Tars and Inhibition of Biological Methanation Using Synthesis Gas of an Allothermal Wood Gasifier

T. Trabold, T. Weidlich, J. Karl
Chair of Energy Process Engineering (EVT), Friedrich-Alexander-Universität Erlangen-Nürnberg, Fürther Str. 244f, D-90429 Nürnberg

Purpose
Some archaea are able to synthesize methane from H₂ and CO₂ or CO₂, respectively. This ability is used to substitute natural gas with the shown metabolic pathways and their combination:

\[ \text{CO} + \text{H}_2 \rightarrow \text{CO}_2 + \text{H}_2 \]

\[ \text{CO}_2 + 4 \text{H}_2 \rightarrow 2 \text{H}_2 \text{O} + \text{CH}_4 \]

The usual H₂-source (electrolysis) can be changed to a new feedstock: ligneous biomass. Therefore, as shown in figure 1, the biomass is gasified. This reduces 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 focuses 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, FAU Erlangen-Nürnberg.

The CSTR body is pointed in figure 2. Complementarily to the shown parts and parameters, the CSTR is amongst others equipped with a pH probe and controlling unit and an O₂ 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.

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

\[ \text{MPR} = \frac{V_{\text{CH}_4 \text{ produced}}}{V_{\text{digester day}}} \]

Experimentation started, with dosage of synthetic and single components of syngas to the stoichiometric feed gas of CO₂ and H₂, leading to the final proof-of-concept with real syngas.

Afterwards the pure culture is augmented with a probe out of a biogas plant to decrease the concentration of by-products and their inhibition effects.

CO and gasification ash poses no challenge. Different behavior is shown with synthetic tar components. As acenaphthene decreases MPR instantly, toluene and methyl-naphthalene do not. After the first addition of real syngas, the cell count decreases and tars are visible during microscopy, which are not vanishing. After an adaption phase the cell count recovers and the tar pearls vanish within three days after each further coupling, like shown in figure 4.

Results
During all of the experimentation with pure culture, cell count and MPR do not get constant due to inhibition through by-products. This can be seen in figure 3, which shows results of addition of real gasification syngas to the digester.

Figure 3: Depiction of the experiments on coupling the digester to the gasifier with ash filtration at different gasification temperatures

CO₂ gasification of an ideal methanation process with a syngas content of 90% CO₂ and 10% CO₃ is shown in figure 4. The methane production rate (MPR) is constant, while the cell count is increased over the time due to inhibition through by-products. Figure 5 shows the evened out MPR of the augmented culture. Here a specie metabolizes the by-products of the used methane building archaean.

Conclusion and further research
Coupling biological methanation to biomass gasification is a promising technology. However, using pure culture is not the ideal way due to the gasification tars. Addition of microorganisms out of a biogas plant show higher and even earlier 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.