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Impact of temperature, microwave radiation and organic loading rate on methanogenic community and biogas production during fermentation of dairy wastewater

Magdalena Zielińska [a], Agnieszka Cydzik-Kwiatkowska [a,*], Marcin Zieliński [b], Marcin Dębowski [b]

[a] Department of Environmental Biotechnology, University of Warmia and Mazury in Olsztyn, Słoneczna 45G, 10-709 Olsztyn, Poland
[b] Department of Environmental Engineering, University of Warmia and Mazury in Olsztyn, Warszawska 117, 10-709 Olsztyn, Poland

HIGHLIGHTS

- ▶ Dairy sewage treatment in a new reactor joining suspended sludge and trickling bed.
- ▶ Fermentation at 1 or 2 kg COD/(m^3 d) at 35 or 55 °C kept by microwaves or convection.
- ▶ Temperature and microwaves as main factors affecting species succession of *Archaea*.
- ▶ Microwaves promoted methanogens' diversity and supported biogas production.
- ▶ *Methanosarcinaceae* determined *Archaea* diversity and methane-rich biogas production.

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ABSTRACT

This study analyzed dairy wastewater fermentation in convection- and microwave-heated hybrid reactors at loadings of 1 and 2 kg COD/(m^3 d) and temperatures of 35 and 55 °C. The biomass was investigated at a molecular level to determine the links between the operational parameters of anaerobic digestion and methanogenic *Archaea* structure.

The highest production of biogas with methane content of ca. 67% was noted in the mesophilic microwave-heated reactors. The production of methane-rich biogas and the overall diversity of *Archaea* was determined by *Methanosarcinaceae* presence. The temperature and the application of microwaves were the main factors explaining the variations in the methanogen community. At 35 °C, the microwave heating stimulated the growth of highly diverse methanogen assemblages, promoting *Methanosarcina barkeri* presence and excluding *Methanosarcina harudinacea* from the biomass. A temperature increase to 55 °C lowered *Methanosarcinaceae* abundance and induced a replacement of *Methanoculleus palmolei* by *Methanosarcina thermophila*.

1. Introduction

Methane fermentation is the process applied in technologies of industrial wastewater treatment, particularly from the food industry, characterized by high organic concentrations. During anaerobic transformations, a stabilization of organic matter occurs with simultaneous production of methane-containing biogas. Fermentation is a multi-phase process and environmental requirements of microorganisms conducting each phase are different. In practice, the operational conditions should be optimized to prevent the accumulation of acid by-products that are the reasons for methanogenesis failure. To maintain stable methane production, the conditions in the reactor should favor the development of multi-species communities, because the highly diverse assemblages of microorganisms are less vulnerable to fluctuations in the environmental parameters (Saikaly et al., 2005). After an environmental disturbance which results in the elimination of some species, others are able to sustain a particular type of metabolic pathway.

The final phase of the fermentation – methanogenesis – is run by obligatory anaerobes, classified as *Archaea*. Since methanogenic *Archaea* are susceptible to changes in environmental factors (Zinder, 1993), it is necessary to define the operational parameters that promote the optimal conditions for the growth of a numerous and diverse community of these microorganisms in the reactor. Despite the fact that these microorganisms are autotrophic, the growth of most of them is driven by the presence of acetate. The types of

* Corresponding author. Tel.: +48 89 523 41 94; fax: +48 89 523 41 31.
E-mail addresses: magdalena.zielinska@uwm.edu.pl (M. Zielińska), agnieszka.cydzik@uwm.edu.pl (A. Cydzik-Kwiatkowska), marcin.zielinski@uwm.edu.pl (M. Zieliński), marcin.debowski@uwm.edu.pl (M. Dębowski).

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