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Direct Biological Methanation of the Synthesis Gas of an Allothermal Wood Gasifier

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Purpose

Some archaea are able to synthesize methane from H_2 and CO_2 or CO, respectively. This ability is used to substitute natural gas with the shown metabolic pathways and their combination:

$$CO + H_2O \rightarrow 2\ CO_2 + H_2$$

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

The usual H_2-source (electrolysis) can be changed to a new feedstock: ligneous biomass. Therefore, as shown in in figure 1, the biomass is gasified in an allothermal steam-gasification. This makes new resources available leading to low costs for primary energy sources, broader areas of application and a reduced dependency on cheap volatile electricity for the electrolysis.

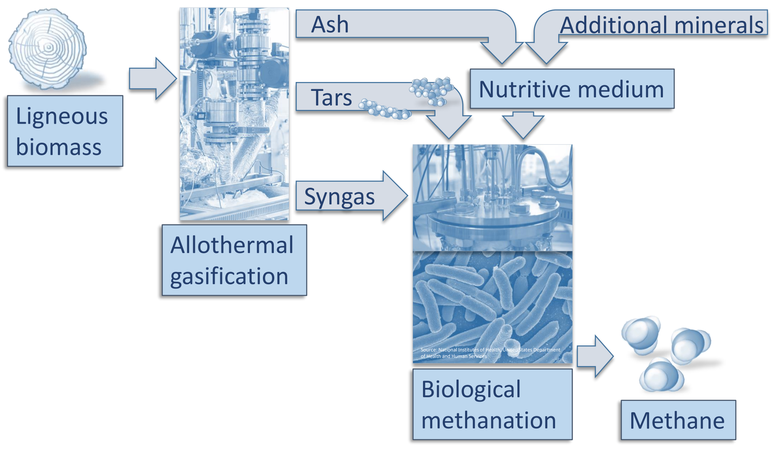


Figure 1: Concept of the biological methanation of ligneous biomass by coupling with allothermal gasification

The presented work is based on the BMWi-Project Ash-to-Gas and focusses on plant design of the CSTR, the done proof-of-concept and the durability of the used culture to syngas components, especially tars.

Approach and methodology

A continuously stirred tank reactor (CSTR) for anaerobe cultures has been built at the Chair of Energy Process Engineering, University of Erlangen-Nuremberg

The CSTR body is pointed in figure 2. Complementary to the shown parts and parameters, the CSTR is amongst others equipped with a pH probe and controlling unit and an O_2 purifier unit. The reactor can be operated in batch or continuously mode. The off-gas is permanently measured with a gas analyzer or a gas chromatograph.

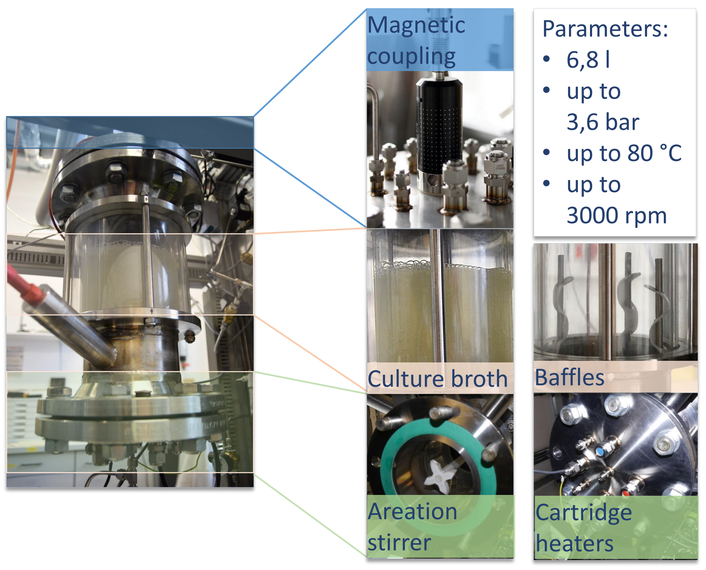


Figure 2: Photography of the CSTR body and its crucial components and parameters

Experimentation started, as shown in figure 3, with dosage of synthetic and single components of syngas to the stoichiometric feed gas of CO_2 and H_2, leading to the final proof-of-concept with real syngas.

Figure 3: Methodology of executed experiments

The crucial factor to measure the performance of the culture is the methane production rate (MPR):

$$MPR = \frac{V_{n,\,produced\ CH_4}}{V_{digester} \cdot day}$$

Results

As all experimentation is carried out with pure culture, cell count and MPR do not get constant due to Inhibition through by-products.

Adding CO and gasification ash to the digester poses no challenge. First results of dosing single, synthetic tar components, namely toluene, methylnaphthalene and acenaphtene, showed different behavior. Toluene and methylnaphthalene do not lower methane production, whereas acenaphtene leads to lowered MPR, immediately.

Experimentation of addition of real gasification syngas to the digester can be seen in figure 4. After the first addition of real syngas, the cell count decreases and tar pearls are visible during microscopy, which are not vanishing.

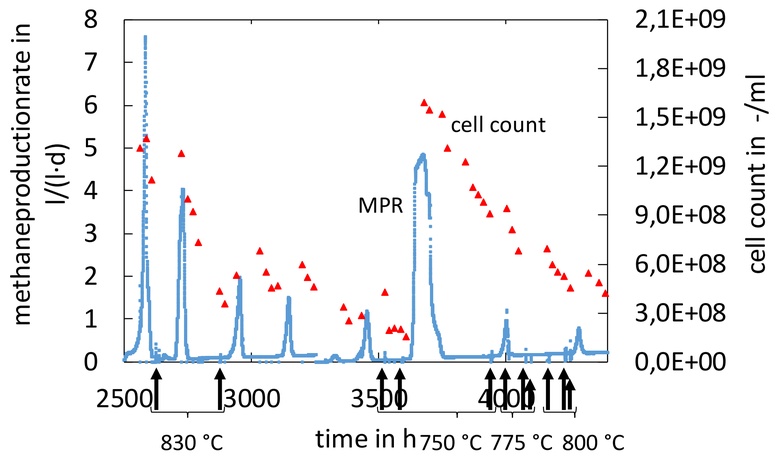


Figure 4: Depiction of the experiments on coupling the digester to the gasifier with ash filtration at different gasification temperatures

After an adaption phase the cell count recovers and the tar pearls vanish within three days after each further coupling, like shown in figure 5.

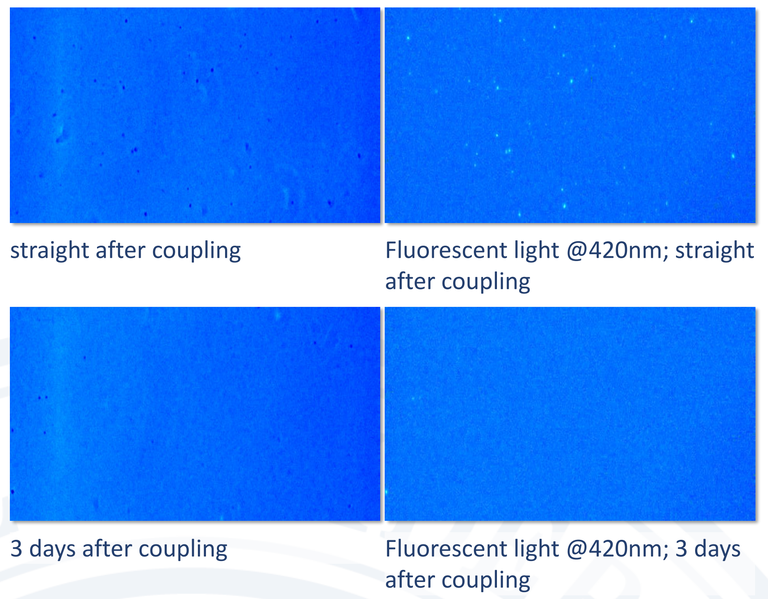


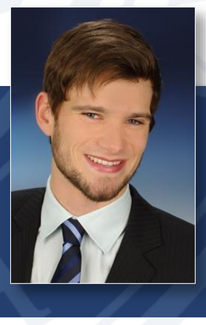
Figure 5: Shots in the transmitted light microscope, augmentation 100:1, show the fading of tar pearls in the culture brooth

Conclusion and further research

Coupling biological methanation to biomass gasification is possible and a promising technology. However, using pure culture is not the ideal way due to the high number of different polycyclic, aromatic hydrocarbons, like they are in tars of gasification. Latest addition of further microorganisms out of biogas digesters show much higher and evener MPR due to the metabolism of by-products and therefore no product inhibition.

With this mixed culture, investigation of limiting concentration of tar components and possible by-products can be done.

Lehrstuhl für Energieverfahrenstechnik
Prof. Dr.-Ing. Jürgen Karl



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