Effect of hydrodynamic disintegration on the methane potential of the organic fraction of municipal solid waste

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The handling of municipal sewage sludge has become one of the primary problems of many wastewater treatment plants (WWTP), and one of the most important environmental and logistic issues. Another important issue is the management of municipal waste. According to data published by Polish Central Statistical Office (PCSO), the amount of municipal waste produced per capita over the last 5 years increased by nearly 20% (the amount of waste per capita produced in 2015 and 2020 was 283 kg and 342 kg, respectively). Moreover, according to PCSO, only 38% of municipal waste was collected selectively in accordance with a domestic system of national selective waste collection systems. The biodegradable fraction accounted for 12% of all selectively collected waste, amounting to approximately 600.000 Mg (PCSO, 2020). These wastes contain a large amount of organic matter, which is important from the viewpoint of searching for a potential co-substrate in the anaerobic digestion process.

Research conducted in the field of co-digestion of sewage sludge (SS) with the organic fraction of municipal solid waste (OFMSW) by different research groups primarily focuses on the determination of the impact of different mixing ratios of SS with OFMSW on the course of the anaerobic digestion process and methane/biogas yields. For example, according to Gosh *et al* (2020), a mixing ratio of 40:60 (w/w) for OFMSW/SS, accordingly, resulted in a cumulative biogas yield of 586.2 ml of biogas/gVS with the highest methane concentration of 69.5% (lab-scale, mesophilic condition). Borowski (2015), examined anaerobic mesophilic digestion with a mixing ratio of 1:1. It resulted in biogas yield of 494 dm^3/kgVS and methane yield of 316 dm^3CH_4/kgVS. The methane production rate was 73% higher in comparison to mono-digestion.

The effect of preliminary processing by means of disintegration methods on the course and efficiency of the co-digestion process is still insufficiently investigated. Scarce works in the scope suggest that the intended increase in methane production cannot always be obtained (Grosser and Neczaj 2017, Alqaralleh *et al* 2019).

The paper will present results of a study primarily aimed at the determination of the effect of hydrodynamic disintegration (HD) on the methane potential of (Y_{CH4}) OFMSW. Moreover, Y_{CH4} values for OFMSW will be compared to the Y_{CH4} of SS, with consideration of the variant with and without HD. Partial objectives of the paper will also include the analysis of the effect of the disintegration process on: i) chemical characteristics of the digestate sludge liquid with particular consideration of nitrogen and phosphorus compounds; ii) capillary suction time (CST). One of the effects of disintegration is liquefying the solid phase, and consequently a change in the characteristics of the liquid phase.

Methods

The research employed the existing organic fraction of selectively collected municipal solid waste in the city of Warsaw (Poland). A 100 kg waste sample was ground (GP "WOLF 12", 0,95kW), and then averaged by means of a mechanical stirrer (DEXTER Power). Before conducting the disintegration, the substrates were diluted with stood tap water to total solids concentration at a level of approx. 5%. This was necessary to conduct the process of hydrodynamic disintegration of the analysed substrates (at higher concentrations of TS, operational problems occurred, such as spontaneous switching off of the device, or clogging of the rotor).

Sewage sludge was obtained from a wastewater treatment plant with biological nutrient removal (PE = 2 100 000). The substrates were subject to the process of hydrodynamic disintegration at three levels of energy density (ε_L): 10, 30, and 60 kJ/L. In order to assess the possibility of increasing their methane potential (Y_{CH4}), Biochemical Methane Potential tests (BMP) were performed. The BMP tests employed the Automatic Methane Potential Test System (AMPTS II). The detailed methodology of the test was presented in our previous paper (Zubrowska-Sudol *et al* 2020). After completing the BMP tests, the digestate sludge liquid was analysed in the following scope: COD, NH_4-N, TN, PO_4-P, TP. The chemical analyses were performed in accordance with standard analytical procedures (APHA).

Results

The figure presents methane production culmination curves for OFMSW and SS disintegrated at different levels of energy density in reference to samples not subject to pre-processing. In both cases, an increase in methane yield was obtained through conducting the disintegration process at 10 and 30 kJ/L. For OFMSW Y_{CH4}, it then increased from 335.6 NmlCH_4/gVTS to 348.6 NmlCH_4/gVTS (10 kJ/L) and 349.1 NmlCH_4/gVTS (30 kJ/L). For SS, an increase was observed from 241.8 to 251.3 NmlCH_4/gVTS (10 kJ/L) and 255.2 NmlCH_4/gVTS (30 kJ/L). Disintegration conducted at 60 kJ/L caused a decrease in the value of the analysed indicator.

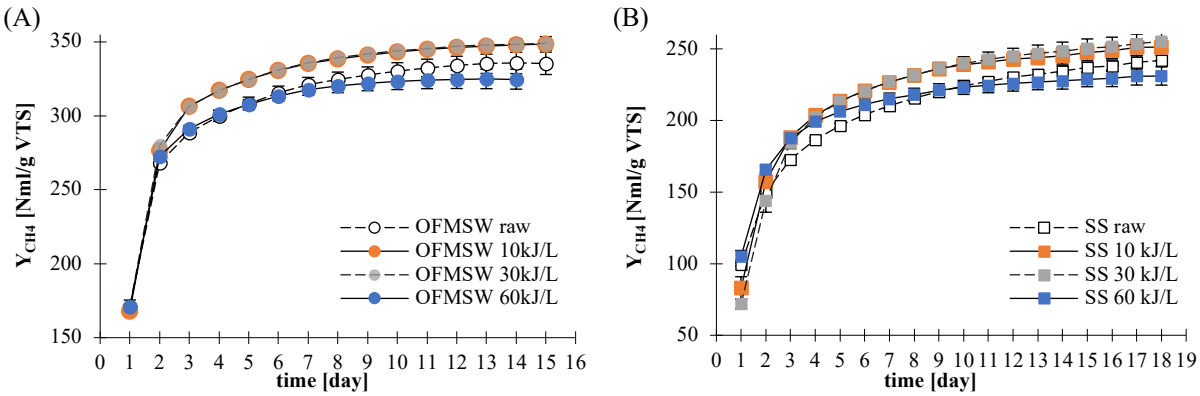

Figure. Methane production culmination curves for OFMSW (A) and SS (B)

Data presented in the Table show that the application of HD had an inconsiderable effect on the concentration of dissolved nitrogen and phosphorus in the samples after the process of anaerobic digestion. TN values in the case of OFMSW and SS increased only by 0.5-3.0% and 1.0-3.4%, respectively in comparison to samples where OFMSW was used as the substrate and SS was not subject to HD. It is worth emphasising that a substantial part of the TN load occurring in digested samples originated from the inoculum, and in the case of OFMSW constituted 95.1-98.2%, and for SS 94.9-98.4%. TP values in disintegrated samples after the process of anaerobic digestion decreased by 1.1-5.5% and 3.4-4.0%, respectively in comparison to samples where OFMSW was used at the substrate and SS was not subject to HD.

The CST of the digested samples OFMSW and SS was in a range of 385.37-401.63 s and 297.29-305.17 s, respectively. In the case of HD of the OFMSW and SS, a decrease in the CST was obtained with increasing energy density up to a value in a range of 349.72-361.43 s and 249.41-254.75 s, respectively (60 kJ/L).

Table. Characteristics of the liquid phase of digested samples

Indicator	Inoculum	OFMSW				Inoculum	SS			
		raw	10 kJ/L	30 kJ/L	60 kJ/L		raw	10 kJ/L	30 kJ/L	60 kJ/L
TN (mg/l)	1102	1122	1130	1128	1156	1028	1044	1054	1044	1080
NH_4-N (mg/l)	960	970	984	978	978	978	982	984	986	998
TP (mg/l)	19.1	18.1	17.9	17.2	17.1	16.3	17.5	17.5	16.8	16.9
PO_4-P (mg/l)	16.3	15.9	15.9	16.0	16.0	15.1	16.2	16.1	15.7	16.0

Conclusion

Considering the above, hydrodynamic disintegration is a promising method of pre-treatment of organic fraction of municipal solid waste and sewage sludge before its use as substrates in the anaerobic digestion process.

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