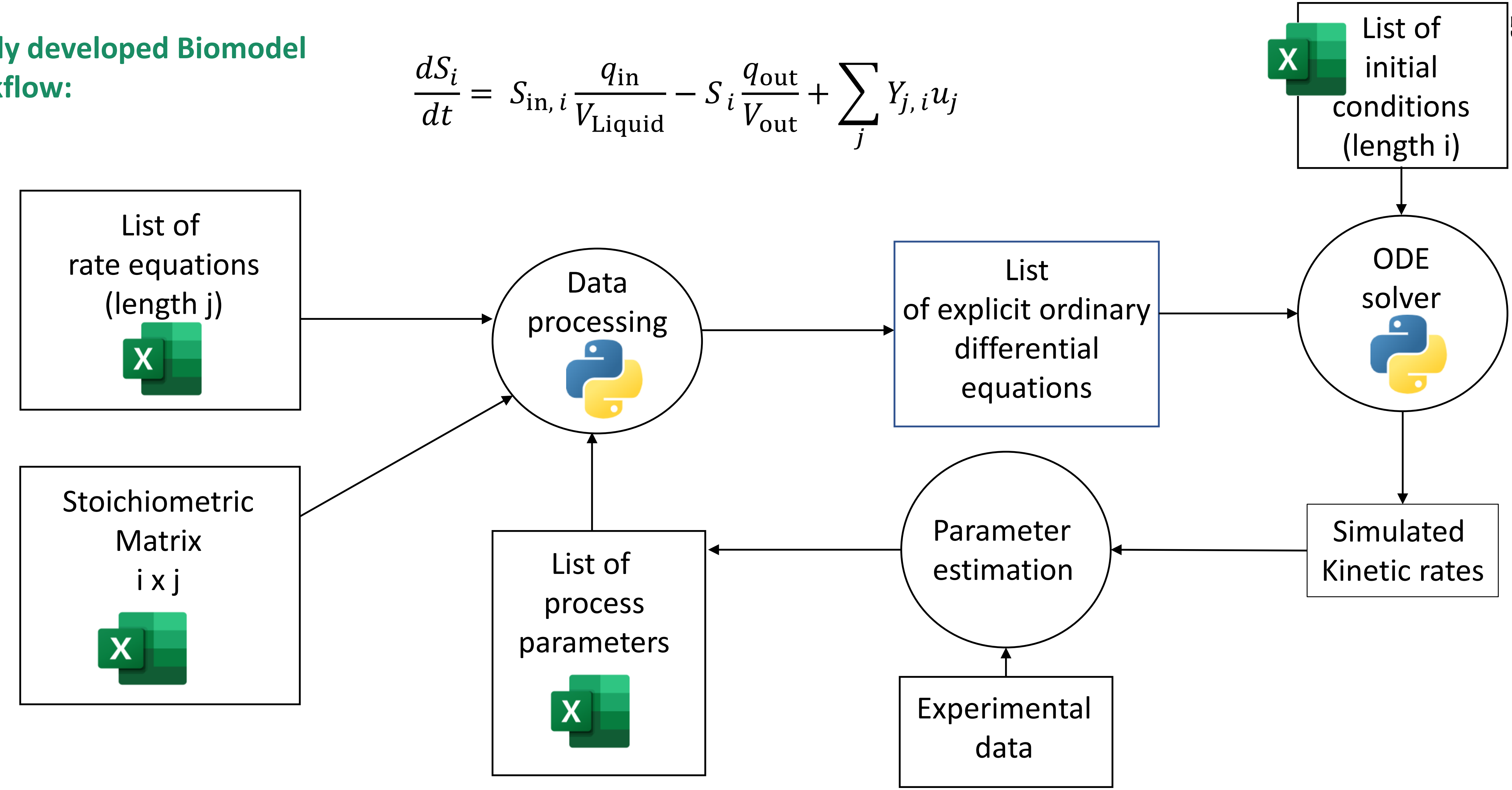
- ● Enzymatic conversion
- Microbiological processes performed by:

1. Glucose fermenting acidogens
2. Amino-acid degrading acidognes
3. Glycerol trioleate (GTO)-degrading acidogens
4. Long chain fatty acids (LCFA)- degrading acidogens
5. Propionic-
6. Butyric-
7. Valeric- acid degrading acetogens
8. Aceticlastic methanogens

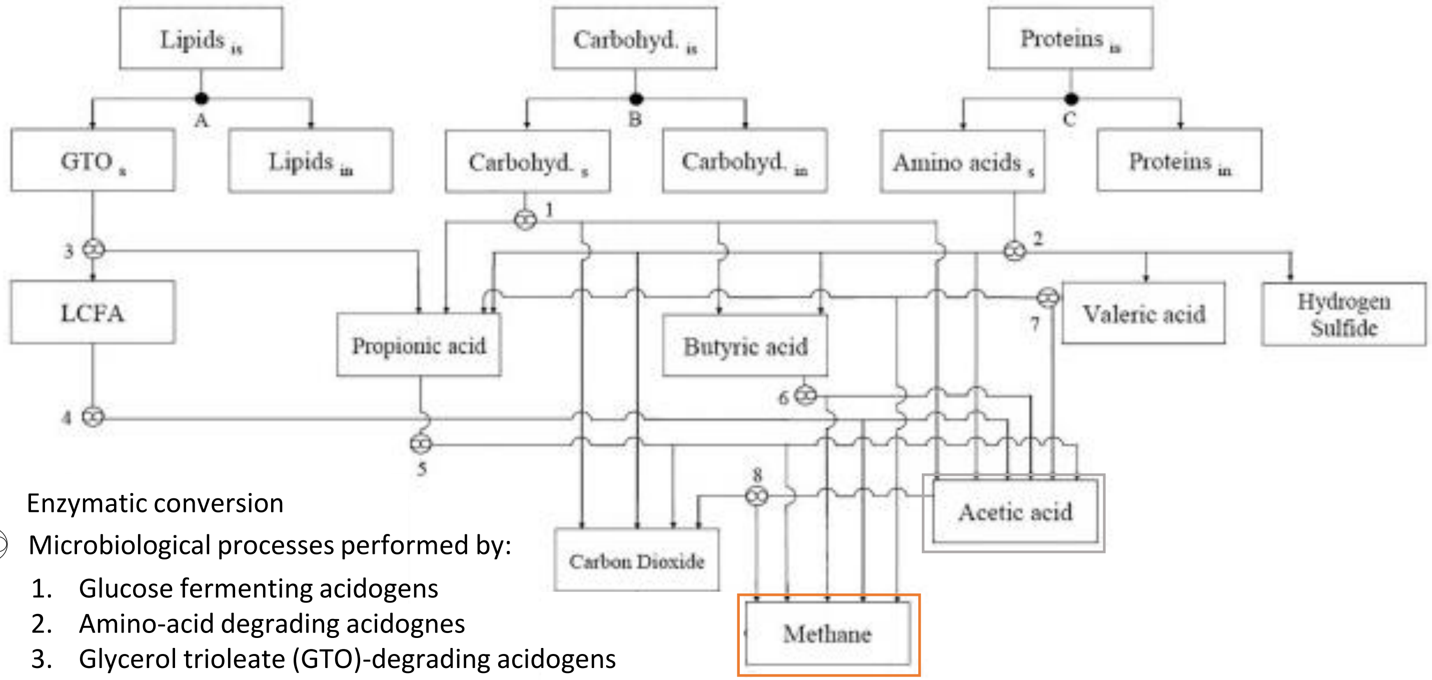
https://doi.org/10.1016/j.biortech.2017.08.181

Newly developed Biomodel workflow:

$$\frac{dS_i}{dt} = S_{\text{in},\,i}\,\frac{q_{\text{in}}}{V_{\text{Liquid}}} - S_i\,\frac{q_{\text{out}}}{V_{\text{out}}} + \sum_j Y_{j,\,i} u_j$$



Research question batch exp. 1: does CO inhibit aceticlastic methanogenesis?



- ● Enzymatic conversion
- ⊗ Microbiological processes performed by:
  1. Glucose fermenting acidogens
  2. Amino-acid degrading acidognes
  3. Glycerol trioleate (GTO)-degrading acidogens
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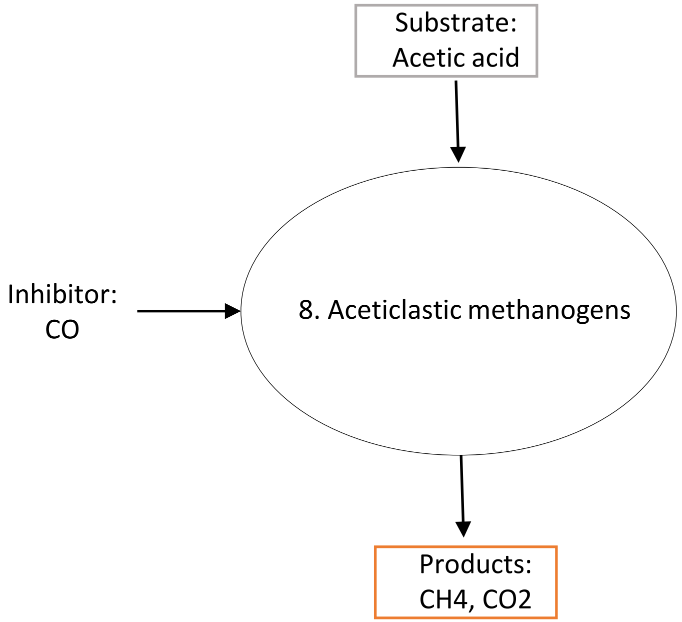
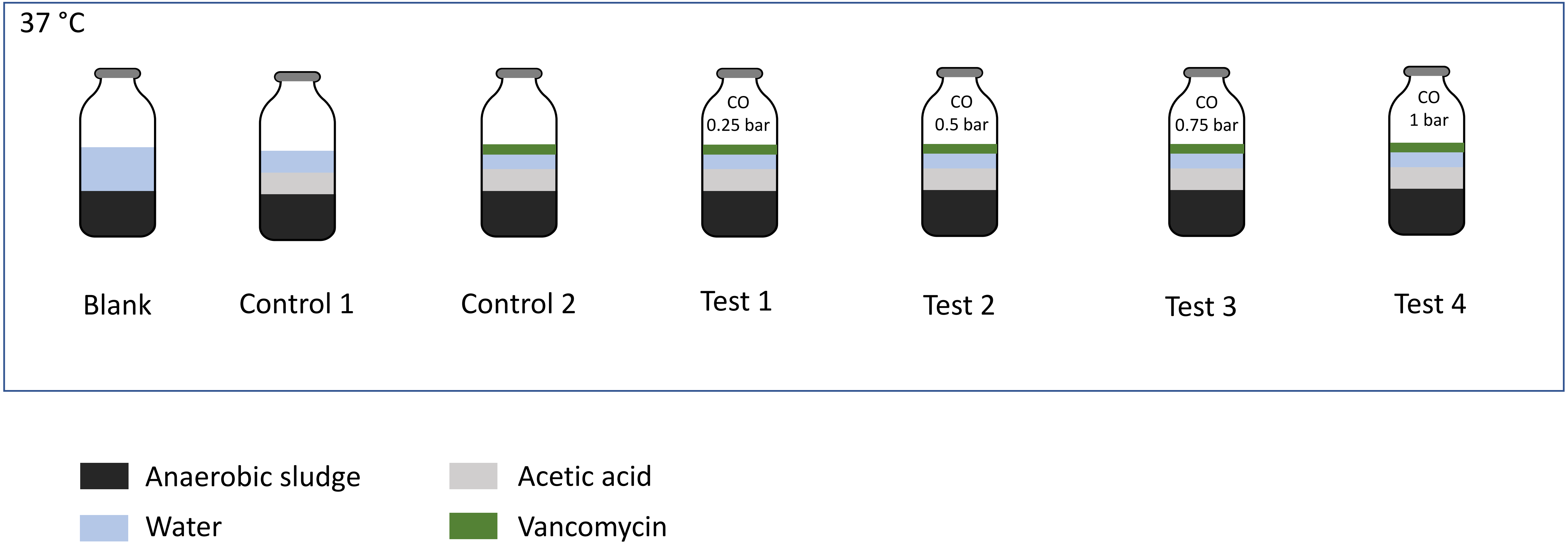
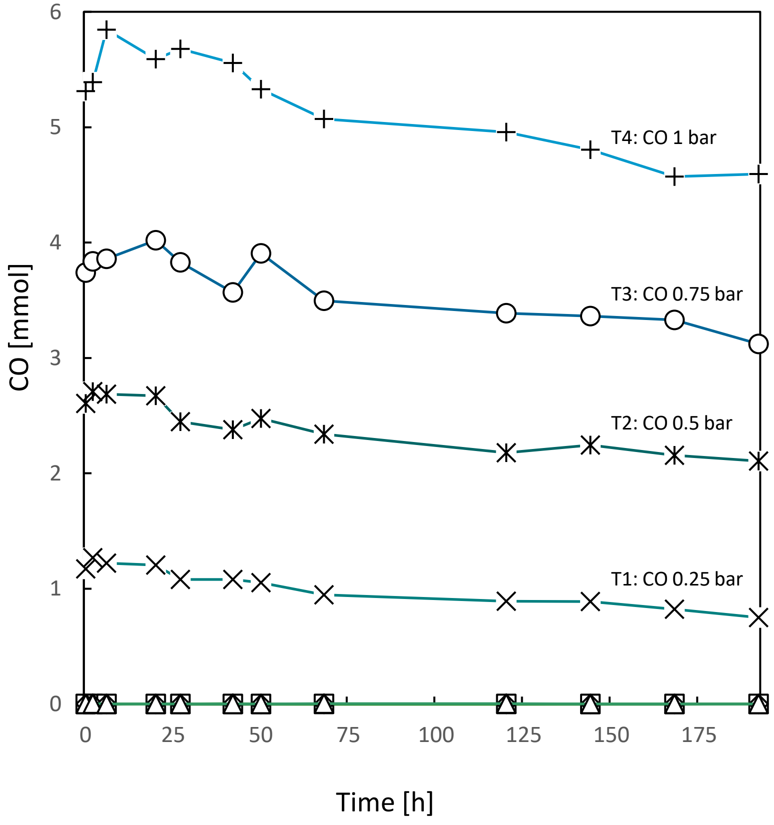


Method batch exp. 1:

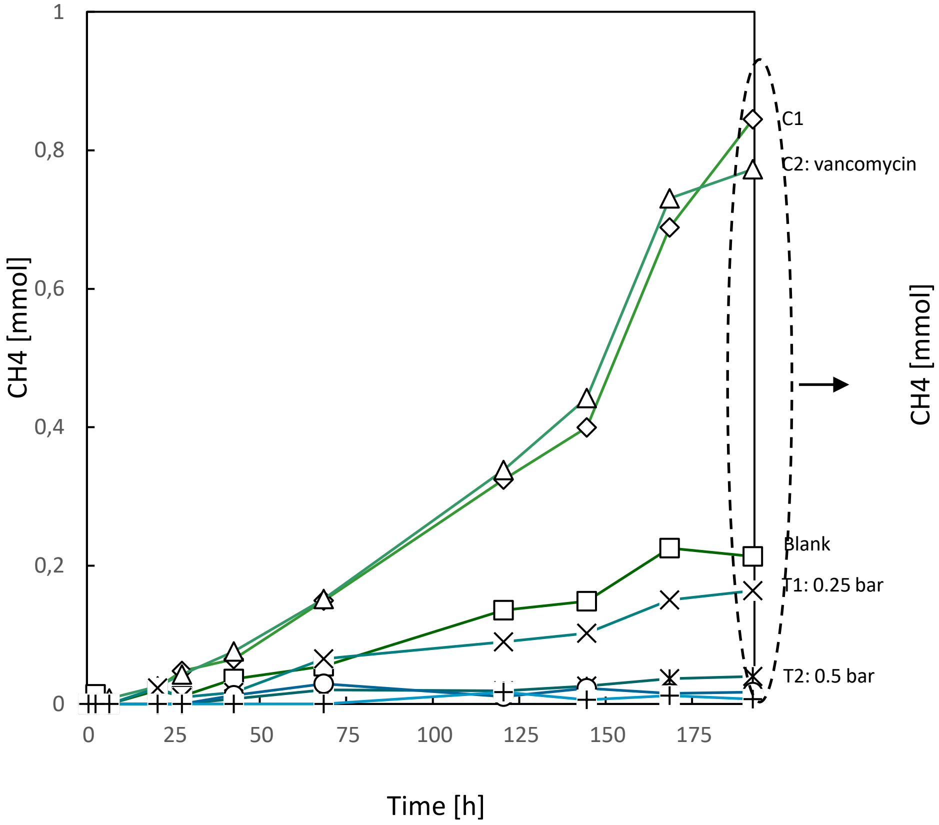


Results batch exp. 1:

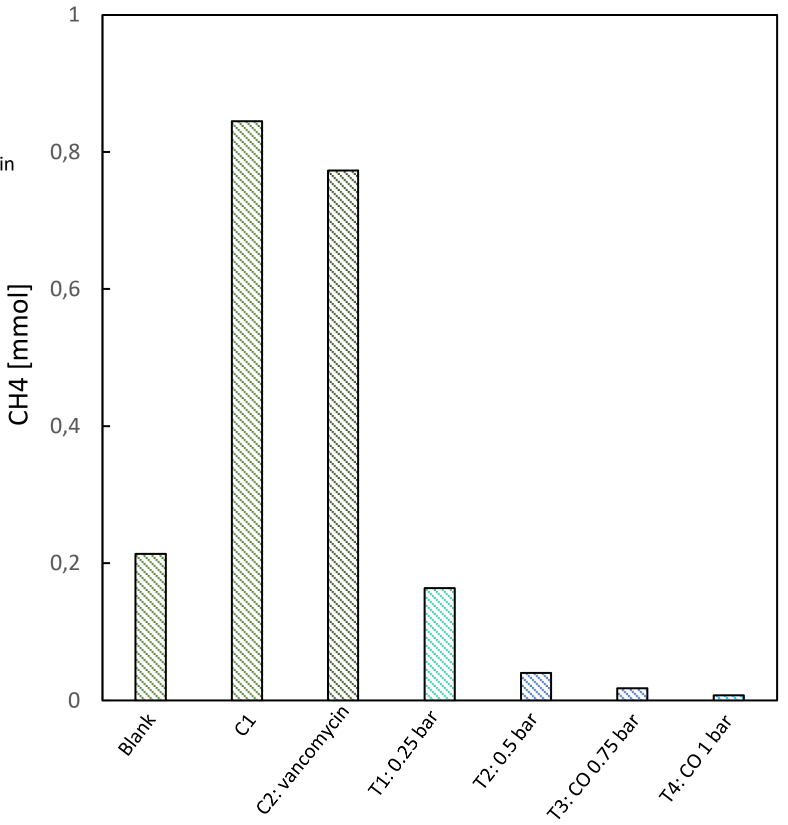
CO in the gas phase



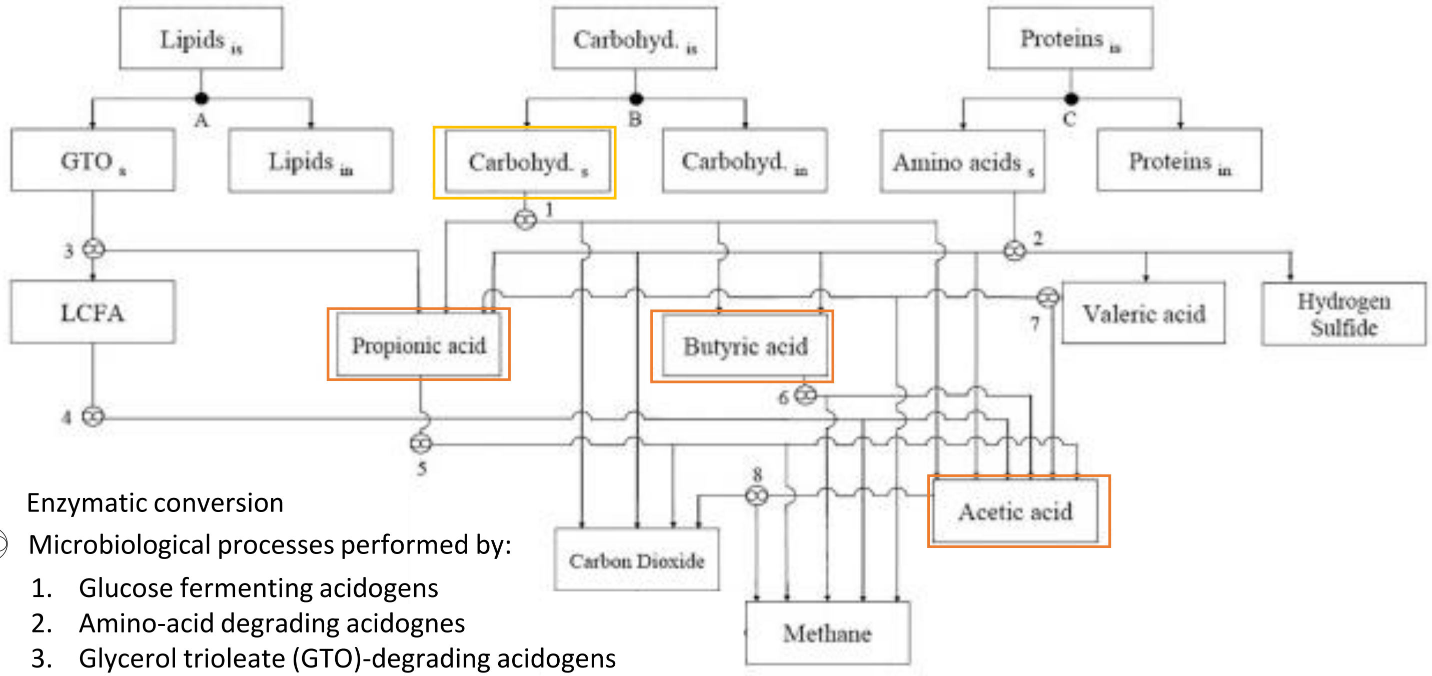
Cum. CH4 production



CH4 produced after 200 h



Research question batch exp. 2: does CO inhibit acidogenesis and acetogenesis?



- Enzymatic conversion
- Microbiological processes performed by:

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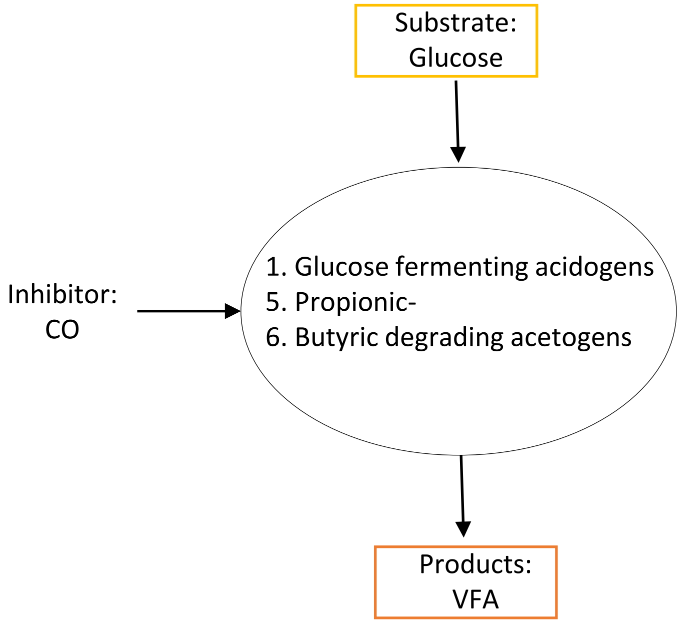
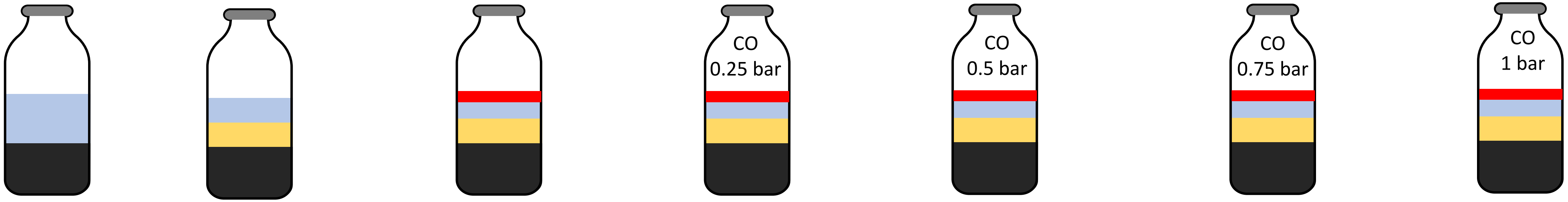


Method batch exp. 2:

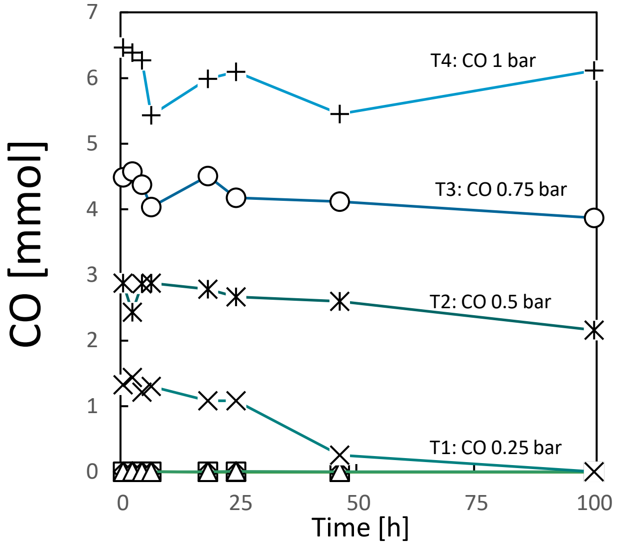
37 °C

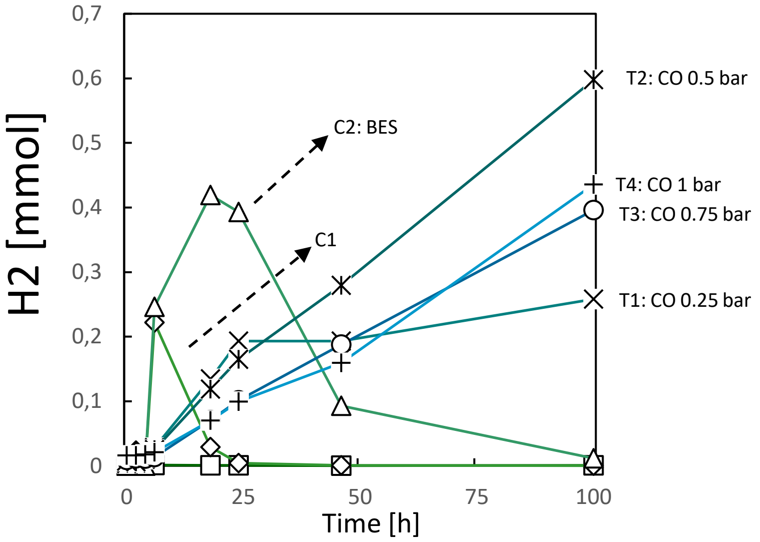


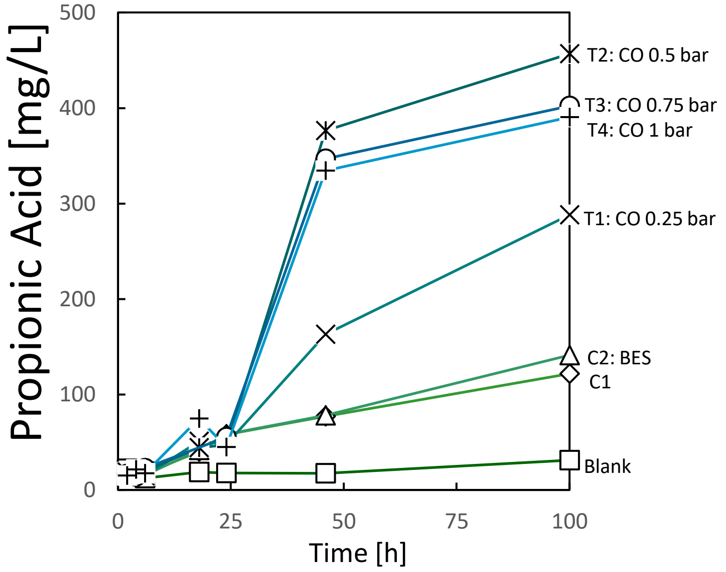
Blank | Control 1 | Control 2 | Test 1 | Test 2 | Test 3 | Test 4

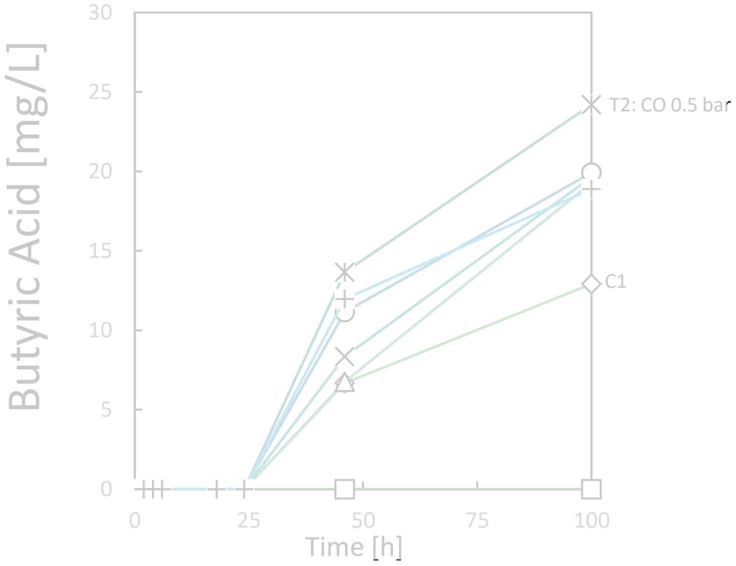
- Anaerobic sludge
- Water
- Glucose
- BES: sodium 2-bromoethanesulfonate

Results batch exp. 2:

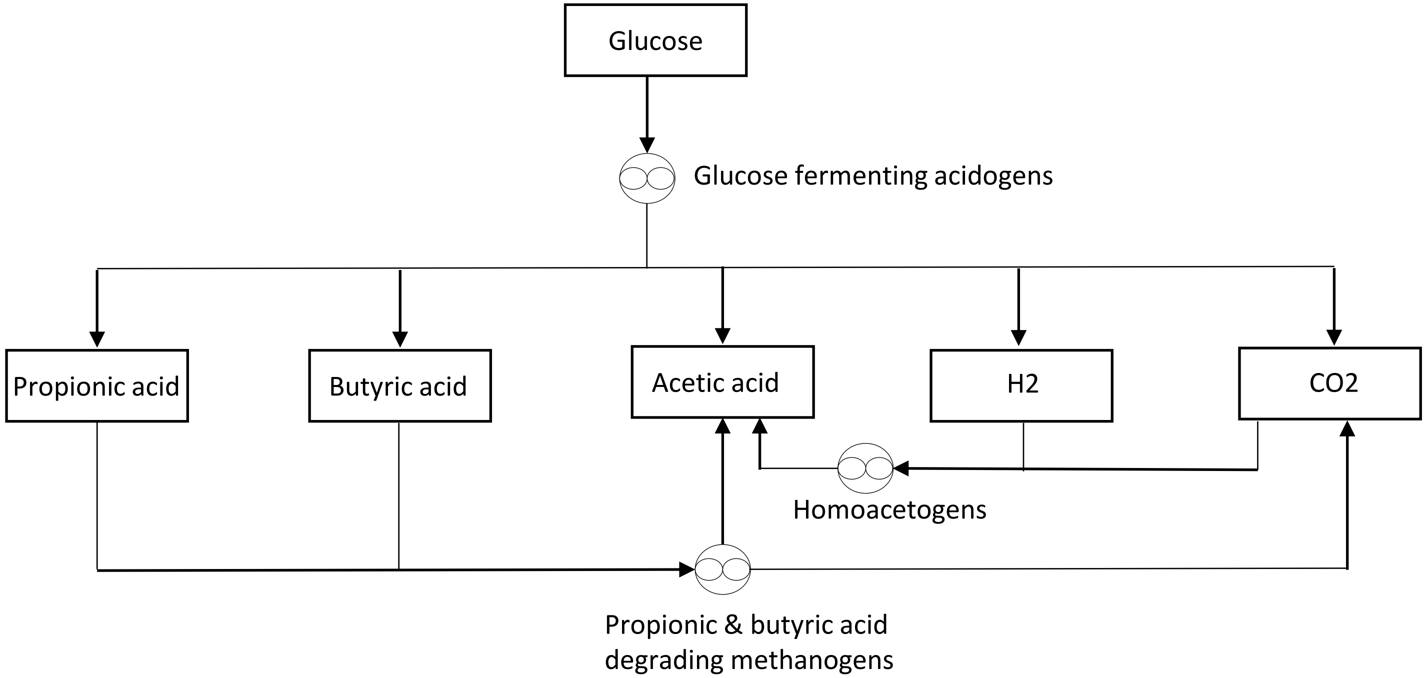








Discussion batch exp. 2:



Conclusions:

- Creation of a generalizable and flexible modeling framework for AD processes
- CO affects glucose conversion processes
- CO has an inhibitory effect on aceticlastic methanogenesis

Outlook:

- Estimation of CO inhibition parameters using the developed modeling framework and obtained experimental data
- Estimation of CO inhibition parameters on other AD steps
- Model continuos co-digestion of syngas with manure
- Evaluation of process scenarios including syngas co-digestion with organic wastes

Thank you for your attention!

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