Two-stage high pressure anaerobic digestion for biomethane production

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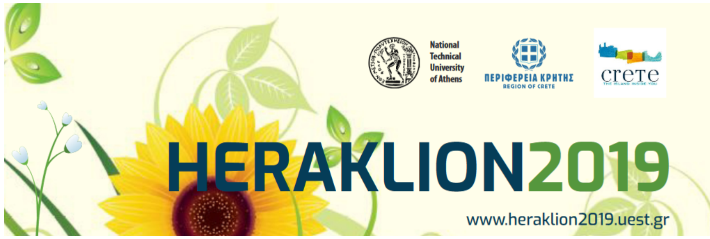


Introduction

By 2018, 9,000 industrial biogas plants in Germany (Biogasfachverband, 2018)

Problem: Biogas is generally used in a combined heat and power plant (CHP);

Most cogenerated heat is wasted

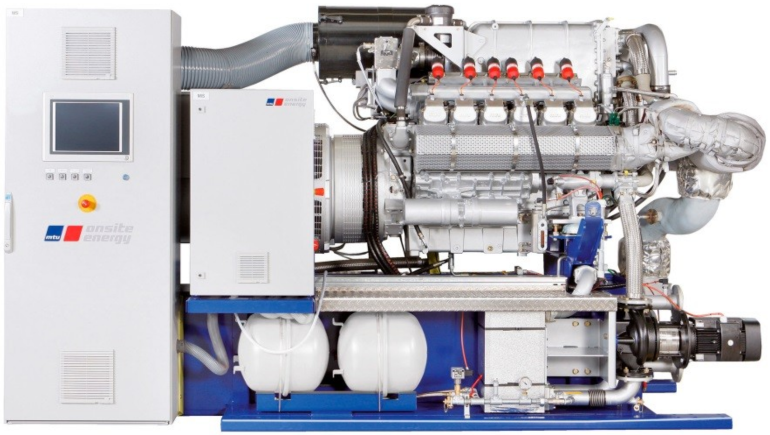
=> Energy utilization efficiency is decreased (Bajohr & Graf, 2013)

Electrical efficiency:

38 – 44% of energy input (ASUE, 2011)

Thermal efficiency :

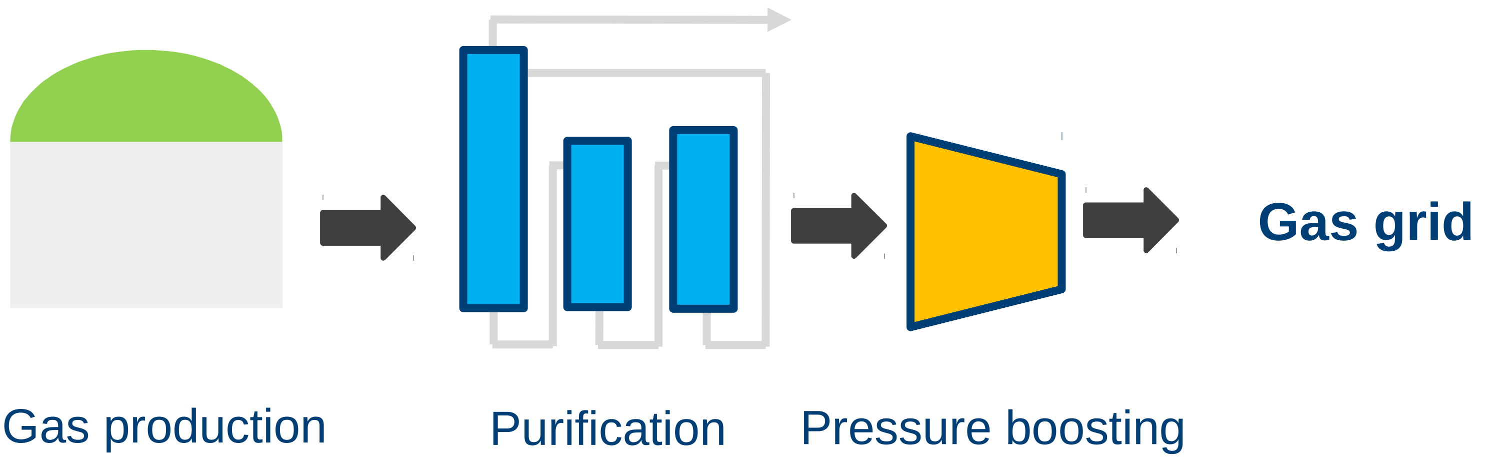
38 - 46% of energy input (ASUE, 2011)



(MTU, 2017)

Introduction

Conventional technologies for CO_2-removal



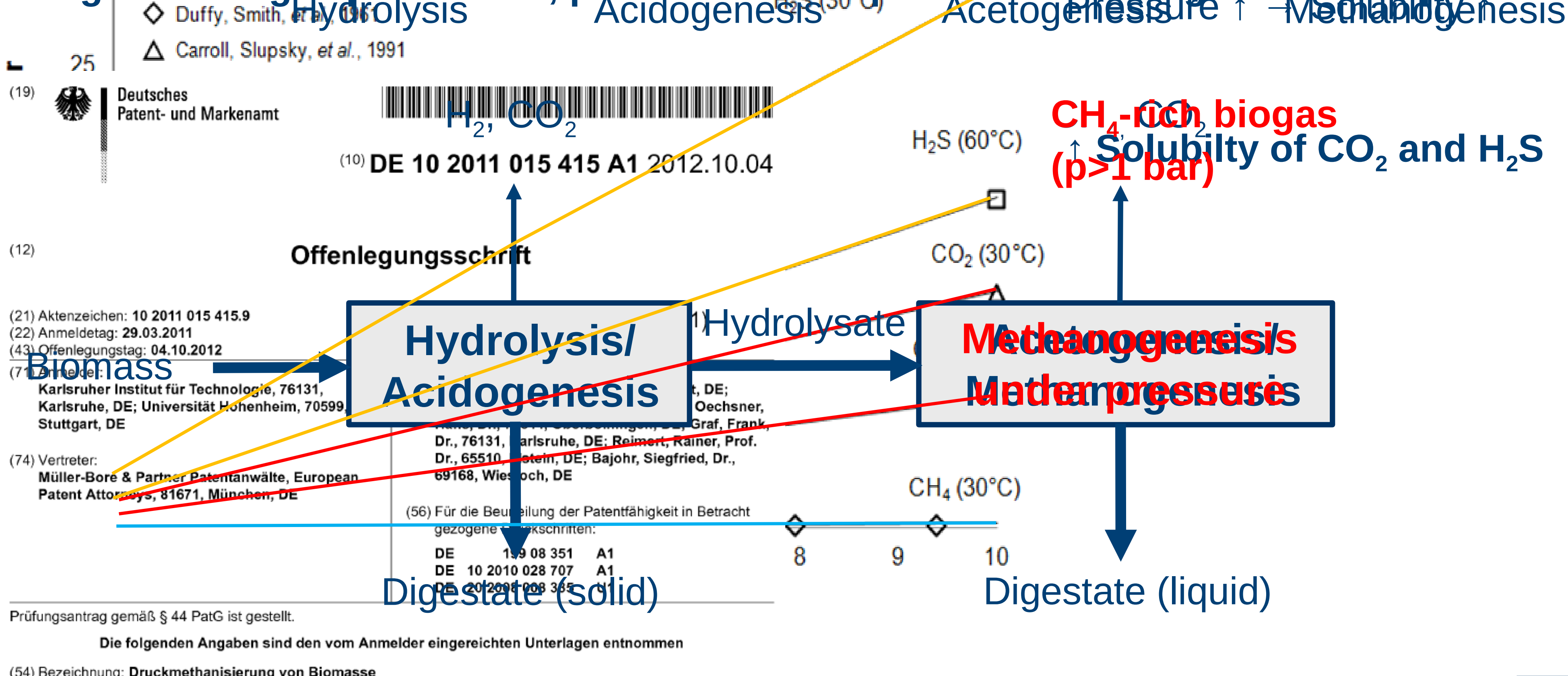
- 190 biomethane plants in Germany; yearly injection capacity of 0,77 billion m³ (BNetzA, 2016)

(Allegue *et al*, 2012; De Hullu *et al*, 2008; Ryckebosch *et al*, 2011 and Zheng *et al*, 2013)

Introduction

Concept of two-stage high pressure anaerobic digestion

- **Integration of gas production, purification and pressure boosting within one process**



Objective

Development of a two-stage high pressure anaerobic digestion plant for production of biomethane at operating pressures up to 50 bar

→ *Integration of gas production, purification and pressure boosting within one process*

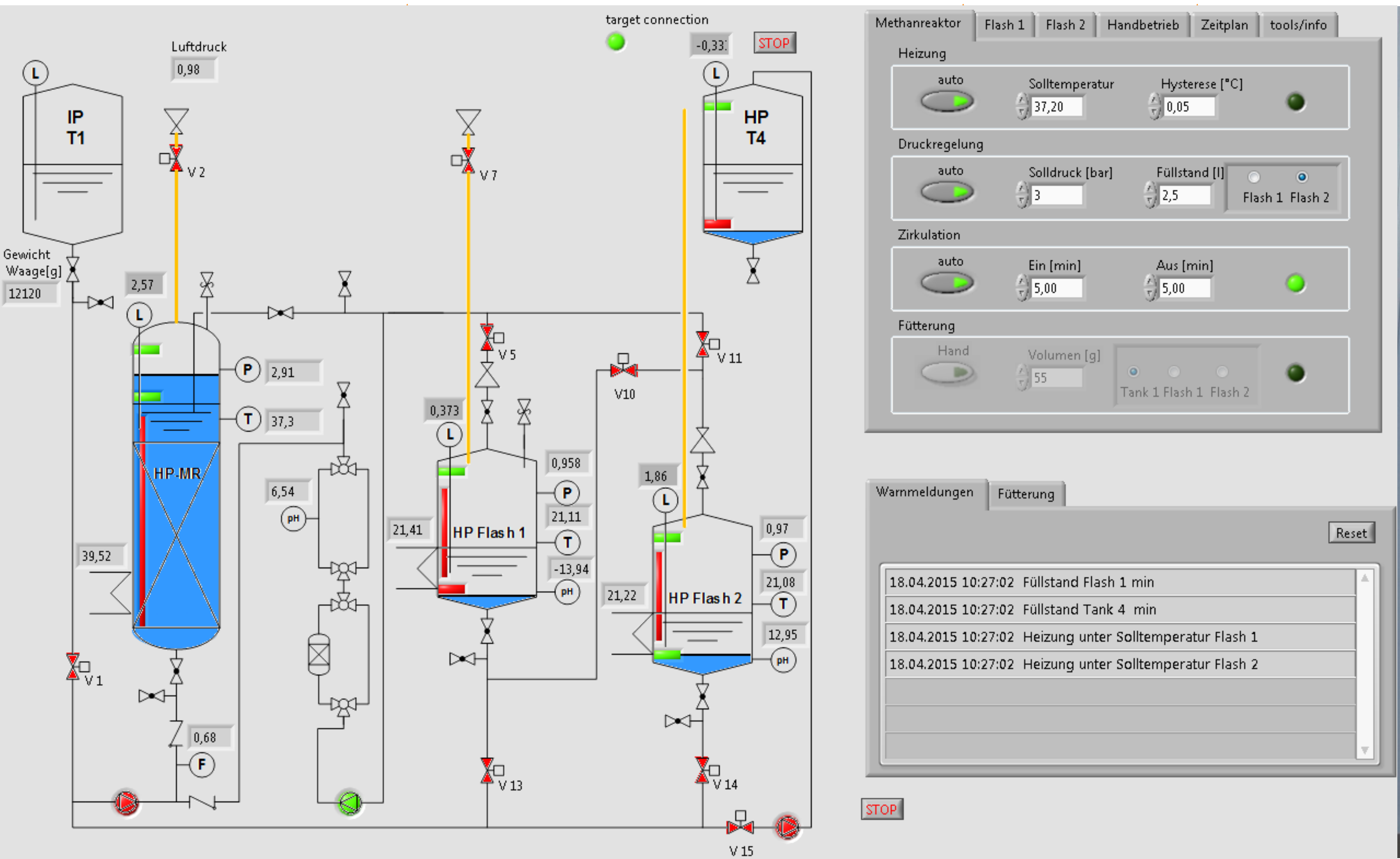
1) Is it technical feasible to run a continuous methane reactor at high operating pressures?

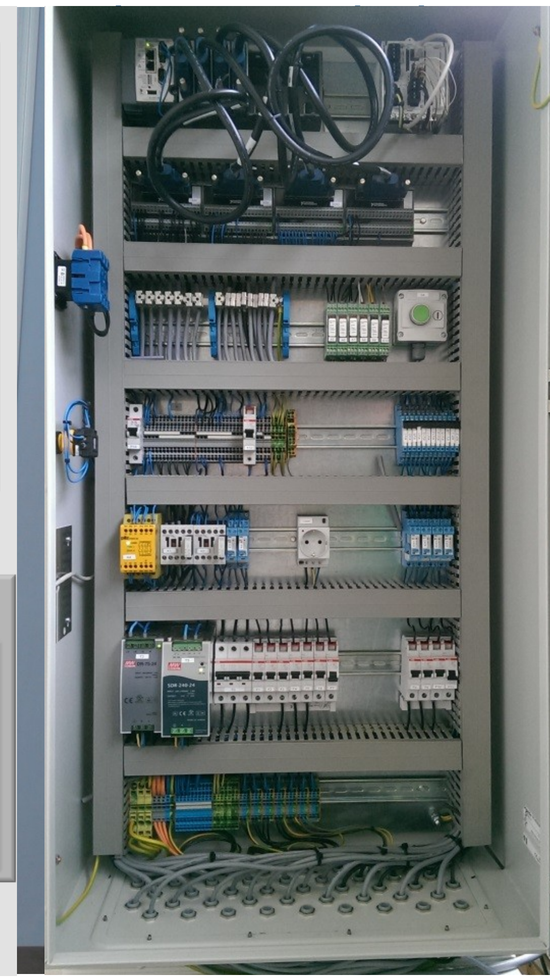
2) Is there an influence of pressure on different process parameters?

3) What methane contents can be reached at these high pressures?

Material and Methods

Application





Material and Methods

Experimental procedure

	MR	Flash 1	Flash 2	Duration
1. Pressure level	**9,83 ± 0,06 bar**	4 bar	1 bar	25 d
2. Pressure level	24,66 ± 0,17 bar	4 bar	1 bar	16 d
3. Pressure level	49,09 ± 0,44 bar	4 bar	1 bar	19 d

- Mixture of hydrolysate und effluent (1:1)
- Organic loading rate (g L^{-1} d^{-1}): 4.4 ± 0.4 (10 bar), 4.3 ± 0.3 (25 bar), 4.1 ± 0.1 (50 bar)
- Hydraulic retention time (d): 4.1 ± 0.1 (10 bar), 4.2 ± 0.1 (25 bar), 4.2 ± 0.1 (50 bar)
- Temperature: 37.0 ± 0.2 °C
- Circulation: 1x total volume of methane reactor per h

Results

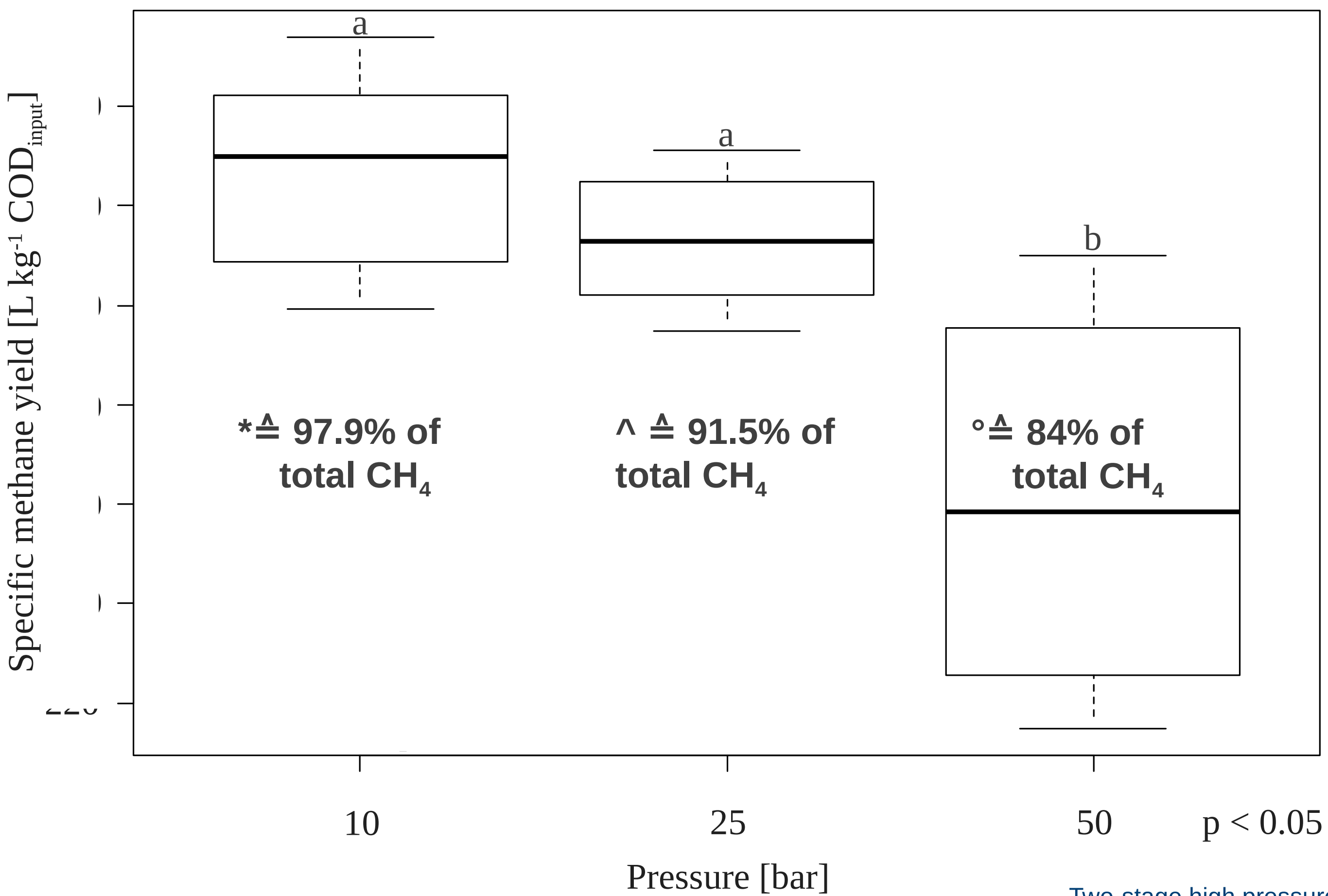
Liquid analysis

	Feed			Methane reactor		
	10 bar	25 bar	50 bar	10 bar	25 bar	50 bar
Actetic acid (g kg^{-1})	3.36	2.94	3.13	[illegible]	[illegible]	0.08
Propionic acid (g kg^{-1})	1.53	1.14	1.22			0.43
iso-Butyric acid (g kg^{-1})	0.10	0.09	0.13			0.04
n-Butyric acid (g kg^{-1})	1.31	1.25	1.20			0
iso-Valeric acid (g kg^{-1})	0.21	0.18	0.19			0.04
n-Valeriic acid (g kg^{-1})	0.44	0.75	0.68			0.01
Caproic acid (g kg^{-1})	0.33	0.47	0.51			0.01
Lactic acid (g kg^{-1})	0.83	0.97	0.67			0
Ethanol (g kg^{-1})	0.30	0.31	0.36			0.02
IC (g L^{-1})	0.26	0.26	0.29	[illegible]	[illegible]	1.54
TC (g L^{-1})	6.95	6.73	6.26	2.49	2.42	2.68
COD (g L^{-1})	17.89	17.48	17.12	2.22	2.25	3.54
				87.6%	**87.1 %**	**80.4 %**

Complete degradation

Results

Specific methane yield of methane reactor



Specific methane yield of MR and Flash:

- 10 bar: 339 L kg^{-1} COD_{input}
- 25 bar: 336 L kg^{-1} COD_{input}
- 50 bar: 310 L kg^{-1} COD_{input}

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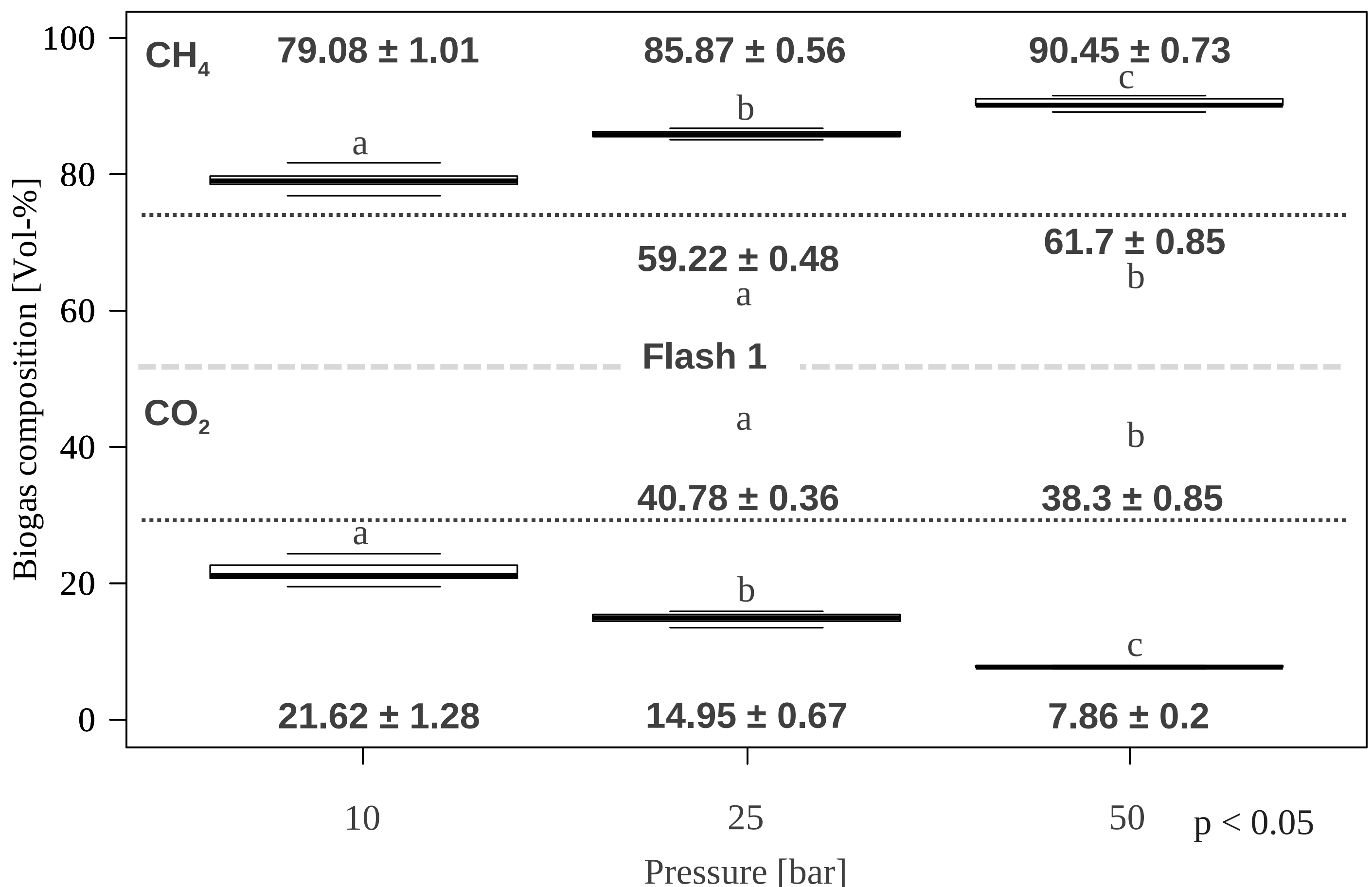
Results

Gas quality



MR:

- CH_4 contents > 90 vol.%
- CO_2 contents < 8 vol.%

Flash 1:

- CH_4 contents > 61 vol.%
- CO_2 contents < 39 vol.%

Summary

- Continuous high pressure anaerobic digestion is feasible up to pressures of 50 bar
- The specific methane yield (in methane reactor) drops by increasing the pressure due to methane slip into the flash reactors
- Propionic acid in the hydrolysate might be a problem at higher pressures
- **Methane contents over 90 vol.-% are possible**

→ **Use in transportation sector, reduced effort for grid injection**

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Influence of pressures up to 50 bar on two-stage anaerobic digestion

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HIGHLIGHTS

- The influence of pressure on anaerobic digestion up to 50 bar was examined experimentally.
- Increasing pressure decreases pH value in the methane reactor until 6.53.
- Increasing pressure increases methane content over 90%.
- Increasing pressure decreases specific methane yield until 0.26 $L\,g^{-1}$ COD_{added}.
- The pressurized methane reactor operates very stable.

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ABSTRACT

The concept of pressurized two-stage anaerobic digestion integrates biogas production, purification and pressure boosting within one process. The produced methane-rich biogas can be fed into gas grids with considerably less purification effort. To investigate biogas production under high pressures up to 50 bar, a lab scale two-stage anaerobic digestion system was constructed including one continuously operated pressurized methane reactor. This investigation examined the effects of different operating pressures in methane reactor (10, 25, 50 bar) on biogas quantity and quality, pH value and process stability. By increasing operating pressures in methane reactor, the pH value decreased from 6.65 at 10 bar to 6.55 at 50 bar. Simultaneously, methane content increased from 79.08% at 10 bar to 90.45% at 50 bar. The results show that methane reactors can be operated up to 50 bar pressure continuously representing a viable alternative to commonly used gas upgrading methods because of reduced purification effort.

THE END

Thank you for your attention

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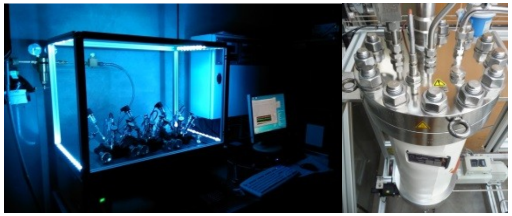

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Appendix

Hydrolysate production

Leachbed reactors: 2 weekly rhythm
Maize- / Gras silage: 1:1 ODM basis
Mixture and storage
Thermophilic operation

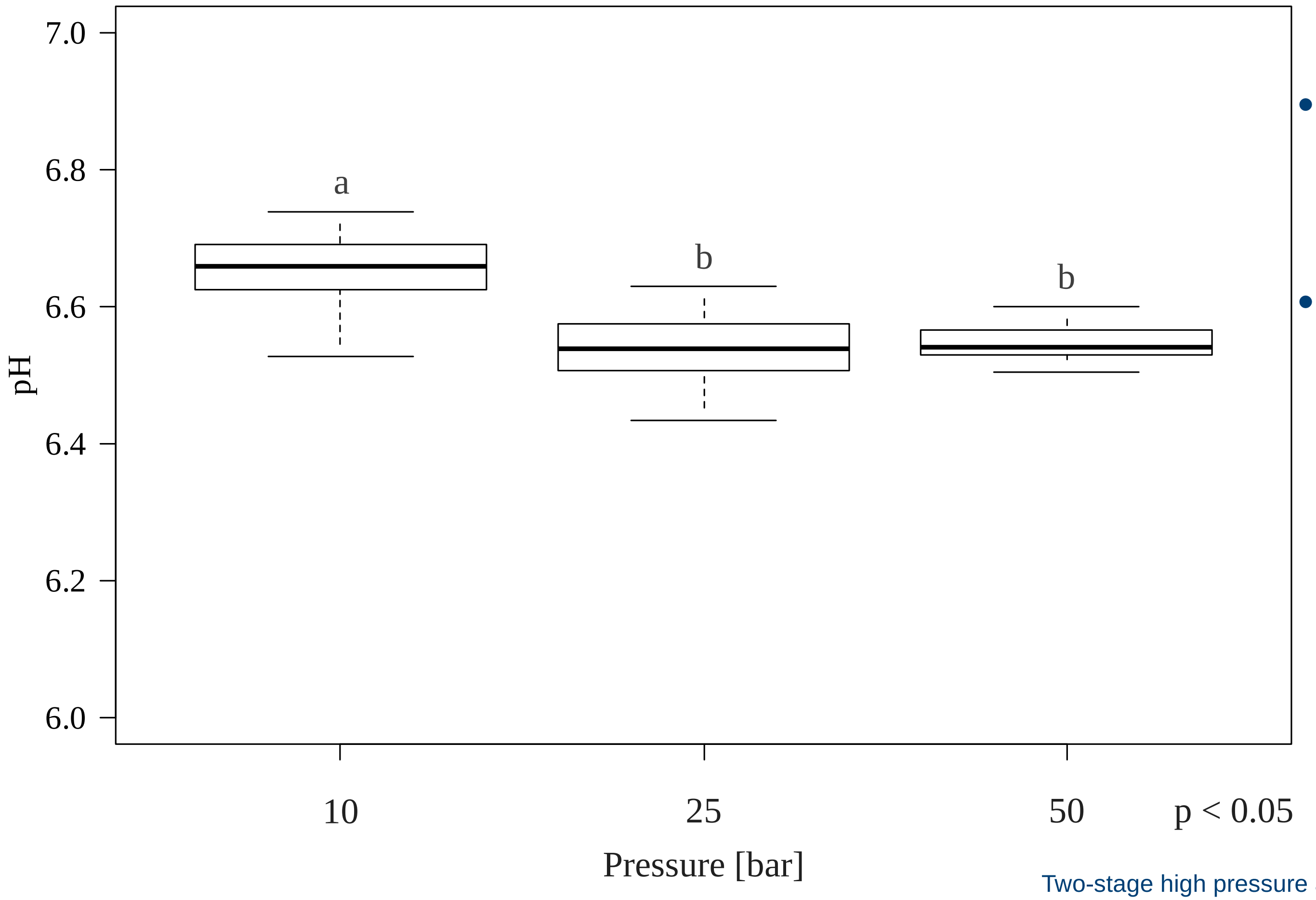
(Steinbrenner, 2018)

Liquid analysis

Chemical Oxygen Demand: COD
Carbon total: TC
inorganic: IC
Fatty acids (GC)
Sugars & Alcohols (HPLC)

Appendix

pH-value



- pH-value declines by increasing the pressure
- Higher pH-values than at Chen et al. (2014)