Application of sewage sludge disintegration method to intensify anaerobic digestion process

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Introduction

It is known that the disintegration of sewage sludge can lead to breaking floc structure and the destruction of cells of microorganisms and, in consequence, allows for the release of substances from intra- and extracellular structures (Yao et al., 2022). Application of the disintegration as the preliminary processing of sludge supplied to fermentation chambers allows for an increase in the availability of the substrate for bacteria carrying out acidogenesis and methanogenesis, therefore is used as one of the methods to intensify the anaerobic digestion process (Jeong et al., 2019).

Previous studies, including own research, based on biochemical potential test results, documented the possibility of increasing the methane potential of sewage sludge and other substrates after the disintegration process (Walczak et al. 2023). In our project we decided to verify the application of sewage sludge disintegration as a pretreatment method in a semi-continuous culture mode, permitting detailed determination of the digestion time and identification of the potential phenomenon of process inhibition.

Methods

The scope of the project assumes the application of a few technological variants: separated disintegration (including hydrodynamic and chemical disintegration) and hybrid disintegration and involves the analysis of the effect of process parameters such as: energy density and dose of the disintegrating medium. This report presents results of variant A: applying hydrodynamic disintegration. The sewage sludge: thickened excess sludge (TES) and inoculum (I) used in the study was obtained from WWTP, with a population equivalent of 2.100.000 and was characterized by TS: 5.53-5.98% and 3.30%, VS: 3.37–5.22 and 2.08%, pH: 6.71-7.2 and 7.5, for TES and I respectively. The disintegration process employed a hydrodynamic disintegrator. The device is powered by an electric 5.5 kW engine with rotational speed of 1500 rpm. Pre-treatment involved hydrodynamic disintegration at two different levels of energy density ($\mathcal{E}_L$): 10 and 45 kJ/L. Batch disintegration tests (Zubrowska-Sudol *et al.*, 2020) were performed to determine the release of organic compounds and to assess the impact of disintegration on in physical-chemical properties of TES. The influence of hydrodynamic disintegration on methane production were performed in a BioReactor Simulator (BRS, BPC Instruments, Sweden) in a semi-continuous culture mode. BRS device composed of 6 test reactors with a working volume of 1.8 L each. The anaerobic digestion process was conducted at a temperature of 37°C with a constant value of sludge retention time - 21 days. Organic loading rate was in range of 1.43-2.05 gVS/(L·d) Each trial, which means digestion: sludge without pretreatment (R1, R2), sludge disintegrated at 10 kJ/L (R3,R4) and 45 kJ/L(R5,R6) was performed in two repetitions.

Results

Results showed that hydrodynamic disintegration at both applied $\mathcal{E}_L$ values led to an increase in the content of soluble SCOD (SCOD) and volatile fatty acids (VFA) concentrations (Figure 1). A higher $\mathcal{E}_L$ value resulted in a higher concentration of organic compounds. SCOD and VFA concentrations averaged from 262±38.4 mgO_2/L and 55.5±8.80 mg/L for raw TES to 683±164 mgO_2/L and 82.5±13.5 mg/L for TES disintegrated at $\mathcal{E}_L$=45 kJ/L. Hydrodynamic pretreatment allowed for only a slight increase in methane production – average daily methane production for sludge disintegrated at $\mathcal{E}_L$=45 kJ/L was a few percent more than in the case of the non-disintegrated sample (Figure 2). Moreover, foaming problems were observed in the reactors with disintegrated sludge.

Conclusion

Although the application of disintegration method before anaerobic digestion of sewage sludge seems justified, results obtained in the first stage of the project are not satisfactory. In the next stage, it is planned to test other variants of disintegration, as well as conduct an analysis of the possibility of obtaining a positive energy balance.

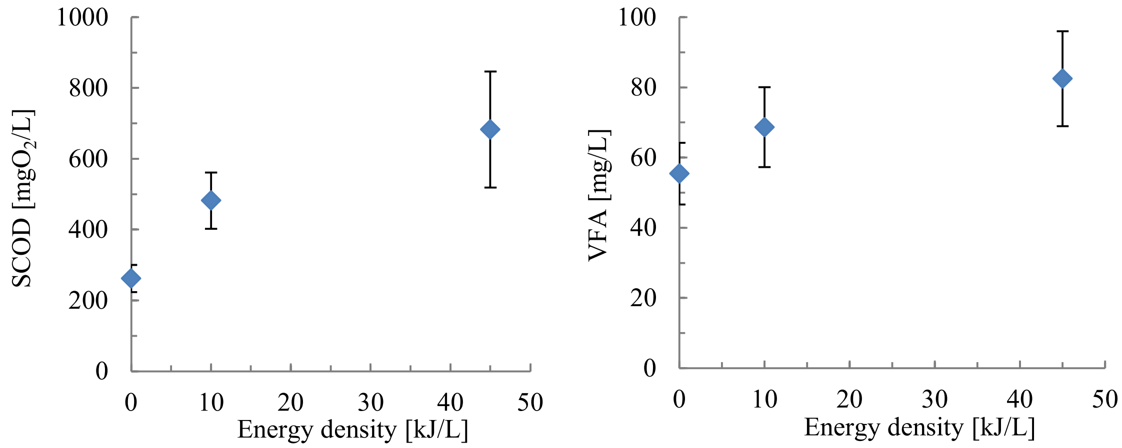

Figure 1. Results of hydrodynamic disintegration tests.

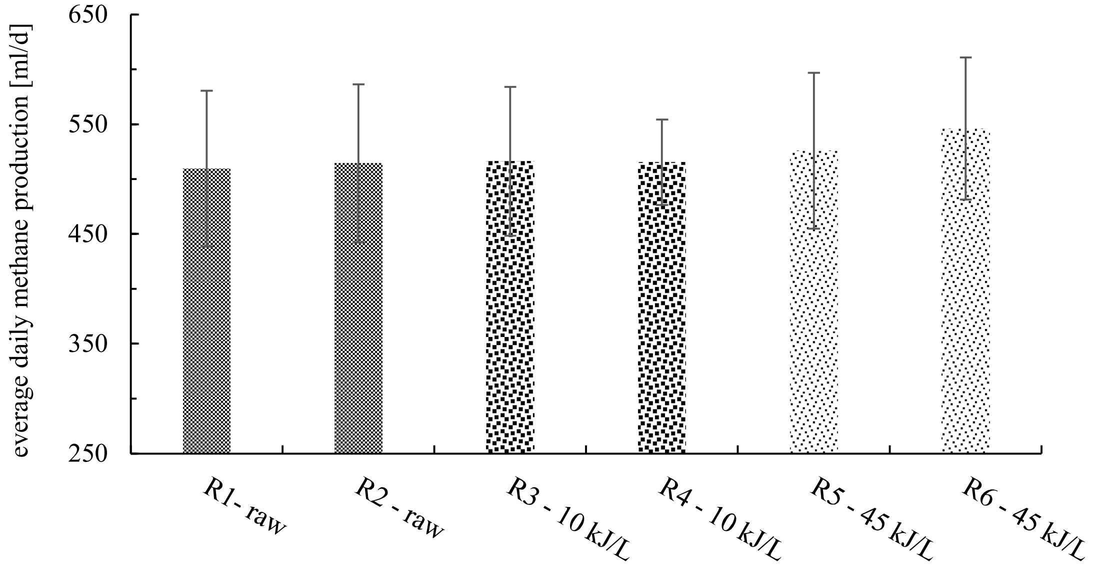

Figure 2. Influence of hydrodynamic disintegration pretreatment on methane production.

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References

Jeong S. Y., Chang S. W., Ngo H. H., Guo W., Nghiem L. D., Banu J. R., Nguyen D. D. (2019). Influence of thermal hydrolysis pretreatment on physicochemical properties and anaerobic biodegradability of waste activated sludge with different solids content. *Waste Management*, **85**, 214-22.

Walczak Justyna, Dzido Aleksandra, Jankowska Honorata, Krawczyk Piotr, Żubrowska-Sudoł Monika: Effects of various rotational speeds of hydrodynamic disintegrator on carbon, nutrient, and energy recovery from sewage sludge, Water Research, vol. 243, 2023, Numer artykułu: 120365, s. 1-11, DOI:10.1016/j.watres.2023.120365

Yao Y., Sun Y., Wang X., Song Y., Wang Z. (2022). Insight into the sludge reduction performances by hydrodynamic cavitation, *Journal of Water Process Engineering,* **49**, 102950

Żubrowska-Sudol, M. Dzido A., Garlicka A., Krawczyk P., Stępień M., Umiejewska K., Walczak J., Wołowicz M., Sytek-Szmeichel K. (2020). Innovative Hydrodynamic Disintegrator Adjusted to Agricultural Substrates Pre-treatment Aimed at Methane Production Intensification—CFD Modelling and Batch Tests. *Energies*, **13**(16), no: 4256