Impact of hydrodynamic disintegration on the methane potential of selected biowaste

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INTRODUCTION

In agricultural biogas plants treating biodegradable fractions of waste in the process of anaerobic digestion, increasingly more attention is paid to the pre-treatment of the substrate introduced to anaerobic digesters. Appropriate preparation of the feedstock permits an increase in the efficiency of anaerobic digestion, resulting in actual profit in the form of a greater amount of produced biogas or/and its better composition (higher content of methane in biogas). One of the methods of pre-treatment of waste is mechanical disintegration, aimed at an increase in the bioavailability of substrates for bacteria performing acetogenesis and methanogenesis. Zieliński et al. [1], using hydrodynamic cavitation pretreatment and ultrasonic pretreatment of cattle manure and wheat straw, obtained a 16.5% and 24.6% increase in biogas production, respectively. A significant improvement in methane yield of fruit and vegetable wastes in the case of ultrasonic pre-treatment has been reported by Zeynali et al. [2]; the methane yield of a pretreated sample was 80% higher than the control. Shanthi et al. [3], subjecting fruit and vegetable residue to ultrasonic disintegration, and applying dimethyl sulphoxide combined ultrasonic pretreatment, obtained a respective 196% and 288% increase in methane yield in comparison to the control sample. Mönch-Tegeder et al. [4], applying mechanical disintegration of horse manure, recorded a 26.5% increase in biogas production. One of the factors determining the practical application of disintegration in the improvement of the efficiency of anaerobic digestion is the energy consumption of the process. The analysis of the available methods of disintegration shows that hydrodynamic disintegration is one of the least energy-consuming methods. This property of hydrodynamic disintegration encouraged us to conduct a study on the possibility of application of the process for increasing the methane potential of organic waste used as substrates in biogas plants. The study results are presented in this paper. The study involved conducting biochemical methane potential tests. Moreover, the effect of pre-treatment on: 1) physicochemical properties of selected organic waste (comparison of properties of waste before and after disintegration) and 2) properties of digestate were analysed. In both cases, the scope of the analysis included: soluble COD (SCOD), VFA, soluble total nitrogen, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, soluble total phosphorus, orthophosphates, alkalinity, and pH.

METHODS

The study was performed for three types of biowaste: remains of fruits (RF), sugar beet pulp (SBP), and sugar beet pulp in the form of pellets (SBP_Pellet). RF were obtained from a plant producing frozen foods, concentrates, and purees, and SBP and SBP_Pellet from a sugar refinery producing sugar from sugar beetroot (Poland). The waste was characterised by the following concentration of total solids (TS): remains of fruits 22.9–30.2%, sugar beet pulp 9.4–9.7%, sugar beet pulp in the form of pellets 88.3–88.7%. The aforementioned substrates were subject to the process of hydrodynamic disintegration at three levels of energy density (ε_l): 35, 70, and 140 kJ/l. Before conducting these processes, the substrates were diluted with stood tap water to total solids concentration at a level of 4–5%. This was necessary to be able to conduct the process of hydrodynamic disintegration of the analysed substrates (at higher concentrations of TS, operational problems occurred, such as spontaneous turning off of the device, or clogging of the rotor). Moreover, in the case of SBP_Pellet, the sample after adding tap water was left for 45 minutes to "soften" the pellets (the disintegration process would be impossible without this procedure). The disintegration process employed a newly designed hydrodynamic disintegrator [patent application: WP-84/JW l3766l18, 27.12.2018]. The process was conducted at variable electricity consumption defined as energy density (ε_L): 35, 70, and 140 kJ/l. Biochemical methane potential tests (BMP) were performed in an AMPTS (Automatic Methane Potential Test System) device in accordance with the methodology by Holliger et al [5], with the assumption that the inoculum load equals 5 g VS/l. All chemical analyses were performed in duplicate and in accordance with APHA Standard Methods.

RESULTS

Table 1 Methane potential yield for the analysed waste

Type of waste	Methane potential yield (Y_{CH4}) $NmlCH_4/g$ VS			
	without HD	with HD at the following ε_L:		
		35 kJ/l	70 kJ/l	140 kJ/l
Remains of fruits	249	273	261	251
Sugar beet pulp	294	276	256	253
Sugar beet pulp in the form of pellets	326	483	335	281

The results presented in Table 1 and Figure 1 indicate that hydrodynamic disintegration allowed for increasing the methane potential of remains of fruits and sugar beet pulp in the form of pellets. Moreover, energy density at which the disintegration process was conducted was found to be an important parameter affecting the Y_{CH4} value. The highest increase in Y_{CH4} was observed for a disintegrated sample at ε_l=35 kJ/l: 48% higher for SBP_Pellet and 9.6% higher for RF. An increase in ε_l to 70 kJ/l still allowed for an increase in Y_{CH4}, but only by 2.7% and 5.2%, respectively. It is also worth emphasising that subjecting SBP_Pellet to the HD process at ε_l =140 kJ/l caused a decrease in Y_{CH4}. An analogical phenomenon was observed for SBP for all the analysed levels of energy density at which the process of hydrodynamic disintegration was conducted. To sum up, hydrodynamic disintegration is a promising method of pre-treatment of biowaste before its use as substrates in the anaerobic digestion process. Nonetheless, obtaining the expected result requires verification at a laboratory scale, before commencing applicative activities, whether the HD process leads to an increase in Y_{CH4} (especially that HD may lead to a decrease in the amount of produced biogas). The research also documented that the application of HD as pretreatment of RF, SBP, or SBP_Pellet affects the physicochemical properties of digestate.

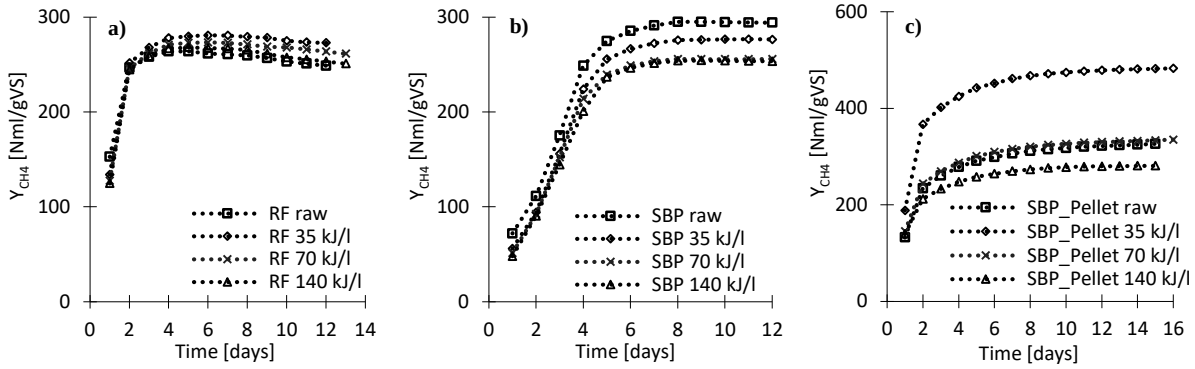

Figure. 1 Cumulative methane potential yield: a) remains of fruits b) sugar beet pulp, c) sugar beet pulp in the form of pellets

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