Application of sewage sludge disintegration method to intensify anaerobic digestion process

Katarzyna Sytek-Szmeichel, Justyna Walczak*, Monika Żubrowska-Sudoł**

*Department of Water Supply and Wastewater Treatment,
Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology,
Nowowiejska 20, 00-653 Warsaw, PL
(E-mail: katarzyna.szmeichel@pw.edu.pl)

Faculty of Building Services, Hydro and Environmental Engineering
Warsaw University of Technology

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*).

RESEARCH CHALLENGE — DISINTEGRATION

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 disintegration (*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. This report presents results of variant A: applying hydrodynamic disintegration (**HD**).

Preliminary treatment in the form of the disintegration process will be analyzed in two technological variants:
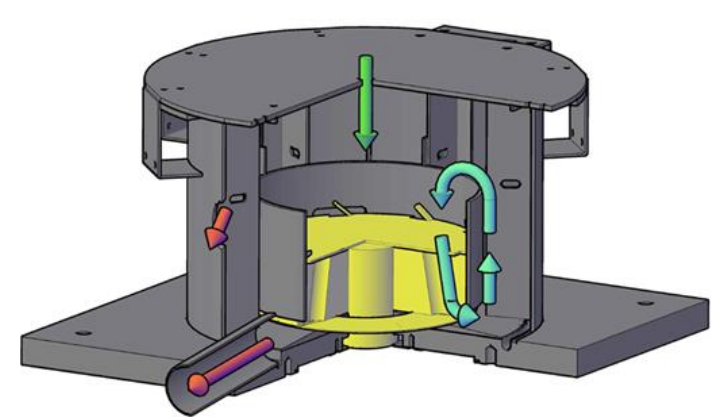
A separated disintegration → • hydrodynamic disintegration • chemical disintegration (NaOH)

B hybrid disintegration → a combination of both methods analysed in A variant

Methods

The sewage sludge: thickened excess sludge (**TES**) and inoculum (**I**) used in the study was obtained from WWTP, PE: 2.100.000.

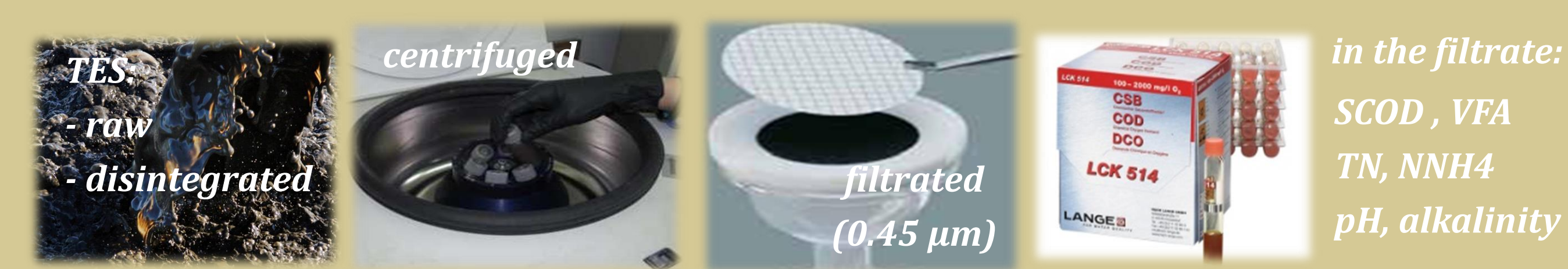| Indicators	TES	I
TS [%]	5.53-5.98	3.30
VS [%]	3.37-5.33	2.08
pH [-]	6.71-7.20	7.50

Pretreatment

The device is powered by an electric 5.5 kW engine with rotational speed of 1500 rpm

Two different levels of energy density (ε_L): 10 and 45 kJ/L

Disintegration Batch Tests (*Żubrowska-Sudoł et al., 2020*)

TES raw - disintegrated → centrifuged → filtrated (0.45 μm) → in the filtrate: SCOD , VFA TN, NNH4 pH, alkalinity

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 (working volume - 1.8 L of each)

mesophilic fermentation (37°C)

constant value of sludge retention time - 21 days organic loading rate: 1.43-2.05 gVS/(L·d)

impact of **HD** on physical-chemical properties of **TES**

Each trial, which means digestion:
- sludge without pretreatment (R1, R2),
- sludge disintegrated at 10 kJ/L (R3, R4)
- sludge disintegrated at 45 kJ/L (R5, R6)
was performed in two repetitions.

Results

Results of hydrodynamic disintegration tests

Results showed that hydrodynamic disintegration at both applied energy density values (10 and 45 kJ/L) led to an increase in the content of soluble COD (SCOD) and volatile fatty acids (VFA) concentrations (*Figure 1*). A higher ε_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 ε_L=45 kJ/L.

Results of semi-continuous anaerobic digestion

Hydrodynamic pretreatment allowed for only a slight increase in methane production – average daily methane production for sludge disintegrated at ε_L=45 kJ/L was a few percent more than in the case of the non-disintegrated sample (*Figure 2*). HD also enabled slightly better reduction of VS (*Table 1*).
Worse dewatering properties were observed in the digested sludge from R4 and R5 - the average CSK value was 5% higher than in the case of raw sludge (*Table 2*). Moreover, foaming problems were observed in the reactors with disintegrated sludge.
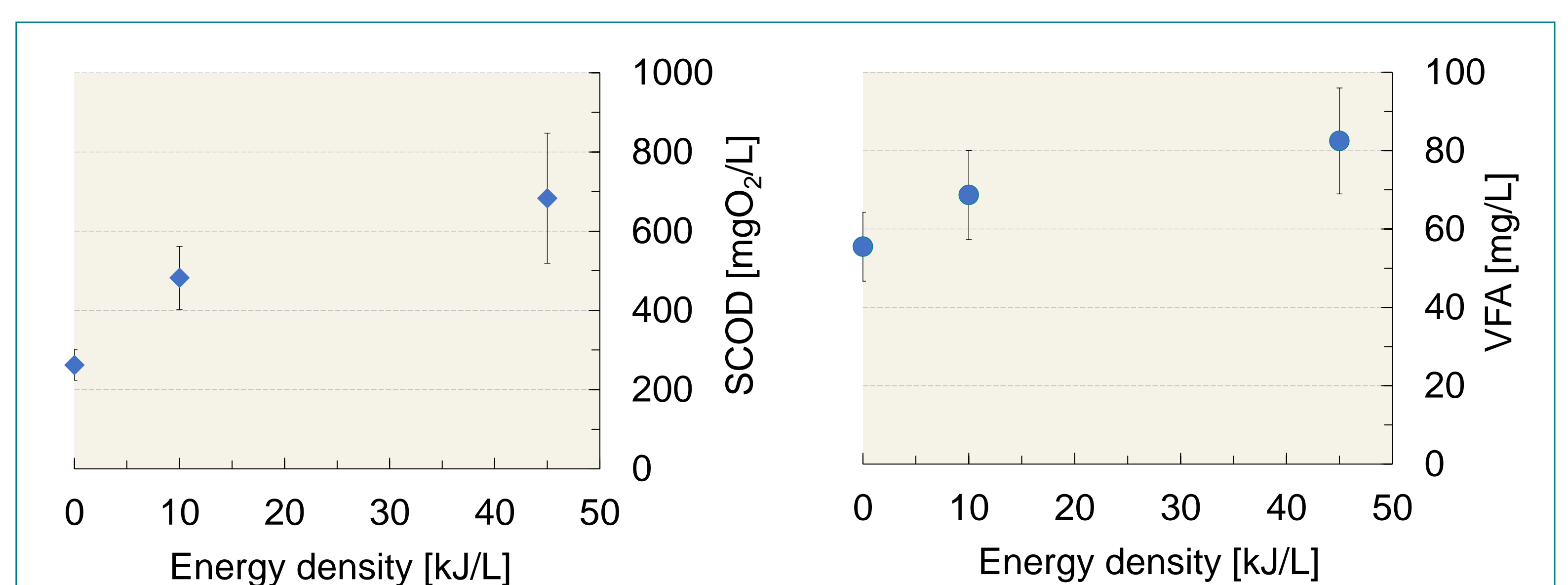

Figure 1. Organic compounds release from solid parts of TES via HD
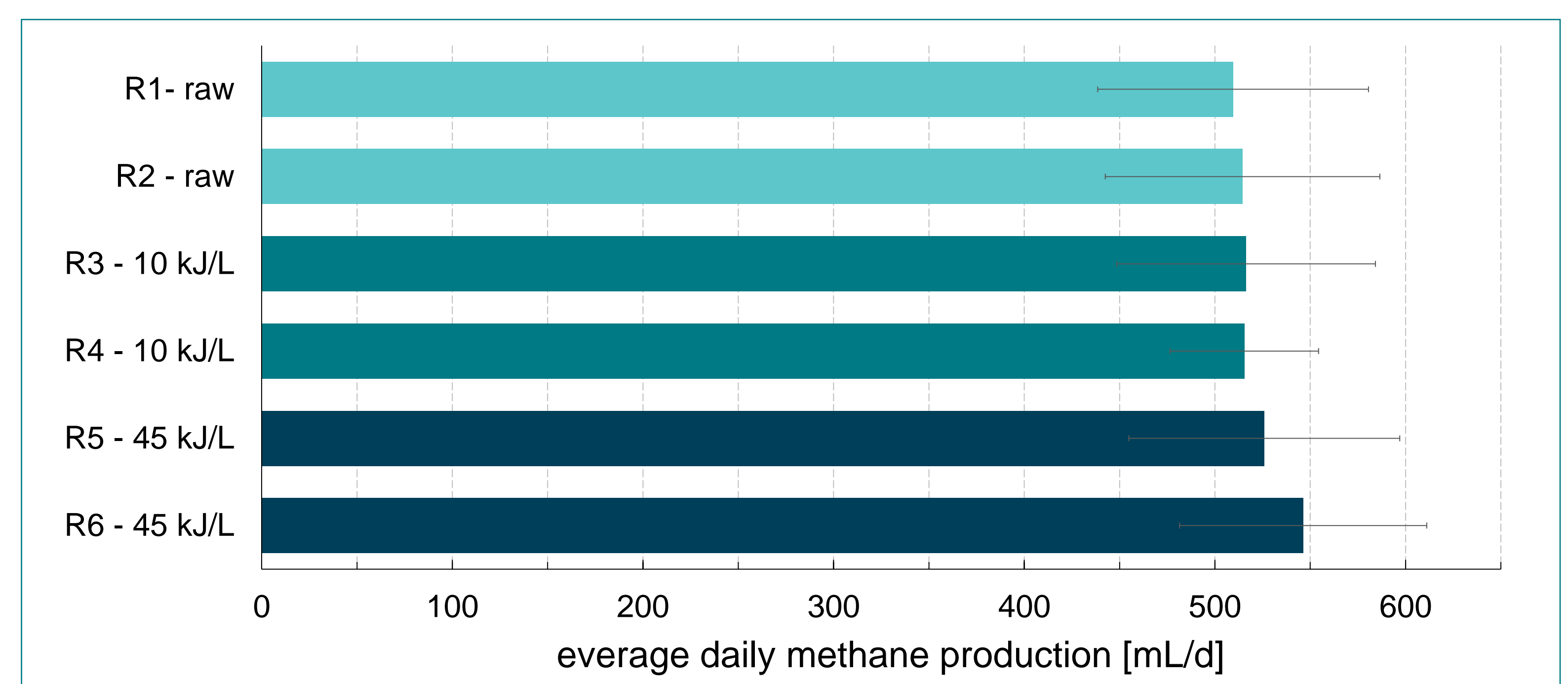
Figure 2. Influence of HD pretreatment on methane production

Table 1. VS reduction in AD

	VS reduction [%]
TES	46.5 ± 2.73
10 kJ/L	47.7 ± 2.11
45 kJ/L	50.7 ± 2.02

Table 2. Dewatering properties

	CSK [sec]
TES	730 ± 171
10 kJ/L	727 ± 58.4
45 kJ/L	855 ± 151

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-Sudoł, 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

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.

Warsaw University of Technology

EXCELLENCE INITIATIVE RESEARCH UNIVERSITY