Syngas biomethanation by enriched microbial consortia: Inhibition and kinetic studies

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Syngas biomethanation by enriched microbial consortia: Inhibition and kinetic studies

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ABSTRACT

Over the last years, several European countries have shown an increasing interest in biomethane production, as it can contribute to reducing the dependency on foreign natural gas supplies and the emission of greenhouse gases. In this context, the development of an integrated biomass gasification and syngas biomethanation process would allow increasing the conversion efficiency of recalcitrant biomasses as well as provide a more cost-effective process in smaller scale compared to alternative catalytic methanation methods. The benefits of the syngas biomethanation lie on the use of mixed microbial consortia (MMC) characterised by high adaptive capacity and resilience [1], and on the fact that sterile operation is not required. An additional advantage is the high product selectivity since CH_4 and CO_2 are the only end products of the overall process. However, a thorough understanding of the biological processes involved in the syngas biomethanation is fundamental when it comes to process control and optimization tasks. This work focuses on the assessment of a mesophilic and a thermophilic enriched methanogenic MMC in respect to their patterns of activity through kinetic characterization and study of growth inhibition due to CO.

The two enriched MMC used in this study originated from the same anaerobic sludge and were enriched based on temperature (37˚C and 60˚C) and substrate composition (1.3 bar H_2, 0.4 bar CO, 0.3 bar CO_2) as the main drivers of the microbial selection. The objectives of kinetic characterization of the enriched MMC were to evaluate the main syntrophic interactions prevailing in each consortium, as well as to determine the yield and kinetic parameters of each reaction. Additionally, the inhibitory effects of CO on the enriched MMC were studied through a series of experiments where the partial pressure of H_2 (P_{H2}) and CO_2 (P_{CO2}) were kept constant at 1 and 0.2 bar, respectively, while the partial pressure of CO (P_{CO}) was gradually increased from 0.2 to 0.8 bar.

Preliminary results of the kinetic studies showed significant differences between the patterns of activity of the two enriched consortia. While syngas was converted through acetic acid as the only intermediate product by the mesophilic consortium, the conversion by the thermophilic consortium took place strictly through H_2. Consequently, the mesophilic consortium presented a more intricate metabolic network involving the syntrophic interaction of 4 microbial groups (table 1). On the other hand, the thermophilic consortium consisted of only two microbial groups, namely the carboxydotrophic hydrogenogens and hydrogenotrophic methanogens (table 1). Significant differences were also observed in the CH_4 yield, corresponding to 78.95 ± 0.06 % and 91.37 ± 0.3 % for the mesophilic and the thermophilic consortium, respectively.

The inhibition studies indicated that the mesophilic consortium was generally more sensitive to high P_{CO} than the thermophilic consortium. Both enriched consortia exhibited increasing maximum specific activities for CO as P_{CO} gradually increased

Table 1. Microbial groups present in each enriched microbial consortia and product yields.

Microbial group	Product yield	
	Mesophilic MMC	Thermophilic MMC
Carboxydotrophic hydrogenogens	No activity	0.85 mol H_2/mol CO (85%)
Carboxydotrophic acetogens	0.22 mol ac/mol CO (88%)	No activity
Homoacetogens	0.21 mol ac/mol H_2 (84%)	No activity
Hydrogenotrophic methanogens	0.23 mol CH_4/mol H_2 (92%)	0.23 mol CH_4/mol H_2 (92%)
Aceticlastic methanogens	0.84 mol CH_4/mol ac (84%)	No activity

(table 2). However, the increase was more pronounced in the thermophilic consortium, indicating a higher tolerance to the toxicity of CO. It is noticeable that CO also exerted a stronger inhibitory effect on the uptake of H_2 in the mesophilic consortium than in the thermophilic. Thus, the methane productivity of the mesophilic consortium was dramatically affected by the increase of P_{CO}. On the contrary, the methane productivity of the thermophilic consortium underwent a moderate increase along with the rising P_{CO}, reaching its maximum at a P_{CO} of 0.6 bar.

Table 2. Methane productivity and maximum specific activity for H_2 and CO.

P_{CO} (bar)	Productivity (mmol CH_4/g VSS/h)		Max. specific uptake activity (mmol H_2/g VSS/h)		Max. specific uptake activity (mmol CO/g VSS/h)	
	MC	TC	MC	TC	MC	TC
0.2	0.78±0.01	2.90±0.61	23.39±1.12	22.53±0.59	2.46±0.23	3.13±1.29
0.4	0.63±0.05	4.03±0.30	17.79±0.96	36.86±0.14	5.26±0.67	9.23±0.66
0.6	0.50±0.09	4.34±0.21	16.39±1.41	42.13±3.18	6.26±0.33	17.42±1.41
0.8	0.21±0.02	4.30±0.03	12.27±0.72	44.19±1.21	7.95±0.87	21.69±0.43

[a] MC: Mesophilic enriched microbial consortium
[b] TC: Thermophilic enriched microbial consortium

CONCLUSIONS

Preliminary results of the kinetic characterization and the inhibition studies showed clear differences between the patterns of activity, yields and productivities of the two enriched methanogenic consortia. The thermophilic consortium presented higher conversion yields and rates, and higher tolerance to high P_{CO}, which would ultimately favour higher productivities and conversion efficiencies in a continuous syngas biomethanation process.

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