Experimental methods for investigations of biomethanation processes at elevated operating pressures

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Investigations on waste to value processes, power to gas applications as well as production of biofuels expanded during the past years within Europe [1]. In addition, storage of renewable electricity from solar or wind energy poses certain challenges because of their intermittent nature. The use of excess electricity for the production of hydrogen (H_2) by electrolytic conversion of water is a well-described way to store this renewable electricity [2]. Therefore, the concept of revaluation of H_2 and waste CO_2 streams into methane (CH_4) as an alternative power to gas approach was developed. Recently, new biological methane production processes (BMP) for the conversion of methane from H_2 and CO_2 created more possibilities for the production of renewable energy sources which are compatible with power to gas and carbon utilization concepts [3-4].

The aim of this work is the development of a bioreactor system operating at elevated pressures in closed batch, fed-batch and continuous processes.

STEP 1

Pre-screening

Hydrogenotrophic and autotrophic methanogens are cultivated in serum bottles at pressures up to 3 bar in closed batch and at atmospheric pressure in fed-batch. The aim of this step is to find suitable strains for biomethane production at elevated pressures.

STEP 2

Simultaneous Bioreactor System (SBRS)

A system with four interconnected pressure resistant vessels was developed in order to allow quadruplicate fermentations for the screening of methanogenic strains in closed batch environments at a high throughput for pressures up to 50 bar (Figure 1). Experiments were performed in each vessel at 10 and 50 bar in closed batch with the hydrogenotrophic strain *Methanobacterium thermaggregans* as an example.

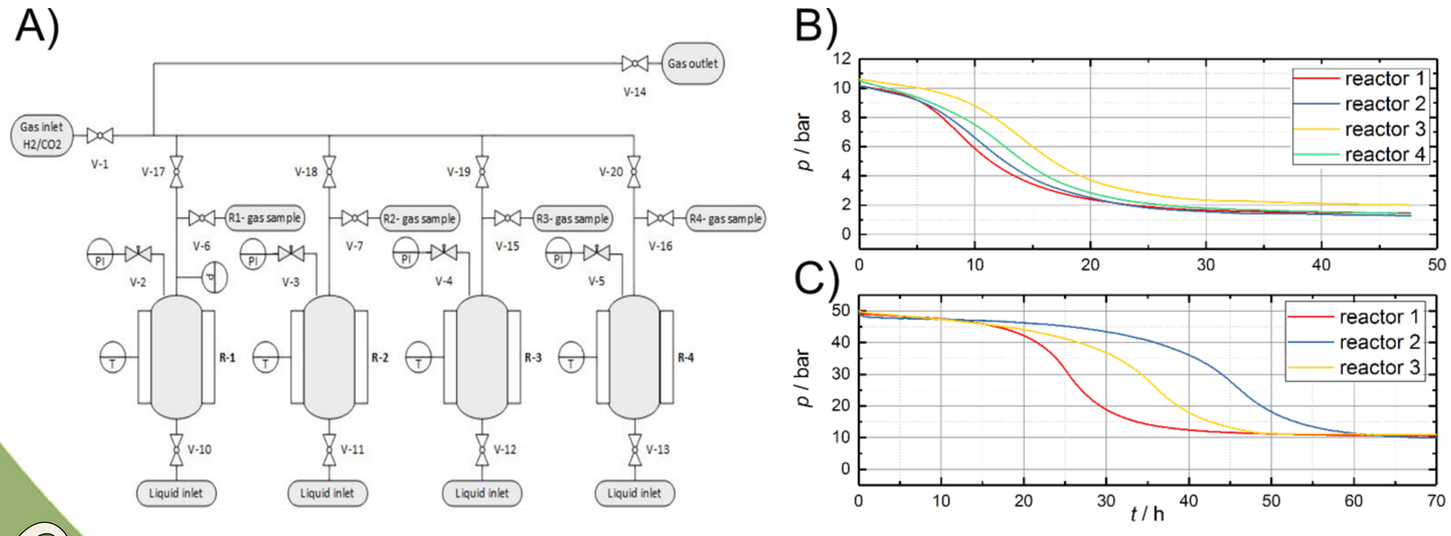

Figure 1: A) SBRS flow sheet. B) High pressure fermentations at 10 bar in the SBRS with *M. thermaggregans*. C) SBRS fermentations at 50 bar with *M. thermaggregans*. Reactor 4 not shown, because gas conversion could not be achieved.

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

STEP 3

Bioreactor

A Büchi reactor system adapted for high pressure applications up to 50 bar was developed. Closed batch fermentations at different pressure levels were successfully performed and bio-methane production was achieved at elevated inoculation pressures. Further adaptions for fed-batch and continuous operations are planned.

Figure 2: Büchi bioreactor system.

General Procedure

- medium composition very simplified and similar for each step
- H_2:CO_2=4:1 as substrate gas
- Off-gas control through GC-TCD measurements
- strains from STEP 1 used for the following steps
- methanogenic CH_4 production leads to a pressure drop

Conclusion

Gas conversion and biomethane production could be achieved in each cultivation system. An off-gas concentration of at least 99.7 % methane (dry gas) was measured after fermentations in the SBRS system with *M. thermaggregans* by contrast to fed-batch processes with a maximum methane concentration of 10 %. Prescreening in the serum bottles as well as in the Simultaneous Bioreactor System is a suitable method to establish the appropriate strain to use for the final Büchi bioreactor system.

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