Methane production potentials of selected microalgae

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Background

Microalgae are commonly known to produce biomass faster than crop plants. This makes them an excellent source for renewable energy, biofuels and biogas. Taking advantage of the stored photosynthetic energy microalgae could enable the development of a sustainable way to generate energy by anaerobic digestion. In this study, methane production potentials of the selected microalgae *Spirulina platensis*, *Dunaliella tertiolecta*, *Scenedesmus obliquus*, *Chlorella vulgaris*, *Haematococcus pluvialis* and a microalgal mixture were investigated. Considering that inoculum-substrate ratio could be a mayor influencing factor of anaerobic digestion, we also examined its effect on the methane production using a *Chlorella-Scenedesmus*-Mixture.

Currently only few studies have been performed on microalgae-based methane production, focussing on differences in methane production due to the usage of different microalgal species as a substrate or different inoculum-substrate ratios. Moreover, most of the results are hardly comparable due to different pre-treatment, co-digestion or extraction of lipids from the algal substrate.

Material and Methods

The microalgae *S. platensis*, *D. tertiolecta*, *S. obliquus*, *C. vulgaris* and *H. pluvialis* were cultivated with specific medium in 1 L flasks with an effective volume of 0.8 – 0.85 L in ambient temperature. The flasks were placed in between neon tubes (120 µMol $m^{-2}s^{-1}$, 5 cm distance) and an additional light bulb (600 µMol $m^{-2}s^{-1}$, 20 cm distance). To determine the percentage of carbon, hydrogen and nitrogen in the different species, an "EA 1110 Elemental Analyzer from CE Instruments" was used. The C/N ratio was based on these measurements. The protein content was calculated using a nitrogen-to-protein conversion factor.

The methanation process was based on the procedure described by Field *et al.* (1987) for wastewater. The triplicate batch assay was carried out at 36.2 ± 2.3 °C in 100 mL vials considering an organic matter concentration of 0,4 % (measured as volatile solids) and using a methanogenic biomass inoculum concentration of 4 $gVSL^{-1}$ (methanogenic activity value of 0,7 g COD*$gVSS^{-1}d^{-1}$). The methanation of the selected algal species was analyzed for a period of 40 days in which the methane production potentials and the effects of the inoculum-substrate ratio were examined. The biodegradability values are based on the COD values which take the carbon percentage obtained by the elemental analyzer as a basis.

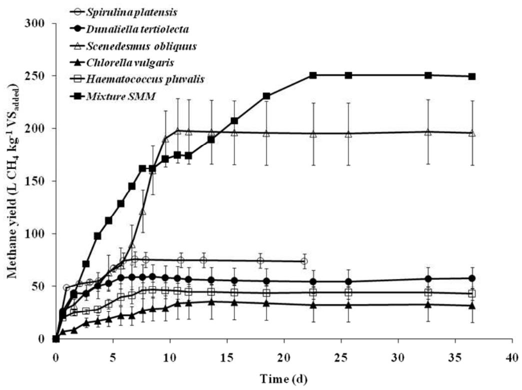

Figure 1. Cumulative methane production of selected microalgae in batch assays and single microalgae mixture containing the leftovers of the sample extraction.

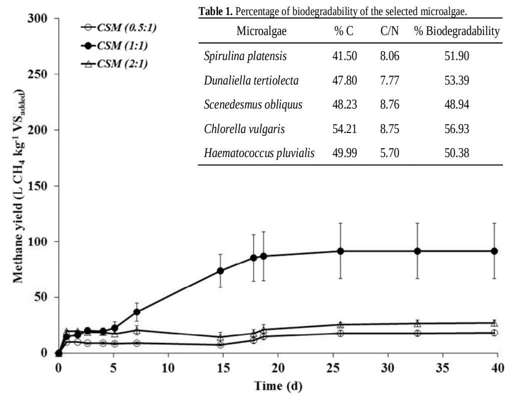

Table 1. Percentage of biodegradability of the selected microalgae.

Microalgae	% C	C/N	% Biodegradability
Spirulina platensis	41.50	8.06	51.90
Dunaliella tertiolecta	47.80	7.77	53.39
Scenedesmus obliquus	48.23	8.76	48.94
Chlorella vulgaris	54.21	8.75	56.93
Haematococcus pluvialis	49.99	5.70	50.38

Figure 2. Cumulative methane production of *C. vulgaris/S. obliquus* – mixture (CSM) in triplicate batch assays with different inoculums-substrate ratios.

Results and Discussion

The cumulative methane production of the selected microalgae species indicate, a strong variation in the examined microalgae (Figure 1). *S. obliquus* produced 198 ± 30 L CH_4 kg^{-1} VS_{added} after 37 days of anaerobic digestion. The digestion of *Spirulina platensis* (76 ± 7 L CH_4 kg^{-1} VS_{added}), *D. tertiolecta* (59 ± 12 L CH_4 kg^{-1} VS_{added}), *H. pluvialis* (47 ± 8 L CH_4 kg^{-1} VS_{added}) and *C. vulgaris* (35 ± 16 L CH_4 kg^{-1} VS_{added}) showed results up to five times lower. However a single microalgae mixture (SMM) containing the leftovers of the sample extraction (0.12 g *D. tertiolecta*, 0.03 g *S. obliquus*, 0.06 g *C. vulgaris* and 0.05 g *H. pluvialis*) with a total of 0.25 g biomass produced 250 L CH_4 kg^{-1} VS_{added}. Regarding the inoculum-substrate ratio, Figure 2 shows a wide range in methane production between the chosen ratios of the *C. vulgaris/S. obliquus*–mixture (CSM). An IS ratio of 1:1 produced up to 5 times more methane than the IS ratio 0.5:1 and 3.4 times more than the IS ratio 2:1.

The strong variation in methane production between *S. obliquus* (198 ± 30 L CH_4 kg^{-1} VS_{added}) and the other selected microalgae was subject of the detailed analysis of the species. The C/N ratio of *S. obliquus* (8.76) is comparable to the ratio of *C. vulgaris* (8.75). The content of protein and pH of the batch reactor (data not shown) is as well comparable. The biodegradability is lowest in *S. obliquus* (49 %) and highest in *C. vulgaris* (57 %). These values are very similar and are expected to result in comparable amounts of produced biogas. Regarding the strong variation in methane production between *S. obliquus* and the other selected microalgae, a possible explanation is that the carbonic material in the other species rather transformed into carbon dioxide than methane. Therefore it is recommendable to measure whole biogas rather than methane only and specify methane content by gas chromatography in following experiments. The variations in methane production are most probably caused by multiple factors and should therefore be analyzed intensively by additionally measuring volatile fatty acids, content of ammonium, fiber content and cell wall characteristics like hemi-cellulose and cellulose.

Conclusion

Our experiments on methane production with different microalgae indicate that *S. obliquus* may be the most suitable source of biomass to use as algal sludge in batch assays. Its handling and culture is comparable to the often used microalgae *Chlorella vulgaris* and thus seems to be promising for large scale application. Furthermore, microalgal mixtures could be a profitable alternative to single species digestion and hence should be researched intensively. We have also found that an inoculum-substrate ratio of 1:1 reaches the highest methane yield and is therefore recommendable until further investigation.

Although the anaerobic digestion of microalgae is not yet adopted to large scale application, we believe it could contribute to a future renewable energy production.

Acknowledgements

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Field J., Sierra R., Lettinga G. (1987). Ensayos anaerobios. Department of Water Pollution Control. Wageningen Agricultural University, Holanda, pp 67-75.