Syngas biomethanation by mixed microbial consortia in trickle bed reactors

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1. Introduction

The devastating impacts of climate change on our societies are currently more evident than ever. As a result, a change towards renewable energy economy is urgent and it can only be achieved through carbon sequestration and recycling.

Syngas is a byproduct of biomass gasification and several industrial activities. Its high energy and carbon content due to its constituents (CO, H_2 and CO_2) render it an important substrate for the production of biofuels. The conversion of syngas to methane is an attractive option due to the high storage capacity of methane in the natural gas grid.

The main advantages of the biological conversion of syngas to methane over catalytic processes are the low infrastructure cost, the mild temperature and pressure, the negligible cost of the catalyst (microbes) and the fact that there is no demand for a fixed H_2/CO ratio. On the other hand, the major bottleneck is the low mass transfer rate of CO and H_2 to the water based media where microbes grow. It has been reported, that trickle bed reactors (TBRs) provide higher gas to liquid mass transfer rates compared to the conventional stirred tanks and bubble columns and, thus, they constitute an interesting solution to the main challenge of syngas fermentation [1].

The aim of this study was to assess the efficiency of syngas biomethanation by mixed microbial consortia under mesophilic and thermophilic conditions in TBRs, maximize the concentration of methane in the gas outlet with additional H_2 supply and examine the scaling up potential of the process.

2. Technology description

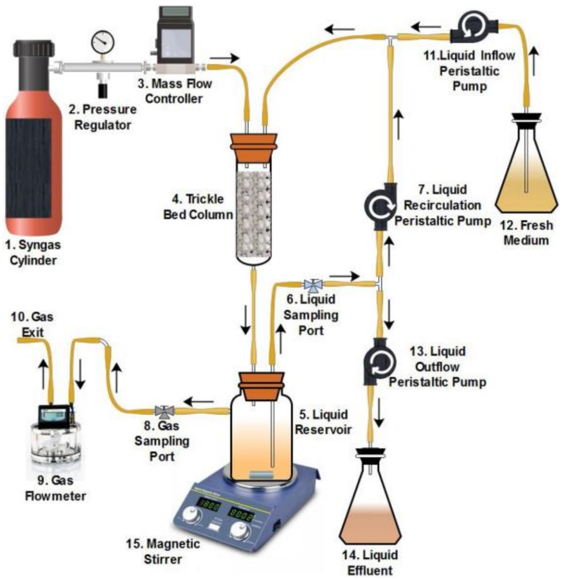

Figure 1. Process Flow Diagram of the lab scale bioreactor configuration [2]

The principal components of the lab scale bioreactor setup were the syngas cylinder containing the substrate gas (H_2 45%, CO_2 25%, CO 20% and CH_4 10%), the trickle bed column filled with packing material where biofilm was formed and where the conversion was performed and the liquid reservoir for the recirculating media. A detailed instrumental depiction of the setup can be seen in Fig. 1.

3. Comparison between mesophilic and thermophilic conditions

Lab scale TBRs were operated under mesophilic (37 °C) and thermophilic (60 °C) conditions for the conversion of syngas to methane. The bioreactors were inoculated with enriched mixed microbial consortia and experimental data regarding the conversion efficiency of the substrate and the volumetric productivity of methane were collected under steady state conditions (Fig. 2).

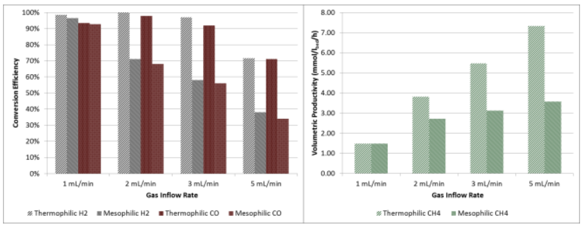

Figure 2. Conversion efficiency of CO and H_2 and volumetric methane productivity of the mesophilic and thermophilic trickle bed reactor

The results showed that the thermophilic reactor outcompeted the mesophilic one as the inflow rate of syngas increased.

4. External H_2 supply for the production of a natural gas grade CH_4

Additional H_2 was supplied in the TBRs due to the fact that the syngas used as a substrate was stoichiometrically limited to be fully converted to methane because of its high content in CO_2 (25%). The obtained results showed that at a gas residence time of 2 h, when the flow of syngas was 46.7% and the flow of pure H_2 53.3%, the conversion efficiency of H_2, CO and CO_2 were 99.7 %, 99.2% and 98%, respectively, resulting to an effluent gas containing 97.5% CH_4 (Table 1).

Table 1. Conversion efficiency of the syngas compounds and CH_4 content in the gas effluent as a function of syngas ratio in the mixture of syngas/H_2 fed.

	Conversion Efficiency of the substrate			CH_4 in the outlet
Syngas flow percentage	H2	CO	CO2	
100% Syngas	99.2%	99.3%	30.5%	55.9%
60% Syngas	99.9%	99.6%	70.7%	84.5%
50% Syngas	99.9%	100.0%	91.3%	94.2%
40% Syngas	81.3%	56.6%	99.8%	51.6%
46.7% Syngas	**99.8%**	**99.2%**	**98.0%**	**97.5%**

4. Scale up of the TBR

The obtained results from the laboratory scale experiments are currently being confirmed in a pilot scale TBR under the respective operational conditions. Syngas from a gasifier is also being tested in the pilot scale TBR.

Figure 3. Scaled up TBR

5. Conclusions

This study showed that thermophilic conditions favour syngas biomethanation and that with the additional supply of H_2 at the proper flowrate the gas effluent can be suitable for injection in the natural gas grid.

6. References

[1] K. Asimakopoulos et al. Reactor systems for syngas biomethanation processes: a review. Chemical Engineering Journal (2018)

[2] K. Asimakopoulos et al. Biomethanation of Syngas by Enriched Mixed Anaerobic Consortia in Trickle Bed Reactors. Waste and Biomass Valorization (2019).