KombiGas: Combined methane and hydrogen production for the application in the stationary motor

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Goal of the project

The application of biogas in the stationary cogeneration of heat and power is state of the art. The application's optimization is currently done by engine improvements; an optimization of the biogas is rarely taken into consideration.

The context of the presented project is the development of a biotechnical process for the generation of a hydrogen-rich biogas from organic residues. By the application of this hydrogen-rich biogas in a stationary gas engine, a decrease of emissions and fuel consumption is expected. A further aim of the project is to discover influencing factors in the fermentation process leading to various hydrogen (H_2) and methane (CH_4) yields.

Figure 1. Set up of the biotechnical process

Experiment

In order to achieve a biotechnical process for a combined H_2 and biogas production the four levels of the anaerobic biogas fermentation needs to be divided into two procedural coupled processes: hydrolysis and methanogenesis. The process step hydrolysis includes the activity of the hydrolytic, acidogenic and partly acetogenic micro-organisms. Its final products are gaseous H_2, carbon dioxide (CO_2), hydrogen sulfide (H_2S), acetate, long-chain fatty acids and dissolved H_2 and CO_2. The hydrolyzate from the first process step, containing acetate, long-chain fatty acids, dissolved H_2, dissolved CO_2 and partly unconverted substrate, is directed to the second process step. The second process step includes parts of the acetogenesis and the methanogenesis. In this step the acetate is converted to CH_4 and CO_2 and furthermore dissolved CO_2 and H_2 react to additional CH_4.

The first process step is conducted in a 3.2 L Semi-Continuous Stirred Tank Reactor (CSTR) and the second process step is conducted in a 5.8 L Fluidized-Bed-Reactor (FBR), which is partly filled with plastic carriers, leading to a biomass retention. Both reactors are semi-continuously fed and brewer´s spent grains are used as substrate.

Results

The performed combined fermentation runs had a total biogas yield of 204.7–210.6 NL Biogas/kg oDM (organic dry matter). An adjustment of pH in the hydrolytic fermentation process changed the gas and VFA yields of the single fermentation steps and then the composition of the combined gas. A low pH of 4.5 increased the H_2 release in the hydrolytic fermentation step and led to a combined gas with a measurable H_2 concentration of 4.5% and a CH_4 concentration of 72.6%. If a higher pH of 5.5 was adjusted in the hydrolytic fermentation run, the H_2 release was lower, leading furthermore to a reduced H_2 concentration of 1.1% in the combined gas. On the other hand the CH_4 concentration increased to 75.4%. The CO_2 concentration in both combined gas was approximately the same.

The gas yields obtained from both fermentation runs were lower as the biogas yield of a one-step digestion test, operating in batch mode for 30 days. Its biogas yield was 301 NL/kg oDM, but the CH_4 concentration was only 61%. As a conclusion the two-step fermentation generated less biogas with a higher CH_4 concentration.

The hydraulic retention time (HRT) of the combined process was eight days. Compared to the digestion test, the HRT was reduced by 73%. One influencing factor leading to this reduction was the retention of biomass in the methanogenic fermenter. After a period of 21 d first significant flocks were found in the fermenter. Granules were even built after 41 d of operation. The FBR showed a good performance in the retention of biomass and reduction of HRT.

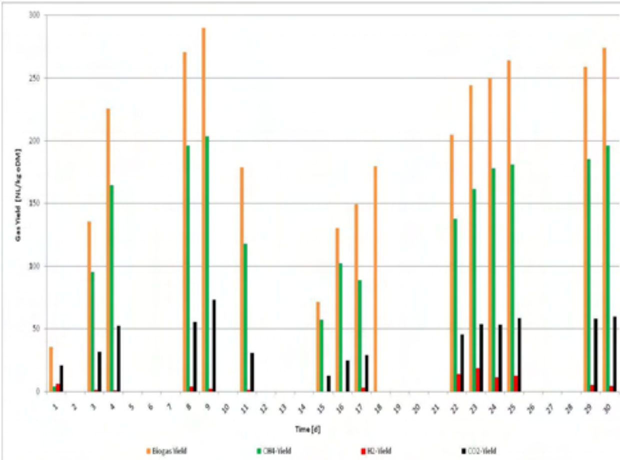

Figure 2. Gas yields of the hydrogen-rich combined fermentation process.

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