Hydrogen concentration as a possible control parameter for biogas plants

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Abstract
Anaerobic digestion processes are used in biogas plants for producing methane as a source of energy. The biological metabolic processes in biogas plants are complex and difficult to understand for the operator. Many of the over 9000 biogas plants in Germany are not operated in the optimal range. This results in incomplete substrate degradation, inefficient biogas yield, acidification, emission of methane, ammoniac, hydrogen sulphide, volatile organic acids and foam generation. All these effects reduce the yield of bioenergy. In order to optimize the fermentation process we investigated the anaerobic digestion process by using different model substrates (glucose, cellulose, starch and albumin). The obtained analytical data were compared to the results of a mathematical model.

Results

The anaerobic digestion process has a high hydrogen sensitivity. Even relatively low hydrogen concentrations have a regulatory effect and may affect the metabolic pathways of the reactor. A low substrate load results in a low hydrogen pressure and acetate as the predominant volatile fatty acid. In contrast, high loads lead to a high hydrogen pressure (> 10^{-4} atm) and subsequently to an increased formation of propionate, butyrate and lactate.

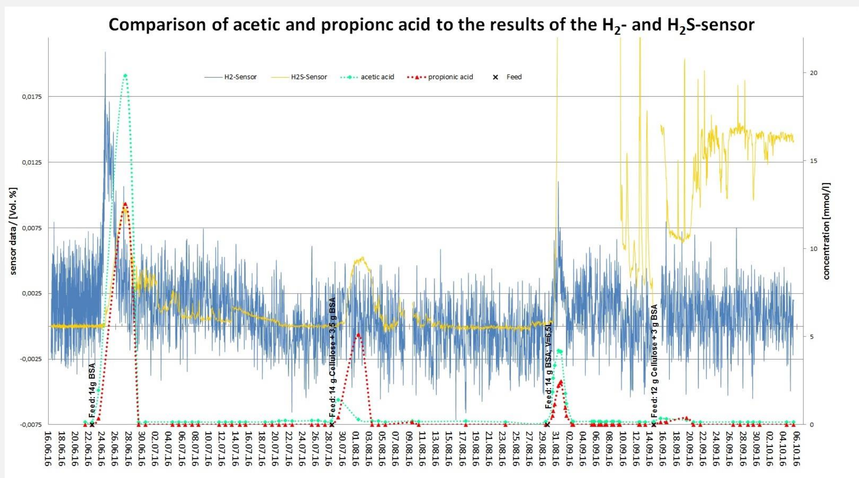


Figure 7: Fatty acids, hydrogen and hydrogen sulfide with albumin and celluse as substrate In the 8 l reactor. Hydrogen and hydrogen sulfide were detected with a sensor system from BlueSens gas sensor GmbH

Treshold H_2 partial pressure	
Acetoklastic methanogenesis	> 10 Pa
Hydrogenotrophic methanogenesis	< 10 Pa
Homo-acetogenesis	52 – 95 Pa
Propionat oxidation	> 10 Pa
Butyrat oxidation	> 100 Pa
Ethanol and lactat oxidation	10^5 Pa

Table 1.Threshold H_2 partial pressure of different anaerobic digestion phases of the biogas building process (THAUER, R.K. et al. 2008; STAMS, A.J.M. (1994); HARPER, S. R. and POHLAND, F. G. (1986)).

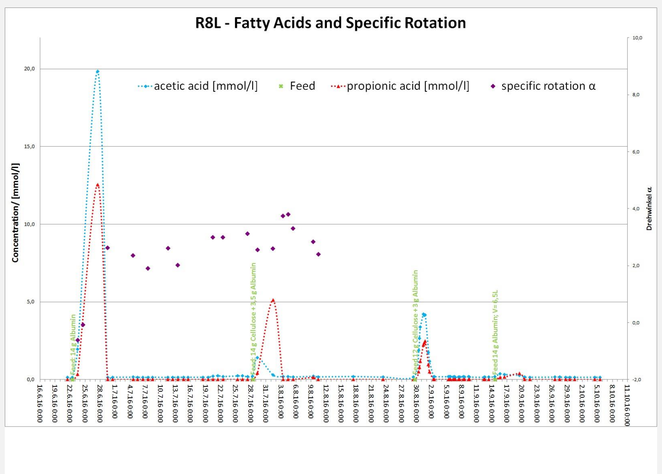


Figure 6: Fatty acids and specific rotation with albumin and celluse as substrate In the 8 l reactor. Specific rotation has been detected with a polarimeter from CiS Forschungsinstitut für Mikrosensorik GmbH, Erfurt.

Based on the Anaerobic Digestion Model No. 1 (ADM1) [1], [2]
New variable for the partial hydrogen pressure $p(H_2)$
Two new processes, formation and decay of hydrogen
Modelling with differential equations using MatLab
Kinetical data from literature [3], [4].

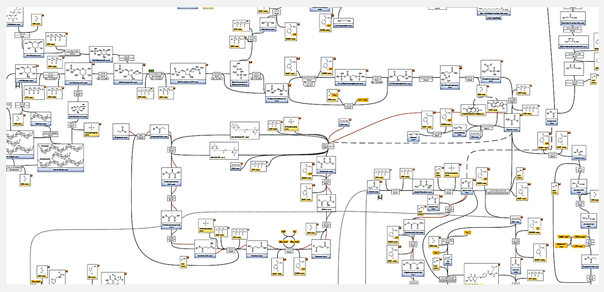
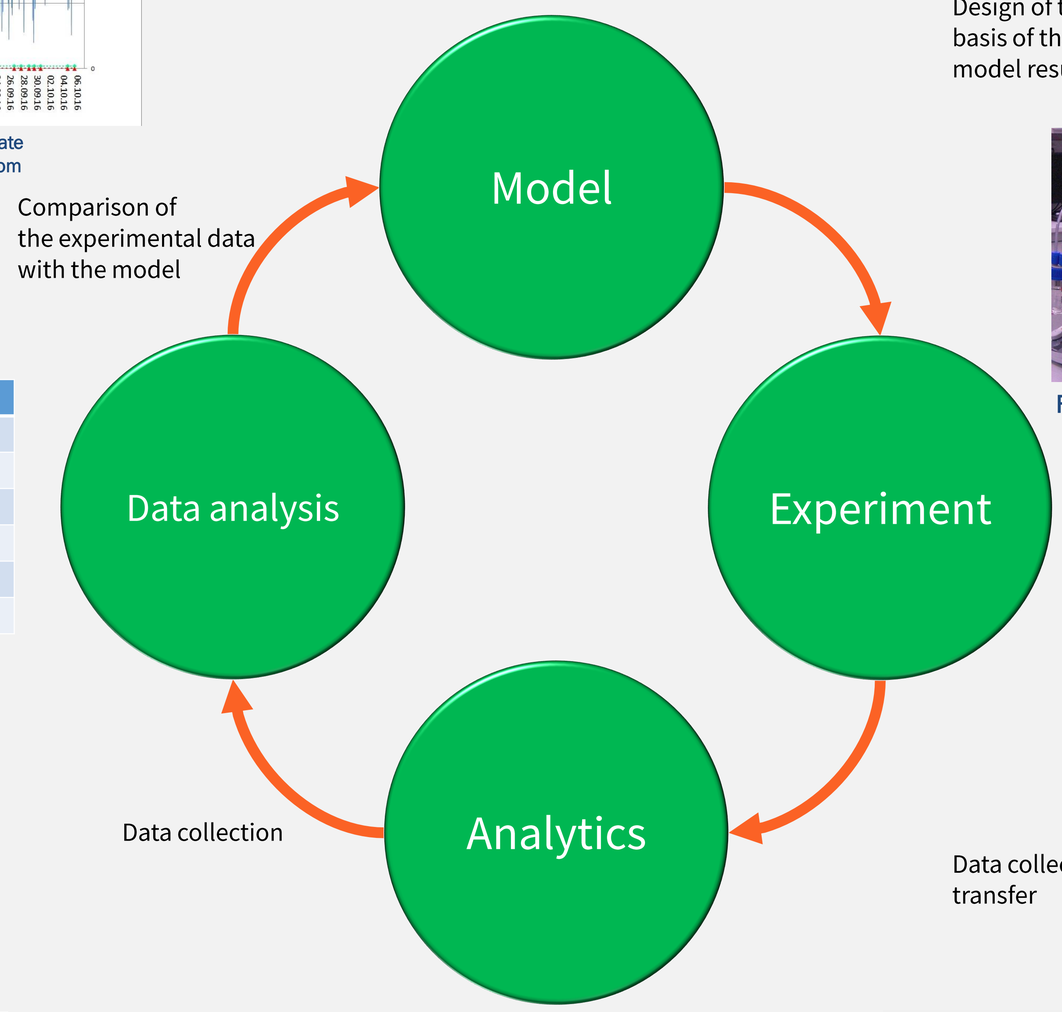


Figure 1: Diagram of the anaerobic digestion



Design of the experiments on the basis of the kinetic data and the model results

Figure 2: Experimental setup with 2L-bioreactors

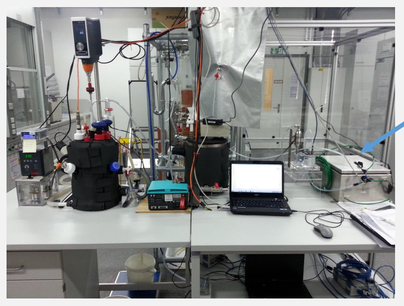


Figure 3: Experimental setup with 8 L-bioreactor

Sensors for on-line detection of CH_4, CO_2, H_2-H_2S, and temperature

Off-line detection of VOA-TAC-value (Ratio of volatile organic acids and total anorganic carbon i.e. the buffer capacity), pH-value, dry organic matter, ammonium-N, specific rotation with polarimetry, Ion chromatography: Fatty acids, amino acids, alcohols, microbial community composition using Illumina Amplicon sequencing [4]

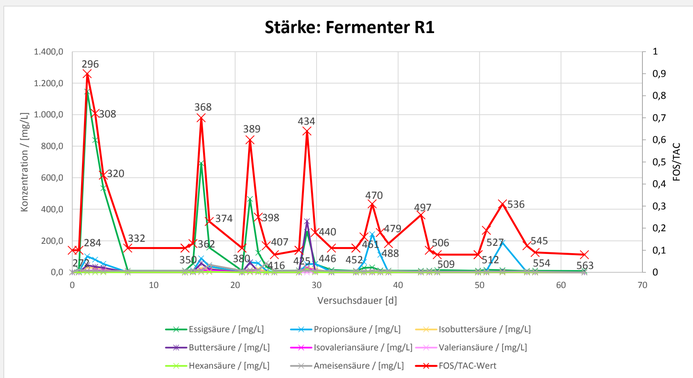


Figure 5: Fatty acids with starch as substrate in a 2 l reactor

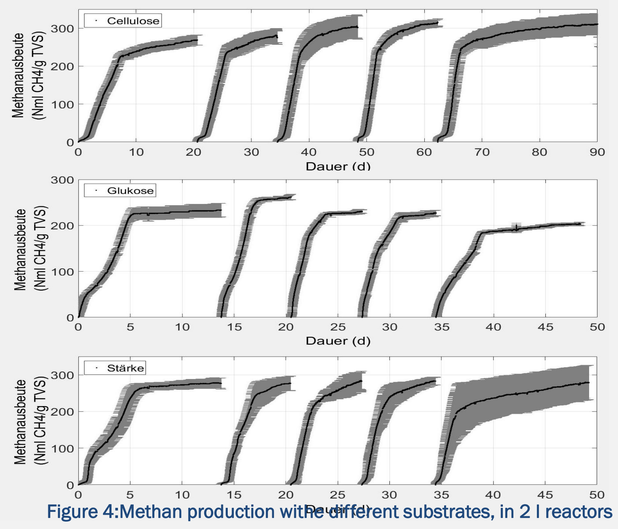


Figure 4:Methan production with different substrates, in 2 l reactors

References
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[2] M. Dudzinski, M. Stiemer: Extended modelling of anaerobic digestion subject to environmental changes, Hammer Bioenergietage, 2015.
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[4] Ellen Euchner, Andreas Walter, Bettina Manns, Maraike Probst, Carolin Griese, Thomas Kirner, Heribert Insam, Dieter Bryniok (2017): Influence of Substrate Concentration and Composition of the Microbial Community on the Biogas Production from Different Carbohydrates, 3rd International Conference on Monitoring & Process Control of Anaerobic Digestions Plants, Leipzig, 29.-30. 3 2017

Projektförderung
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