

Organizator:

A stylized graphic on the left side of the slide. It consists of a dark blue water drop shape at the top, which transitions into a series of flowing, wavy lines in shades of blue and white, resembling water or a wave.

19. Konferencja
METODY ZAGOSPODAROWANIA OSADÓW ŚCIEKOWYCH
30 września - 2 października 2025r. / Uniejów

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Organizator:



Dezintegracja mechaniczna – proces, możliwości, zastosowania

Justyna WALCZAK

Katarzyna SYTEK-SZMEICHEL

Monika ŻUBROWSKA-SUDOŁ

Osad ściekowy — alternatywne źródło:



**Związków
organicznych**

**Energii
elektrycznej**

Ciepła

Azotu

Fosforu

Alginianów

Białka

Enzymów

**Materiałów do
produkcji kruszyw**

PHA

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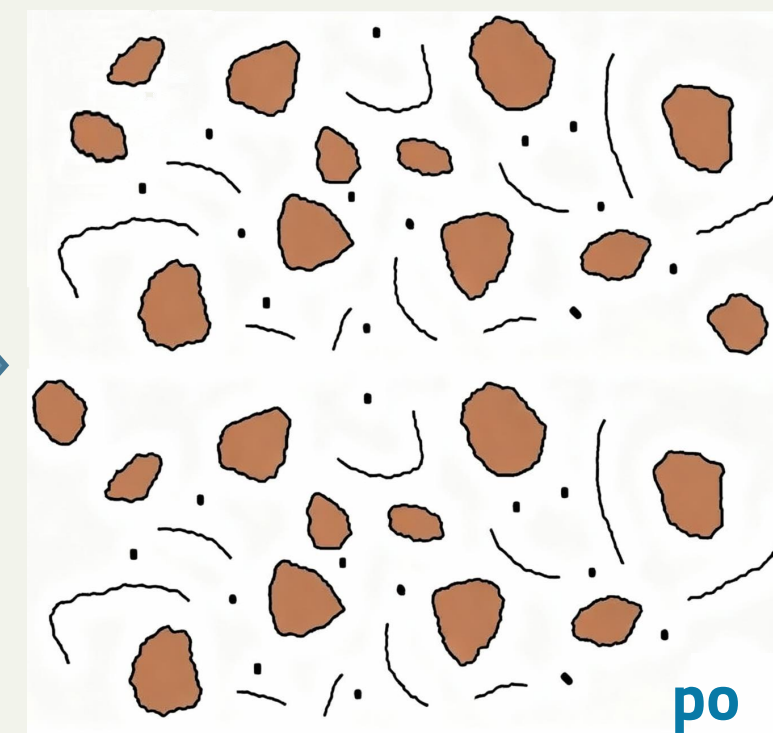
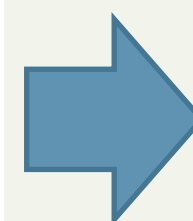
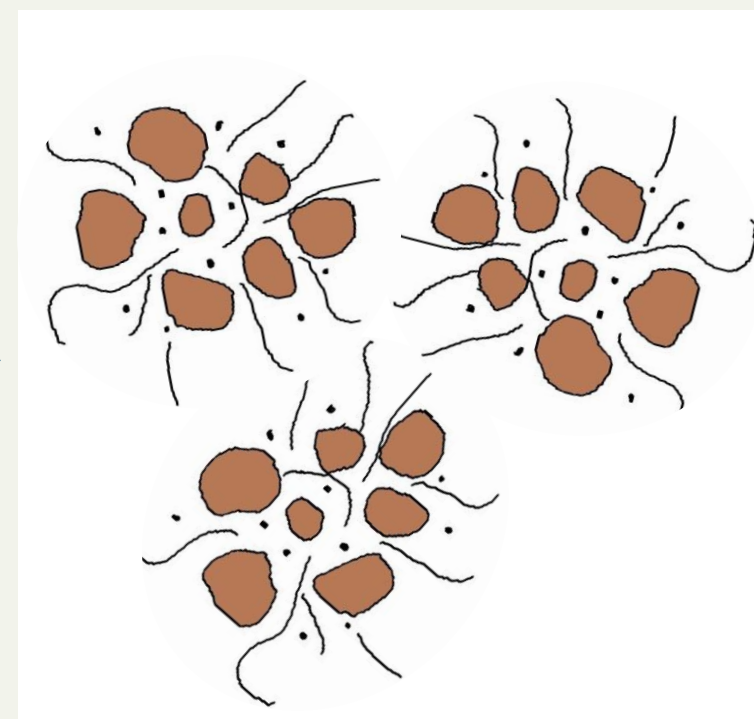
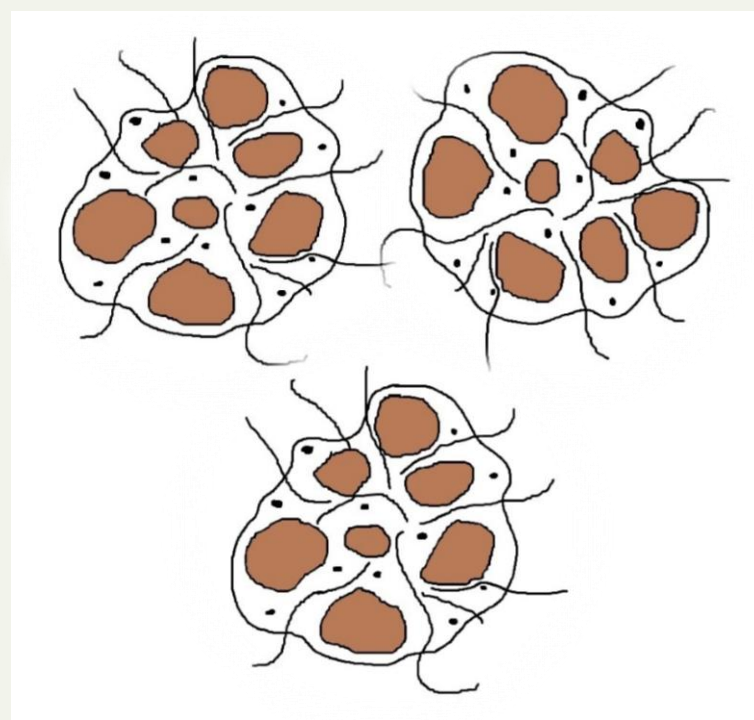
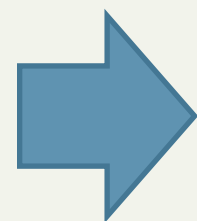
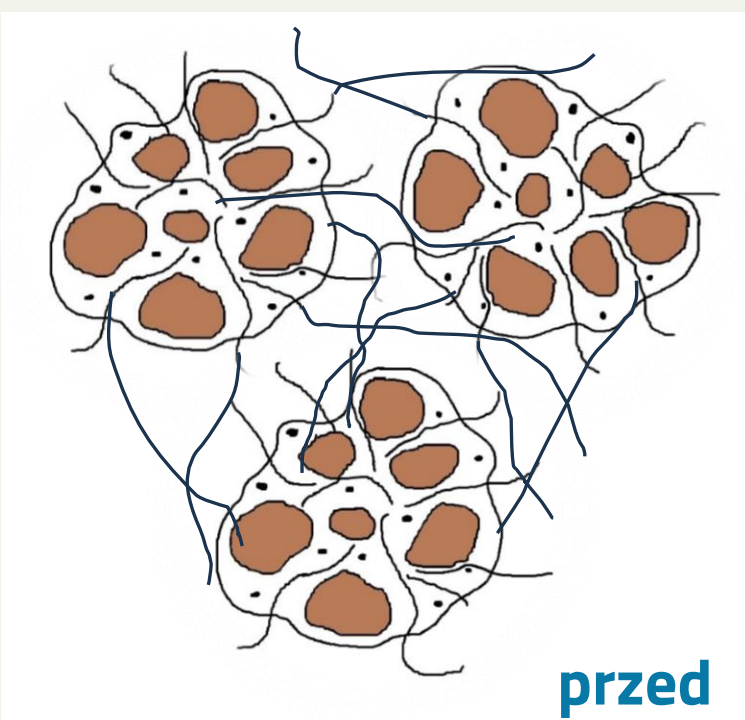
Enzymów

PHA

Proces dezintegracji przed procesem fermentacji metanowej ma na celu zwiększenie dostępności substratu dla drobnoustrojów biorących udział w procesie fermentacji metanowej

Mechanizm dezintegracji

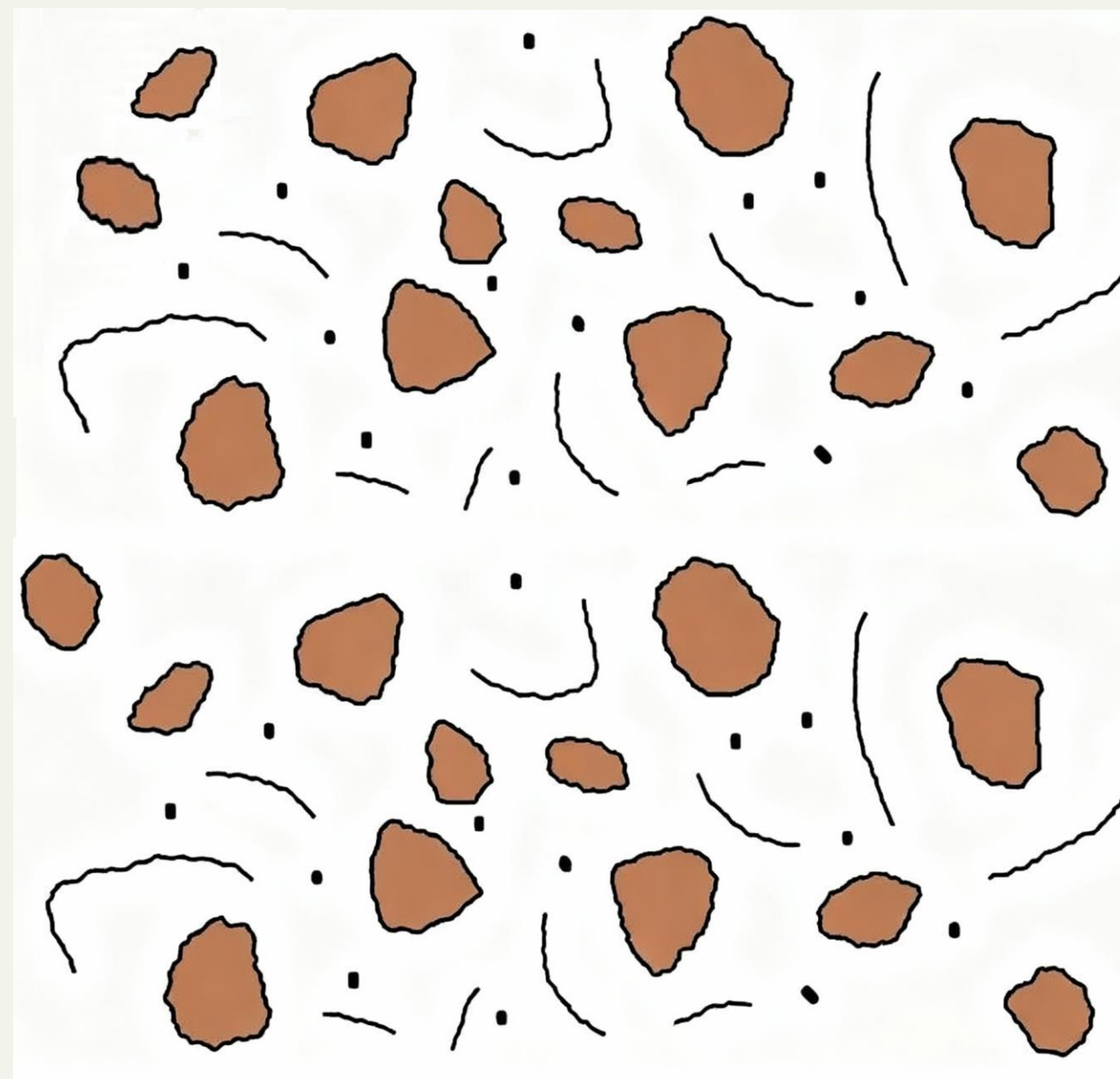
- i) rozbicie kłaczkowatej osadu struktury osadu czynnego, utworzonej przez zewnątrzkomórkowe substancje polimeryczne (EPS),
- ii) zniszczenie komórek mikroorganizmów i uwolnienia struktur wewnątrzkomórkowych,
- iii) fragmentacja substancji wielkocząsteczkowych uwolnionych ze struktur zewnątrz- i wewnątrzkomórkowych.



związki
organiczne (C)

DNA, RNA

PHA, białka, inne



składniki
odżywcze (N i P)

jony np. Ca^{2+} i Mg^{2+}

Metody dezintegracji

Fizyczne

Hydroliza termiczna
Hydrodynamiczna
Ultradźwiękowa
Mikrofalowa
Wysokociśnieniowa homogenizacja
Zamrażanie-rozmrażanie

Chemiczne

Alkaliczna
Kwasowa
Ozonowanie
Odczynnik Fentona

Biologiczne

Bakterie egzogenne
Liza enzymatyczna
Komórki elektrolizy
mikrobiologicznej
Mikronapowietrzanie

Metody dezintegracji

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Hydroliza termiczna
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Mikronapowietrzanie

metody hybrydowe

Metoda dezintegracji	Podstawowe parametry dezintegracji	Wzrost produkcji metanu/biogazu ^{*)}	Pozycja literatury
Ultradźwiękowa	3 min.	13,1 % ^{*)}	Cimochowicz-Rybicka 2014
	5 min.	11 % ^{*)}	
	7 min.	34,5 % ^{*)}	
	9 min.	35 % ^{*)}	
	96 kJ/ kg osadu	27 % ^{*)}	Houtmeyers S. et al. 2014
	15 000 kJ/kg s.m.	8,58 % ^{*)}	Lizama et al. 2017
	25 000 kJ/kg s.m.	22,95 % ^{*)}	
	35 000 kJ/kg s.m.	31,43 % ^{*)}	
	15 min.	19,4 % ^{*)}	Hajduk et al. 2015
	1W/ml, 10 min.	18,6	Li et al. 2019
Hydrodynamiczna	24 kJ/g s.m.o	20	D. Lu et al. 2018
	200 kJ/kg s.m.	ok. 7 ± 6 % ¹⁾	Lippert et al. 2018
	300 kJ/kg s.m.	25 %	Bandelin et al. 2020
	2850 rpm, moc silnika 5,5kW	12,7 % ^{*)}	Petkovšek et al., 2015
	30 kJ/L	14,1 % ^{*)}	Żubrowska-Sudol et al., 2017
	20 kJ/l	33,9 % ^{*)}	Żubrowska-Sudol et al., 2018
	140 kJ/l	152 %	Garlicka et al. 2020
	210 kJ/l	35 %	

Metoda dezintegracji	Podstawowe parametry dezintegracji	Wzrost produkcji metanu/biogazu ^{*)}	Pozycja literatury
Mikrofalowa	4 min., 700 W	49 % ^{*)}	Bohdziewicz et al. 2011
	4 min., 900 W	60 % ^{*)}	
	336 kJ/ kg osadu	50 %	Appels L. et al. 2013
	96 kJ/ kg osadu	20 % ^{*)}	Houtmeyers S. et al. 2014
	20 MJ/kg s.m.	93,7 %	Peng et al. 2018
	20 MJ/kg s.m.	20 %	Gil et al., 2018
	4 min	63 %	Liu X. et al. 2019
	8 min	92 %	
	12 min	106 %	
Termiczna	134°C, 3,4 Bar, 30 min.	95 %	Liu J. et al. 2020
	134°C, 3,4 Bar, 30 min.	96 %	Chen et al. 2020
	60°C	13,7 %	Kumar Biswal B. et al. 2020
	80°C	27 %	
	100°C	29 %	
	120°C	29, 6%	
Chemiczna	0,1 g NaOH/g s.m.o.	112 % ^{*)}	Zawieja i Wolny 2014
	pH 12,0 (5 M NaOH), 30 min.	11,8 %	Lu D. et al. 2018
	pH 10 (1 N NaOH), 10 min, 60°C	43,61 %	Tulun i Bilgin 2019
	pH 5 (1 N H ₂ SO ₄), 15 min., 40°C	12,34 %	
	pH 12,0 (4 M NaOH), 12 h	49,4 %	Xu X.-J. et al. 2020

Metoda dezintegracji	Podstawowe parametry dezintegracji	Wzrost produkcji metanu/biogazu ^{*)}	Pozycja literatury
Hybrydowa	hydroliza alkaliczna+hydrodynamiczna pH 9,0, 30 min	57 %	Grubel et al., 2014
	mikrofale+cytrynian sodowy 20 MJ/kgTS + 0,11 g /g s.m.	147,7 %	Peng et al. 2018
	hydroliza alkaliczna+mikrofale+H ₂ O ₂ pH 10,0, 80°C, 600W+0,2 H ₂ O ₂ /g s.m.	19,9 %	Liu J. et al. 2018
	wolny amoniak + termiczna pH 9,0 + 70°C+135,4 mg N-NH ₃ /l, t=24 h	25,2 %	Liu X. et al. 2018
	hydroliza alkaliczna+utradźwięki pH 12,0 + 24 kJ/g s.m.o	32,8 %	Lu D. et al. 2018
	hydroliza alkaliczna +utradźwięki 0,05 g NaOH/g s.m + 9 min.	31,5 %	Tian et al. 2018
	nadtlenek wapnia + ultradźwięki 0,1 g CaO ₂ /g s.m.o + 1W/ml, 10 min.	36 %	Li et al. 2019
	tlenek wapnia + ultradźwięki 0,04 g CaO/g s.m.+ 20kHz, 150W, 30 min.	40 %	Yuan et al. 2019
	wolny kwas azotawy+żelazian potasu 0,06 g NaNO ₂ /g s.m. + 0,25 g K ₂ FeO ₄ /g s.m.	140 %	Wang et al. 2020
	hydroliza alkaliczna+termiczna pH 12,0 + 134°C, 3,4 Bar, 30 min.	138 %	Liu J. et al. 2020
	hydroliza alkaliczna+termiczna pH 12,0 + 134°C, 3,4 Bar, 30 min.	142 %	Chen et al. 2020

Pozytywne przykłady

Energia włożona
(dezintegracja)



Energia wyprodukowana
(netto)

Pozytywne przykłady

- Ponad 12% wzrost produkcji metanu
- 122% nadwyżka energii w stosunku do energii włożonej w proces sonifikacji



Bioresource Technology

Volume 264, September 2018, Pages 298-305



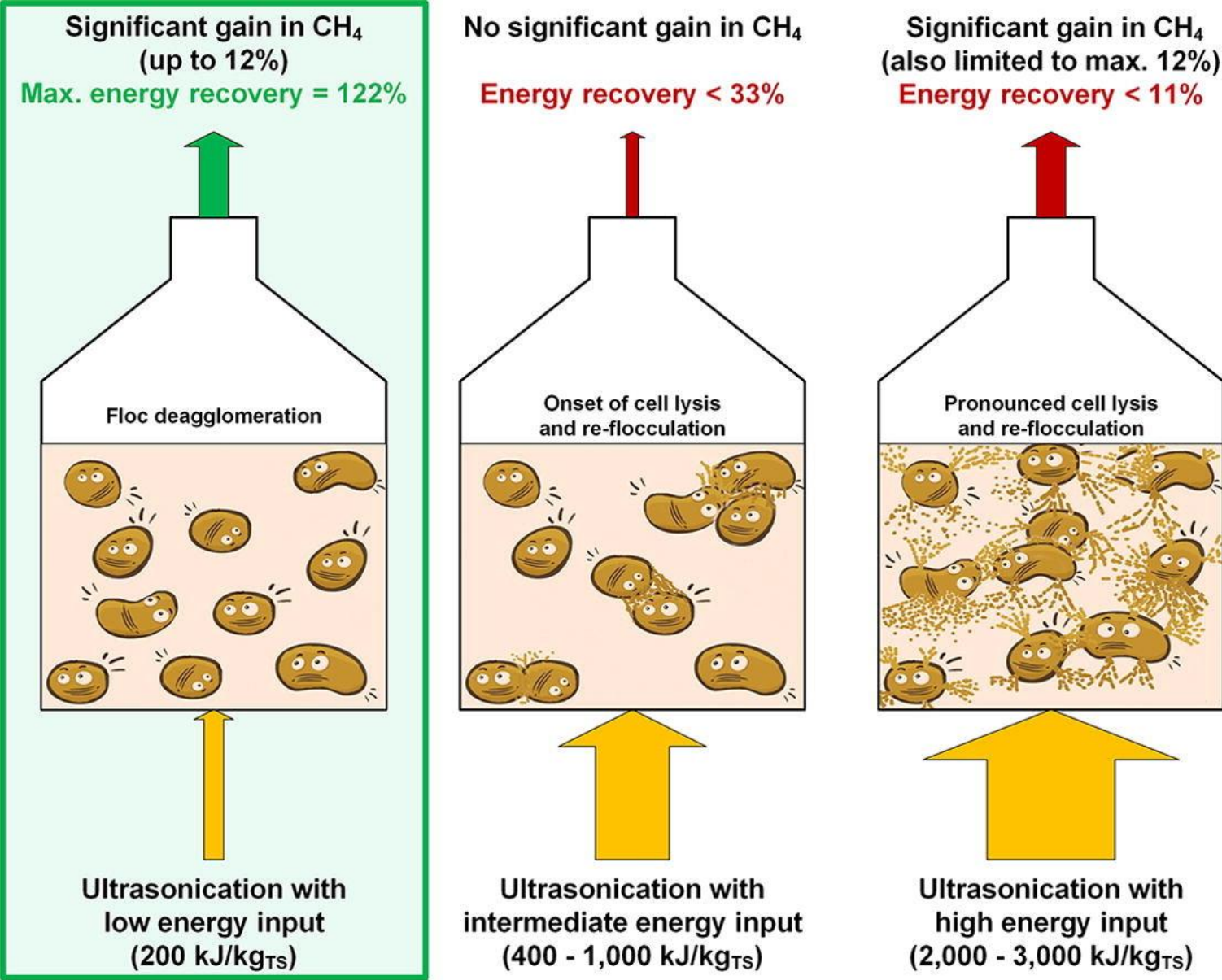
Energy-positive sewage sludge pre-treatment with a novel ultrasonic flatbed reactor at low energy input

Thomas Lippert, Jochen Bandelin, Alexandra Musch, Jörg E. Drewes, Konrad Koch

Show more

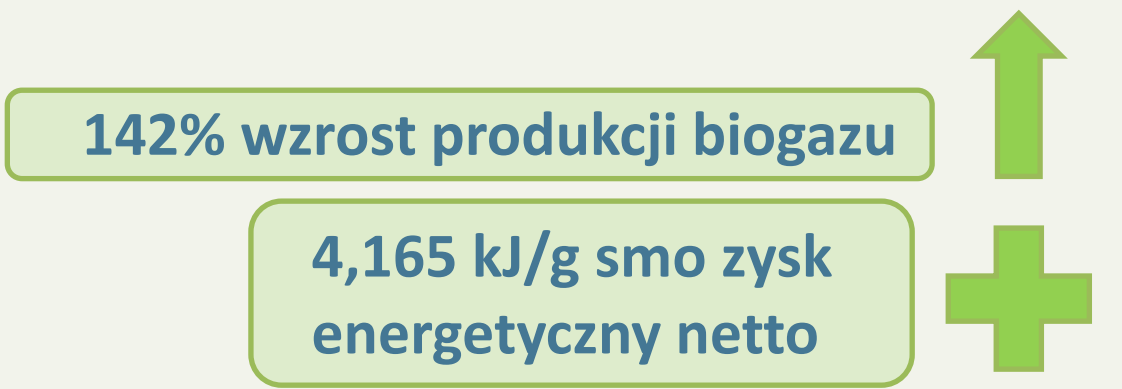
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<https://doi.org/10.1016/j.biortech.2018.05.073> [Get rights and content](#)



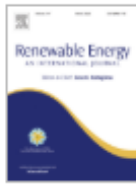
Lippert et al. 2018. Energy-positive sewage sludge pre-treatment with a novel ultrasonic flatbed reactor at low energy input. Bioresource Technology 264, 298–305

Pozytywne przykłady





Renewable Energy
Volume 147, Part 1, March 2020, Pages 2409–2416



Effects of thermal and thermal-alkaline pretreatments on continuous anaerobic sludge digestion: Performance, energy balance and, enhancement mechanism

Hong Chen ^a, Hao Yi ^b, Hechao Li ^c, Xuesong Guo ^d, Benyi Xiao ^d  

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<https://doi.org/10.1016/j.renene.2019.10.051> [Get rights and content](#) 

Table 6
Energy balance of the ADs during the steady period.

Item		AD-RS	TP + AD	TAP + AD
E _o (kJ/g VS)		3.449	7.153	10.219
E _i	E _{i, Pretreatment} (kJ/g VS)	0	7.449	9.163
	E _{i, AD electricity} (kJ/g VS)	0.523	0.571	0.636
	E _{i, AD heat} (kJ/g VS)	0.919	−3.360	−3.745
E _o /E _i		2.392	1.535	1.688
ΔE (kJ/g VS)		2.007	2.493	4.165

E_o: Energy output; E_i: Energy input; E_{i, Pretreatment}: Energy input in pretreatment.
E_{i, AD electricity}: Electricity input in AD; E_{i, AD heat}: Heat input in AD.

Chen et al. 2020. Effects of thermal and thermal-alkaline pretreatments on continuous anaerobic sludge digestion: Performance, energy balance and, enhancement mechanism. Renewable Energy 147 (1), 2409-2416

 **Journal of Environmental Management**
Volume 213, 1 May 2018, Pages 271-278

Research article

Combining microwave irradiation with sodium citrate addition improves the pre-treatment on anaerobic digestion of excess sewage sludge

Liyu Peng ^{a, b}, Lise Appels ^{b, 1}  , Haijia Su ^{a, 1}  

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<https://doi.org/10.1016/j.jenvman.2018.02.053> [Get rights and content](#) 

Abstract

This study investigated the synergistic effect of sodium citrate (SC; $\text{Na}_3\text{C}_3\text{H}_5\text{O}(\text{COO})_3$) and microwave (MW) treatment on the efficiency of the anaerobic digestion of excess sewage sludge. In terms of the methane yield, an increase of the digestion's efficiency was observed. Taking into account the cost for the MW energy supplied to the system, the optimum treatment conditions were a MW energy input of 20 MJ/kg TS and a SC concentration of 0.11 g/g TS, obtaining a methane yield of 218.88 ml/g VS, i.e., an increase of 147.7% compared to the control. MW treatment was found to break the sludge structure, thereby improving the release of extracellular polymeric substances (EPS) and volatile fatty acids (VFAs). The treatment of sodium citrate further strengthened the breakage of loosely bound extracellular polymeric substances (LB-EPS) and tightly bound extracellular polymeric substances (TB-EPS). The increased VFA content stressed the improved digestion by this pretreatment. Furthermore, the preliminary economic analysis showed that at this point in the research, only operational but no financial gains were achieved.



Original Research

Waste sludge disintegration, methanogenesis and final disposal via various pretreatments: Comparison of performance and effectiveness

Haiyang He ^a, Xiaodong Xin ^b, Wei Qiu ^a , Dong Li ^c, Zhicen Liu ^d, Jun Ma ^a

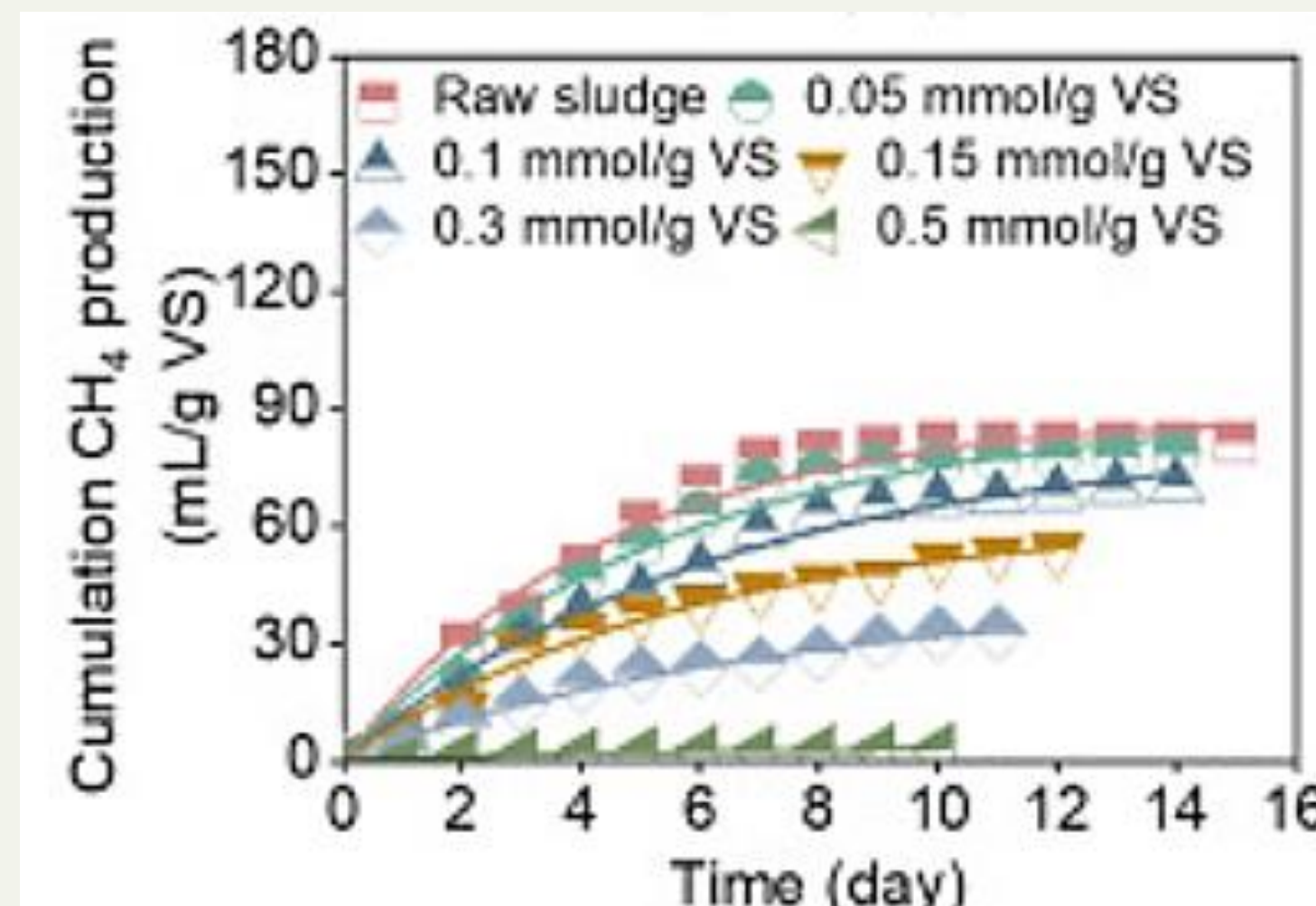
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<https://doi.org/10.1016/j.ese.2021.100132>

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Spadek produkcji metanu



Przyczyny/zagrożenia

- i) reflokulacja kłaczków
- ii) inhibicja (np. wzrost stężenia azotu amonowego i potencjalne zwiększenie stężenia wolnego amoniaku czy wzrost stężenia LKT powodujące inhibicję metanogentów)
- iii) niepożądany stosunek C/N
- iv) zmiana podatności pofermentu na procesy odwadniania
- v) wpływ na jakość odcieków



Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Hydrodynamic disintegration effects assessment by CFD modelling integrated with bench tests

Aleksandra Dzido^{a,*}, Justyna Walczak^b, Honorata Jankowska¹,
E. Gözde Özbayram^c, Monika Żubrowska-Sudol^b

^a *Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Institute of Heat Engineer*^b *Warsaw University of Technology, Faculty of Building Services, Hydro and Environmental Engineering, Now*^c *Department of Marine and Freshwater Resources Management, Faculty of Aquatic Sciences, Istanbul Universi*

ARTICLE INFO

Keywords:

Hydrodynamic disintegration

Sewage sludge

Biogas production

Non-Newtonian fluid

Computational fluid dynamics

Waste

Biogas p

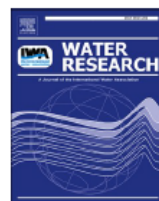
ABSTRACT

The hydrodynamic disintegration proces speed or introduced energy. The study pre parameters impact assessment on the int sludge treatment. Three rotational speed: tegration stages. Disintegration effects w (SCOD) and volatile fatty acids (VFA) wer the effects of disintegration employed the production employed biochemical metha gration stages does not cause a significa results, at 1500 rpm no cavitation phenon rotational speed 1500 rpm, organic compo to biological decomposition than those r values for 1500 rpm). Obtained results h tegration effect is mechanical shredding i



Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

and

Warsaw

TORY
jember 2019
May 2020Disintegration
egration
hydrodynamic

Effects of various rotational speeds of hydrodynamic disintegrator on carbon, nutrient, and energy recovery from sewage sludge

Justyna Walczak^{a,*}, Aleksandra Dzido^b, Honorata Jankowska^a, Piotr Krawczyk^b,
Monika Żubrowska-Sudol^a

^a *Warsaw University of Technology, Faculty of Building Services, Hydro and Environmental Engineering, Nowowiejska 20, 00-653 Warsaw, Poland*^b *Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Institute of Heat Engineering, Nowowiejska 21/25, 00-665 Warsaw, Poland*

ARTICLE INFO

Keywords:

biocircular economy

hydrodynamic cavitation

sewage sludge

methane production

sludge rheology

CFD modelling

ABSTRACT

Until recently, sewage sludge produced in wastewater treatment processes was consid currently constitutes a valuable substrate for raw materials and energy recovery. One sifying resource recovery from sludge is its pretreatment by means of disintegration met the CFD modelling and experimentally investigates the use of a hydrodynamic cavit various rotational speeds (1500, 2500, and 300 rpm) for the recovery of organic co energy. Rheological properties of raw sludge, a non-Newtonian fluid, were determined a calculations. Cavitation zones were observed for 2500 rpm and 3000 rpm, although a : occurred for a rotational speed of 3000 rpm. A rotational speed of 1500 rpm was too lc drop below 1705 Pa, and no cavitation was recorded. An increase in rotational speed fro for each analysed energy density caused an increase in SCOD and nitrogen concent determined that at low energy densities (<105 kJ/L), mechanical tearing was the domin carbon recovery, and at its higher values (≥105 kJ/L), the cavitation phenomenon important. Rotation speed also had a significant effect on methane yield (Y_{CH_4}). An incr recorded only for disintegrated sludge at a rotational speed of 1500 rpm in refere Disintegration conducted at higher rotational speeds led to a decrease in Y_{CH_4} (-0.7% fo 3000 rpm).



Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Effect of co-digestion and hydrodynamic disintegration on the methane potential of sewage sludge and organic fraction of municipal solid waste with consideration of the carbon footprint

Justyna Walczak^{*}, Beata Karolinczak, Monika Żubrowska-Sudol

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ARTICLE INFO

Handling Editor: Petar Sabev Varbanov

Keywords:

Co-digestion

Hydrodynamic disintegration

Sewage sludge

Organic fraction of municipal solid waste

Carbon footprint

ABSTRACT

The study objective was to investigate the applicability of co-digestion and/or hydrodynamic disintegration as potential methods of methane production intensification from sewage sludge (SS) and the organic fraction of municipal solid waste (OFMSW) with consideration of carbon footprint (CF) assessment. Methane production was determined by means of biochemical methane potential tests. For co-digestion, the highest increase in methane production (53.8 %) was observed for the SS:OFMSW mixing ratio 40:60. Hydrodynamic disintegration at all tested energy densities (10, 30 and 60 kJ/L) caused release of soluble organic compounds from both substrates, although accelerated methane production was only observed at 10 kJ/L. An increase in methane potential for substrates disintegrated separately did not imply analogical results for the disintegration of their mixture. Within the assumed limits, CF per 1 Nm³ of produced methane, CF per 1 t of wet feedstock for the digester, and estimated CF per 1 kWh produced were also calculated. Comparable values of all indicators were obtained for monodigestion and co-digestion. The highest CF indices were achieved for monodigestion of disintegrated SS and increased significantly with applied energy density. The obtained results can serve as valuable material for operators of wastewater treatment plants facilitating the selection of sustainable methods of increasing renewable energy production.

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The effects of mechanical sludge disintegration to enhance full-scale anaerobic digestion of municipal sludge

Monika Żubrowska-Sudol^{1,*}, Jolanta Podedworna², Katarzyna Sytek-Szmeichel²,
Agnieszka Bisak², Piotr Krawczyk², Agnieszka Garlicka²

¹ *Warsaw University of Technology, Faculty of Building Services, Hydro and Environmental Engineering, 20 Nowowiejska Str., 00-653 Warsaw, Poland*² *Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, 24 Nowowiejska Str., 00-665 Warsaw, Poland*

ARTICLE INFO

Keywords:

Anaerobic digestion

Mechanical disintegration

Waste activated sludge

Biogas production

ABSTRACT

The main goal of the study was to evaluate the effects of mechanical sludge disintegration in enhancing full-scale anaerobic digestion of municipal sludge. Batch disintegration tests and lab dewatering tests were performed to determine the release of organic compounds and to assess the impact of disintegration of excess sludge before the fermentation process of mixed sludge on the dewaterability of post fermented sludge, respectively. In the study, a disc disintegrator driven by a motor with a power of 30 kW, revolution n = 2950 rpm, was used. It was shown that increased amounts of organic compounds were released from the sludge along with an increase in energy consumed in the disintegration. A part of the organic compounds were volatile fatty acids (VFAs). The highest share of VFAs in the released organic compounds (COD/VFA in the range of 6.6 – 8.2) was obtained by performing disintegration at an energy density of 140 kJ/L. It was also documented that the introduction of excess sludge disintegration prior to the fermentation tank resulted in a significant increase in biogas production (by an average of 23.9%) and in an increase in volatile total solids reduction in the fermented sludge (by an average of 22.7%). Such a surplus of produced biogas would allow to produce ca. 1600 kWh/d net electricity and 7.5 GJ/d (2040 kWh/d) of heat. Moreover, it was documented that the share of disintegrated waste activated sludge in the mixed sludge subjected to the fermentation process could favourably influence the efficiency of post fermented sludge dewatering.



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^{*} Correspondence: monika.sudol@pw.edu.pl

Abstract: This study aimed to evaluate the effects of mec sludge (WAS) on full scale anaerobic digestion, consideri energy balance. The results showed that an increase in e was accompanied by an increase in the release of organic c from $211 \pm 125 \text{ mg O}_2/\text{L}$ for $\epsilon_L = 0 \text{ kJ/L}$ to $6292 \pm 2860 \text{ n}$ were volatile fatty acids. The percentage share of WAS subj as a crucial parameter affecting the efficiency of biogas pn parameter from 25% to 100%, even at much lower ϵ_L use smaller amounts of organic compounds released from slud



Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Disintegration of waste sludge as an element bio-circular economy in waste water treatment plant towards carbon recovery for biological nutrient removal

Monika Żubrowska-Sudol^a, Justyna Walczak^a, Grzegorz Piechota^{b,*}

^a *Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology, Nowowiejska 20, 00-653 Warsaw, Poland*^b *GPCHEM, Laboratory of Biogas Research and Analysis, ul. Legionów 40a/3, 87-100 Toruń, Poland*

HIGHLIGHTS

- Biocircular economy of excess sludge via disintegration process was investigated.
- Disintegrated excess sludge as a source of C to increase N and P removal was used.
- N and P removal depended on energy

GRAPHICAL ABSTRACT

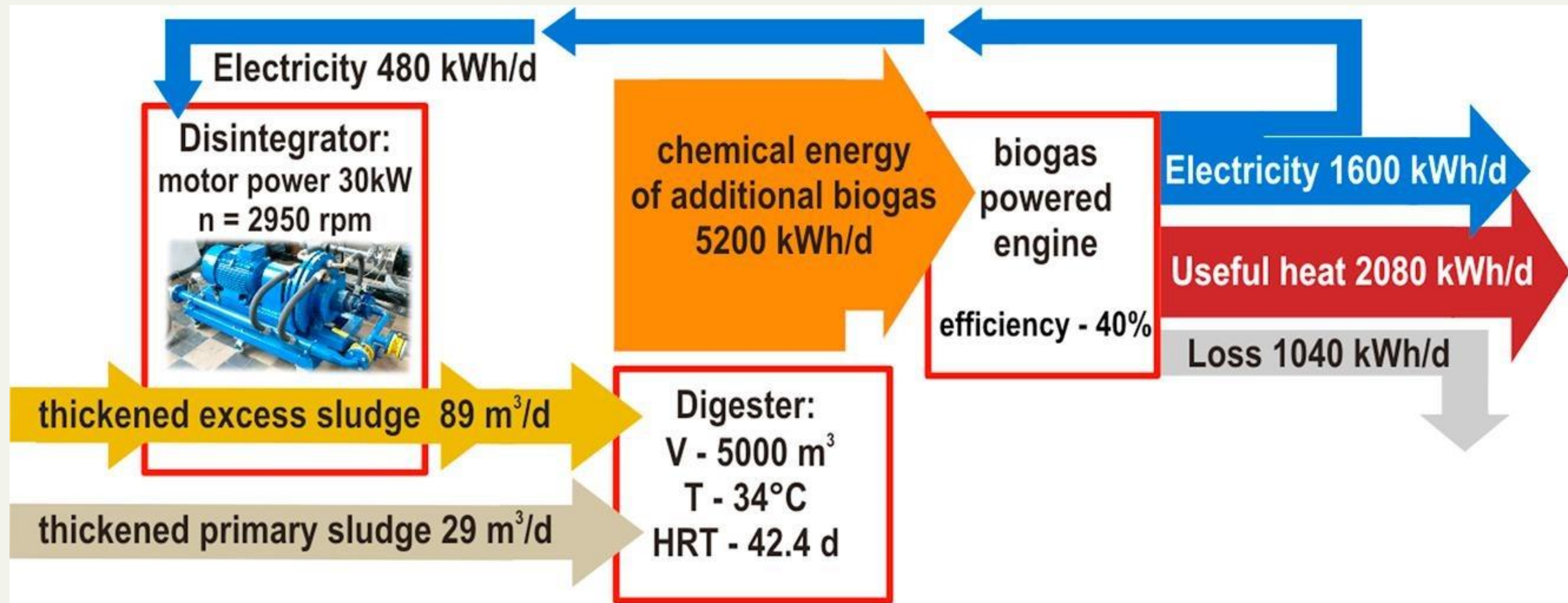


Energy 282 (2023) 128949



parameters were introduced in the disinte gration process, called: energy density

Pozytywne przykłady



Zubrowska-Sudol et al. 2018. The effects of mechanical sludge disintegration to enhance full-scale anaerobic digestion of municipal sludge. Thermal Science and Engineering Progress, 289-295

Aparatura do wyznaczania potencjału metanowego AMPTS II (Automatic Methane Potential Test)



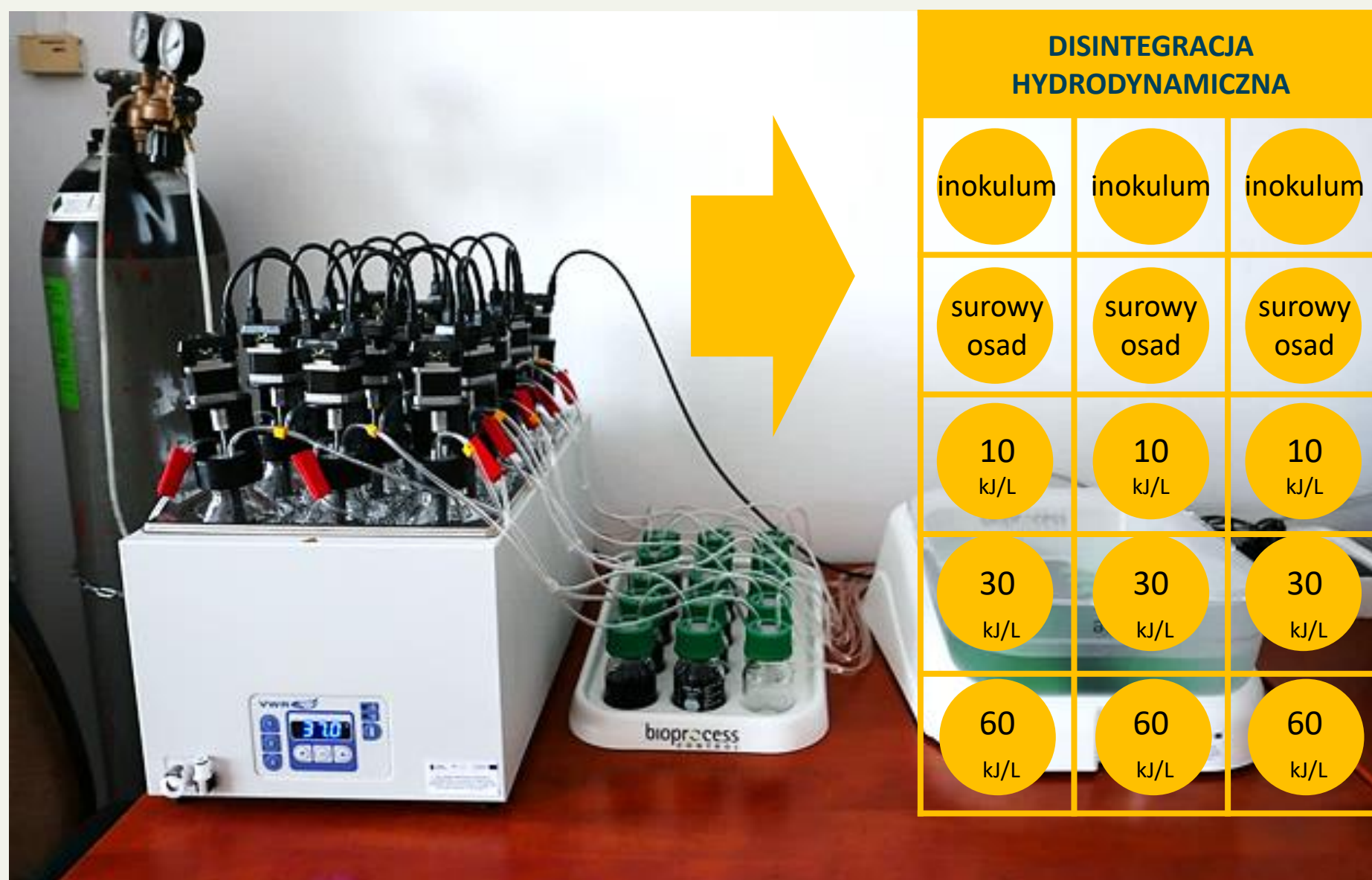
- 15 reaktorów
- temperatura 37°C
- objętość czynna: 400 mL
- obciążenie 5 g s.m.o/l

Aparatura do prowadzenia testów półciągłych BRS (BioReactor Simulator)



- 6 reaktorów
- temperatura 37°C
- SRT = 22 dni
- objętość czynna: 1,8 L
- obciążenie 1,3-2,1 g s.m.o/(L·d)

Aparatura do wyznaczania potencjału metanowego AMPTS II (Automatic Methane Potential Test)



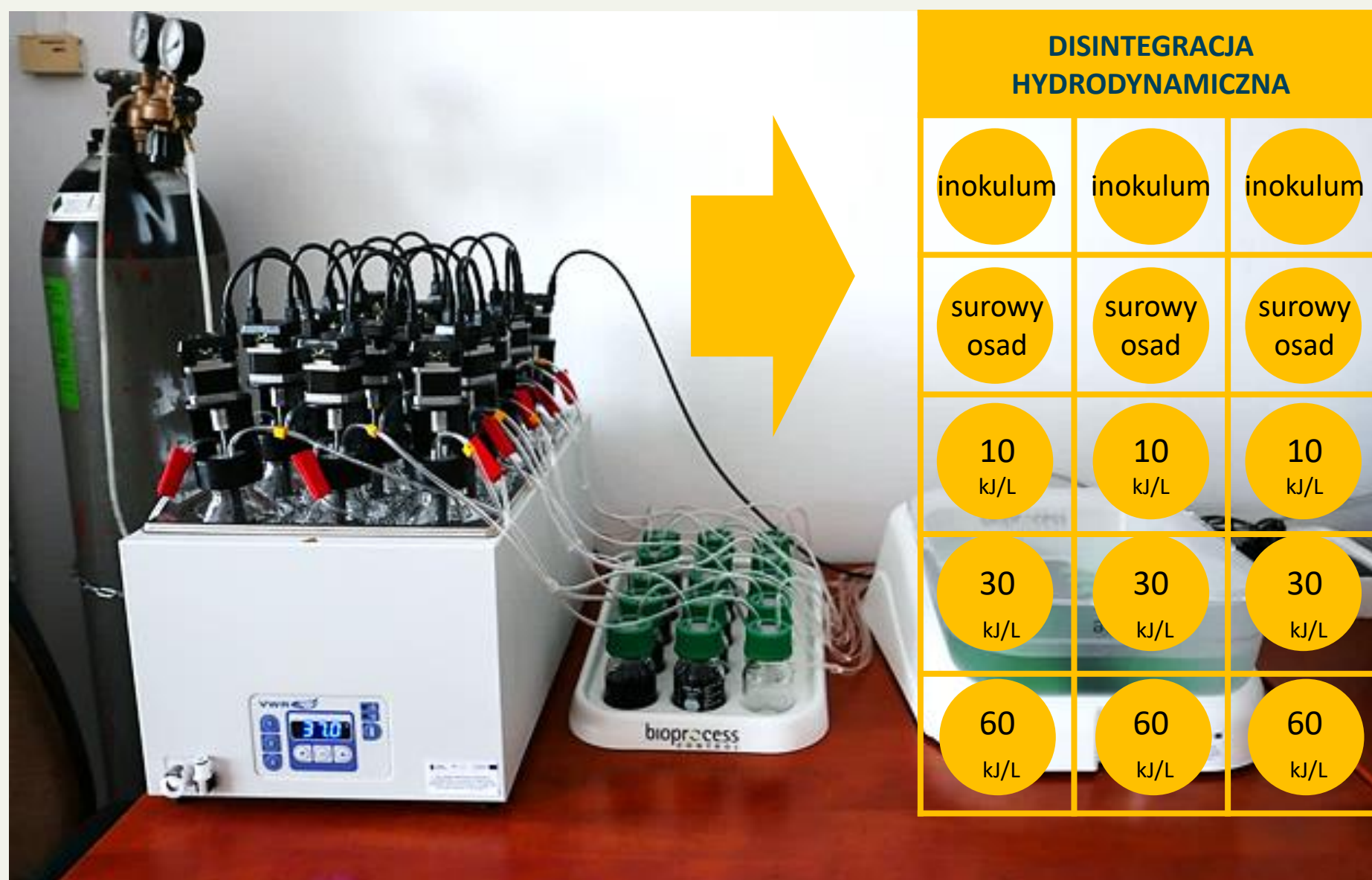
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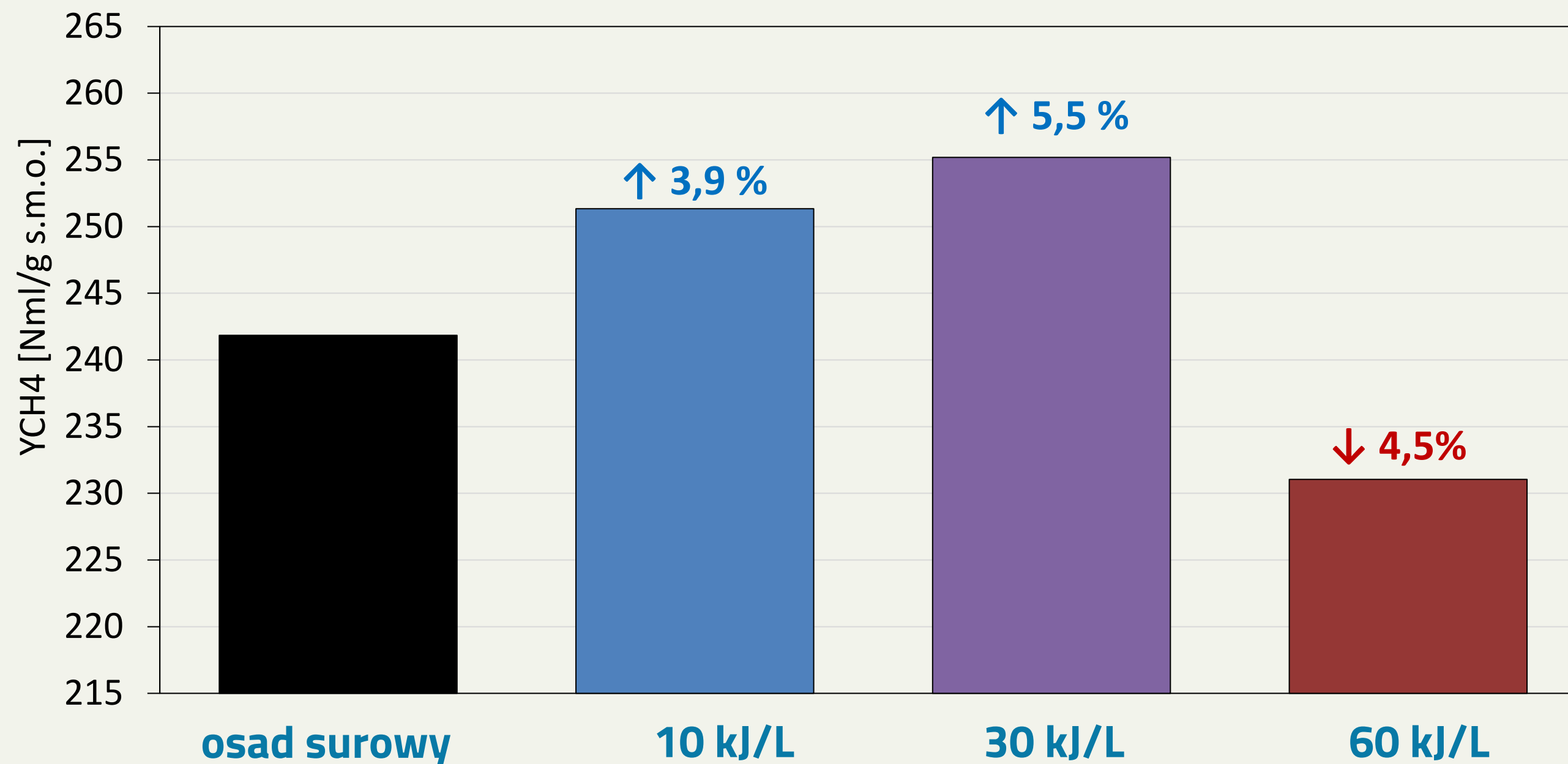
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- obciążenie 5 g s.m.o/l

Aparatura do prowadzenia testów półciągłych BRS (BioReactor Simulator)



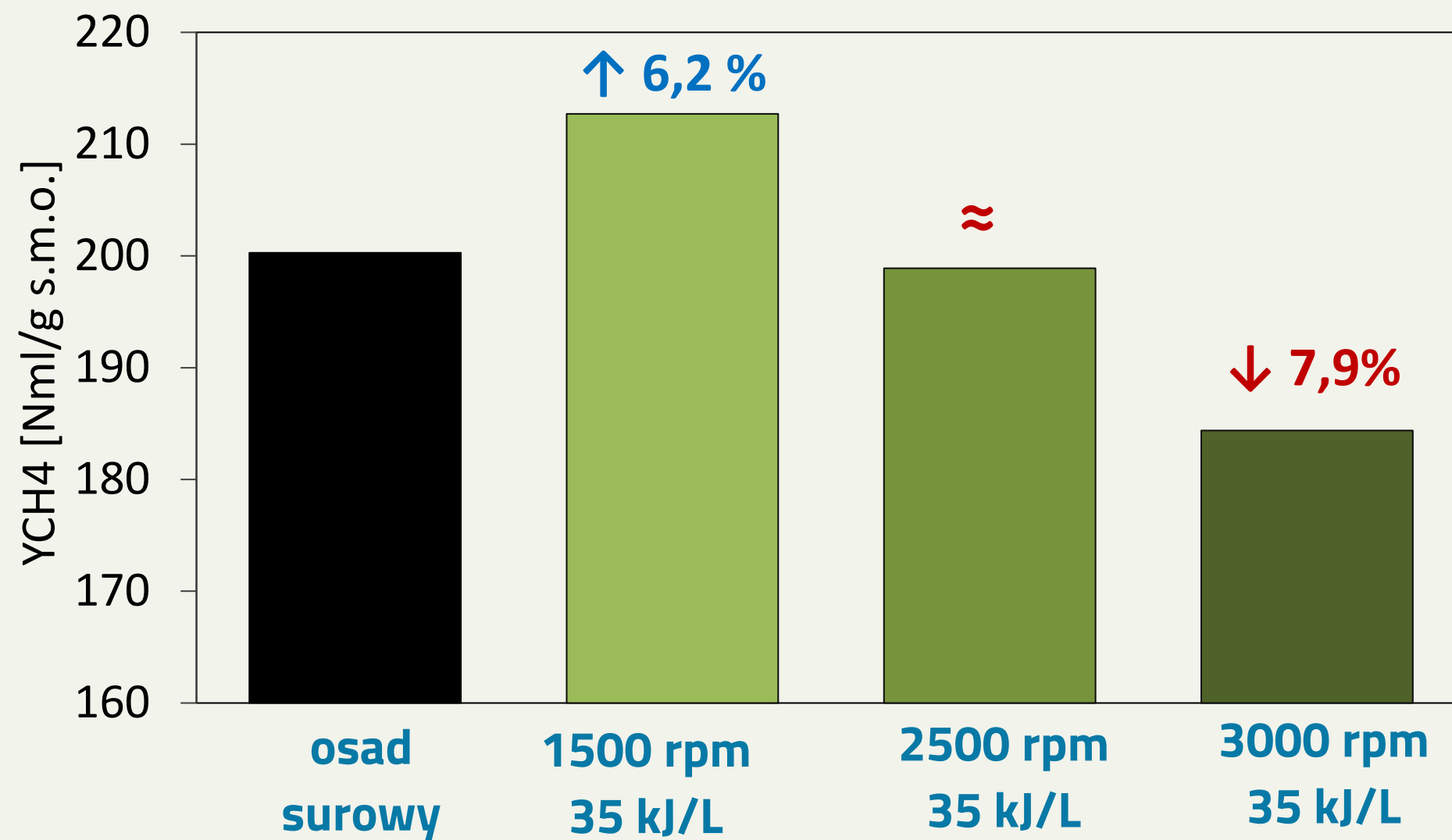
- 6 reaktorów
- temperatura 37°C
- SRT = 22 dni
- objętość czynna: 1,8 L
- obciążenie 1,3-2,1 g s.m.o/(L·d)

WYNIKI – wpływ gęstości energii na potencjał metanowy (AMPTS)



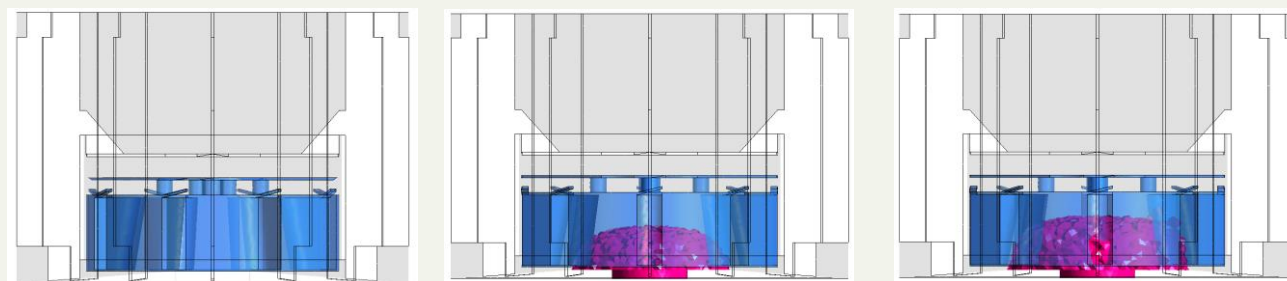
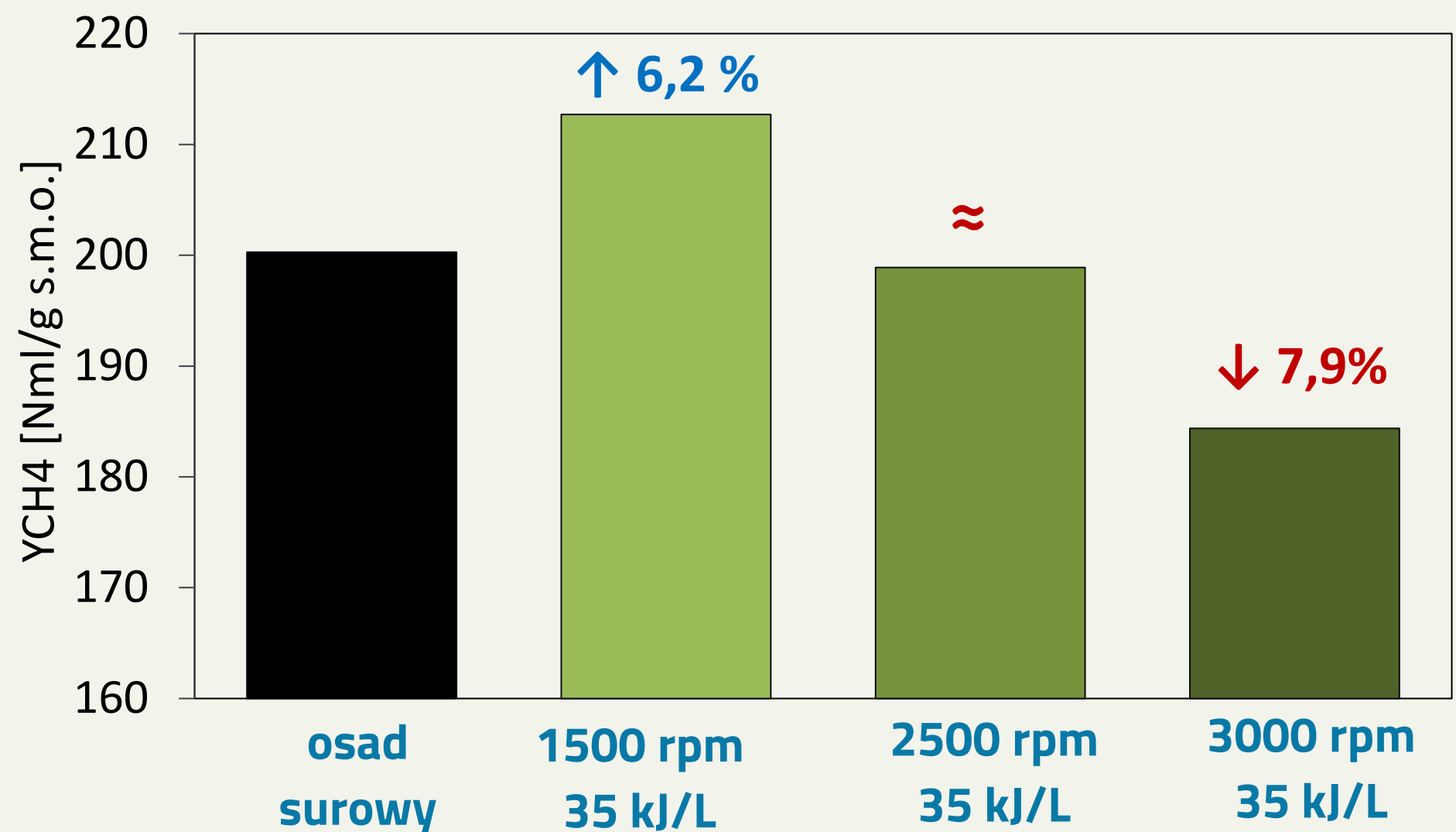
Walczak et al. 2023. Effect of co-digestion and hydrodynamic disintegration on the methane potential of sewage sludge and organic fraction of municipal solid waste with consideration of the carbon footprint. Energy 282, 128949

WYNIKI – wpływ obrotów wirnika na potencjał metanowy (AMPTS)



Walczak et al. 2023. Effects of various rotational speeds of hydrodynamic disintegrator on carbon, nutrient, and energy recovery from sewage sludge. Water Research 243, 120365

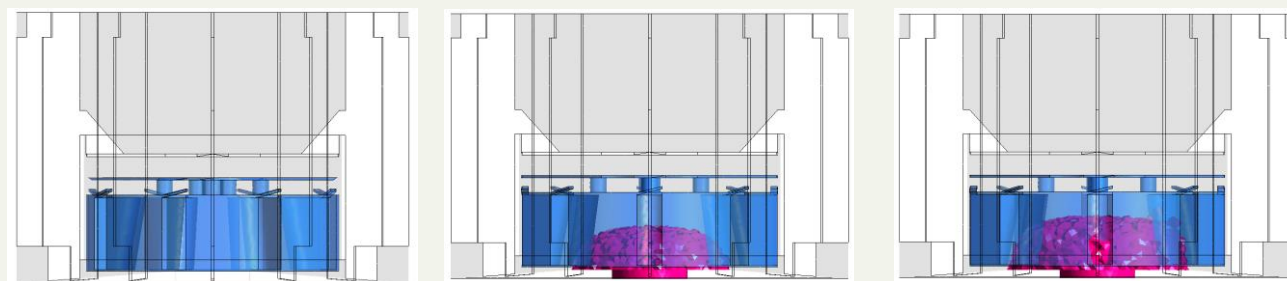
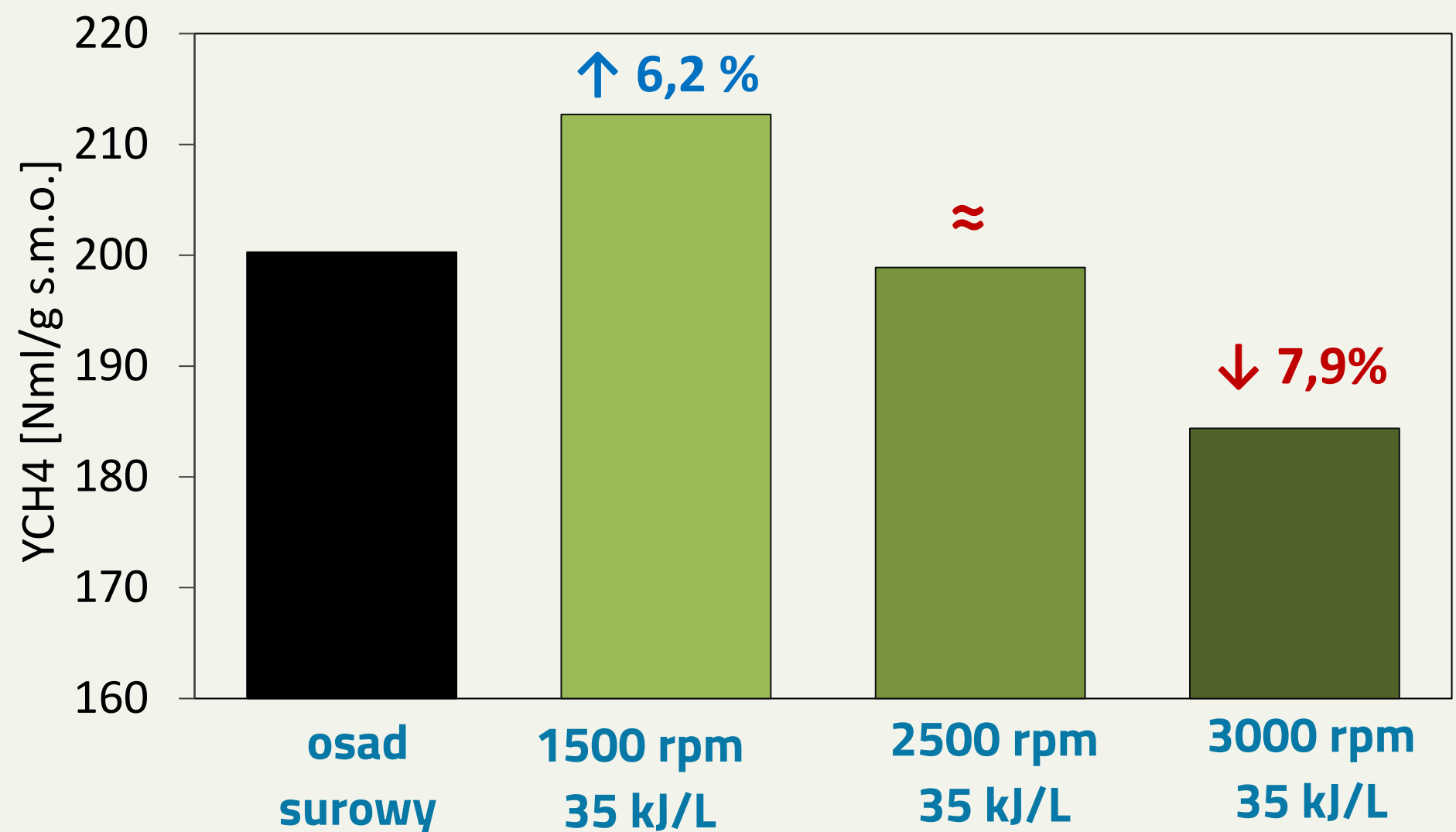
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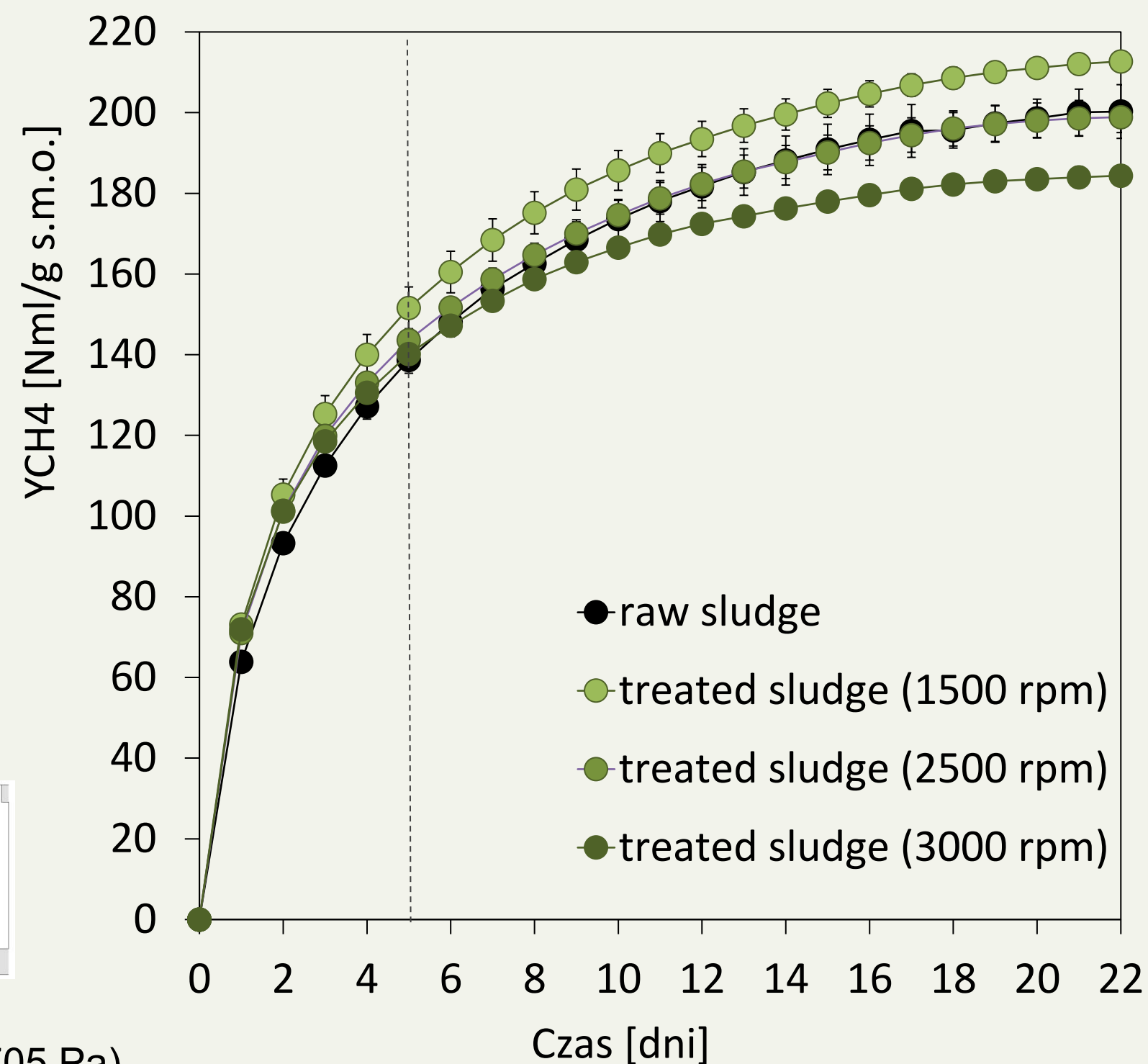
Strefa poniżej ciśnienia kawitacyjnego (1705 Pa)

Walczak et al. 2023. Effects of various rotational speeds of hydrodynamic disintegrator on carbon, nutrient, and energy recovery from sewage sludge. Water Research 243, 120365

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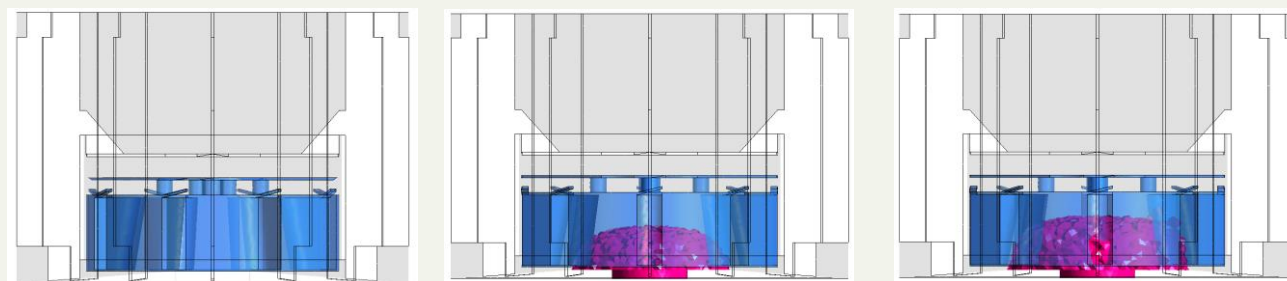
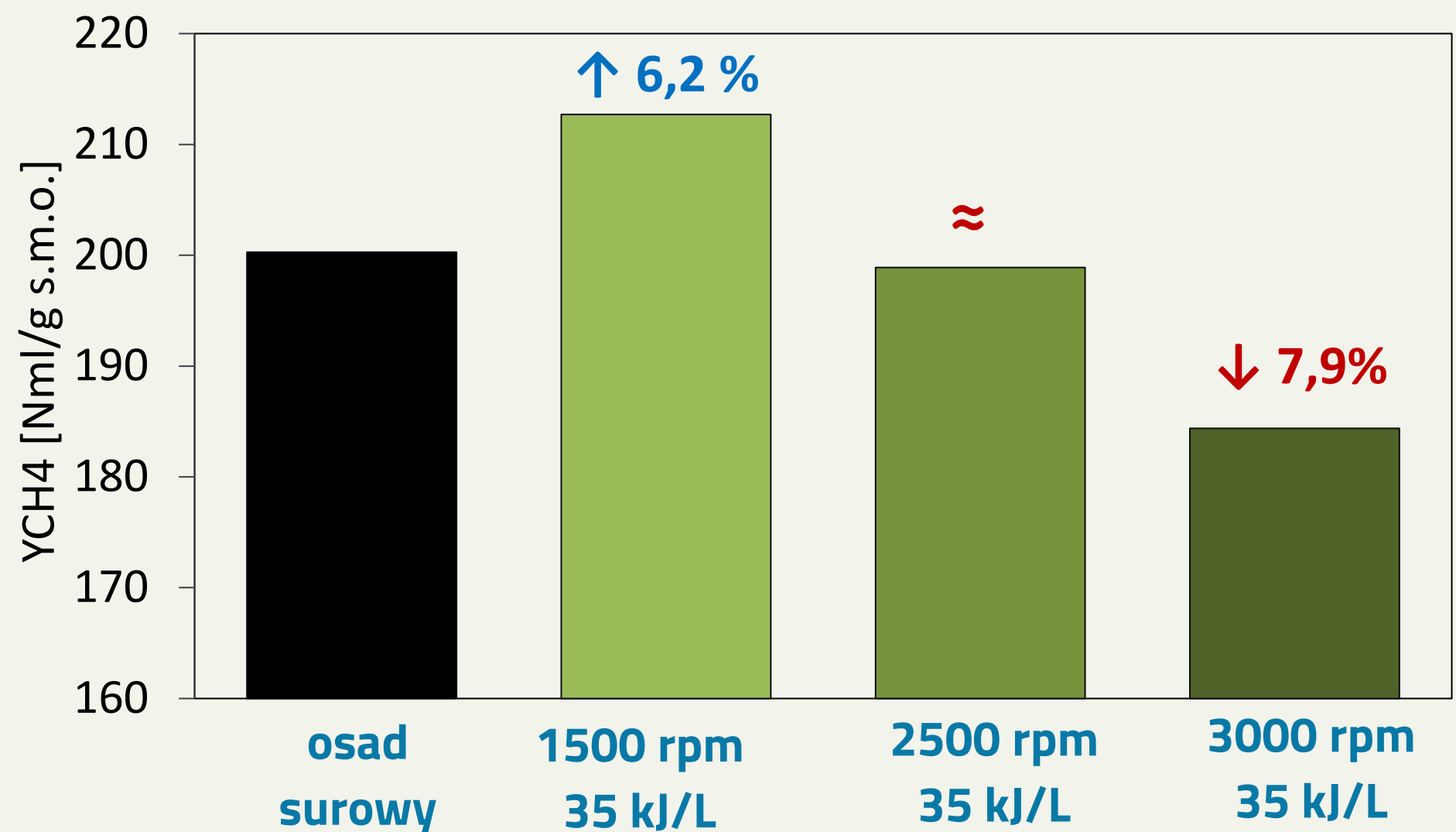


Strefa poniżej ciśnienia kawitacyjnego (1705 Pa)

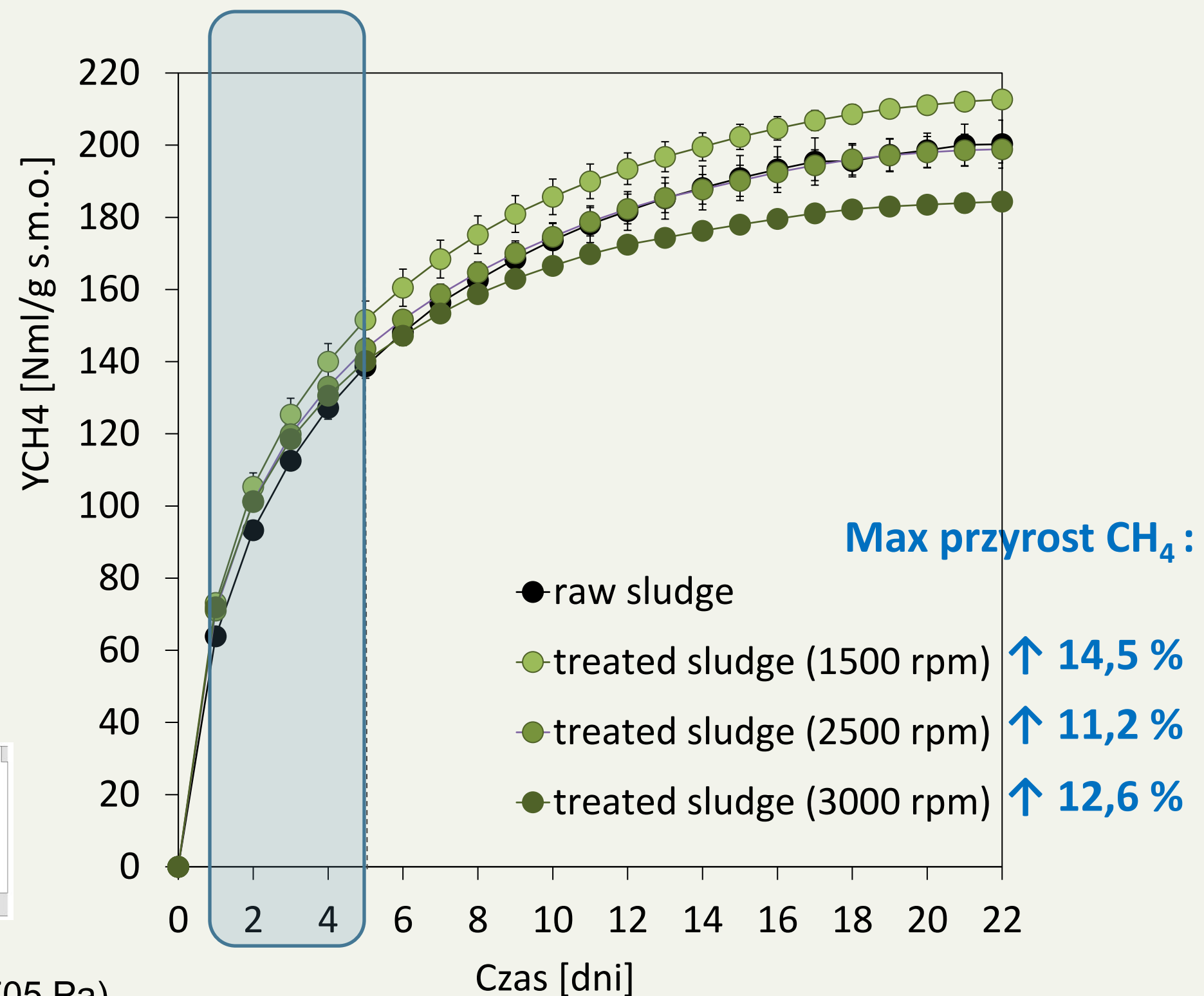


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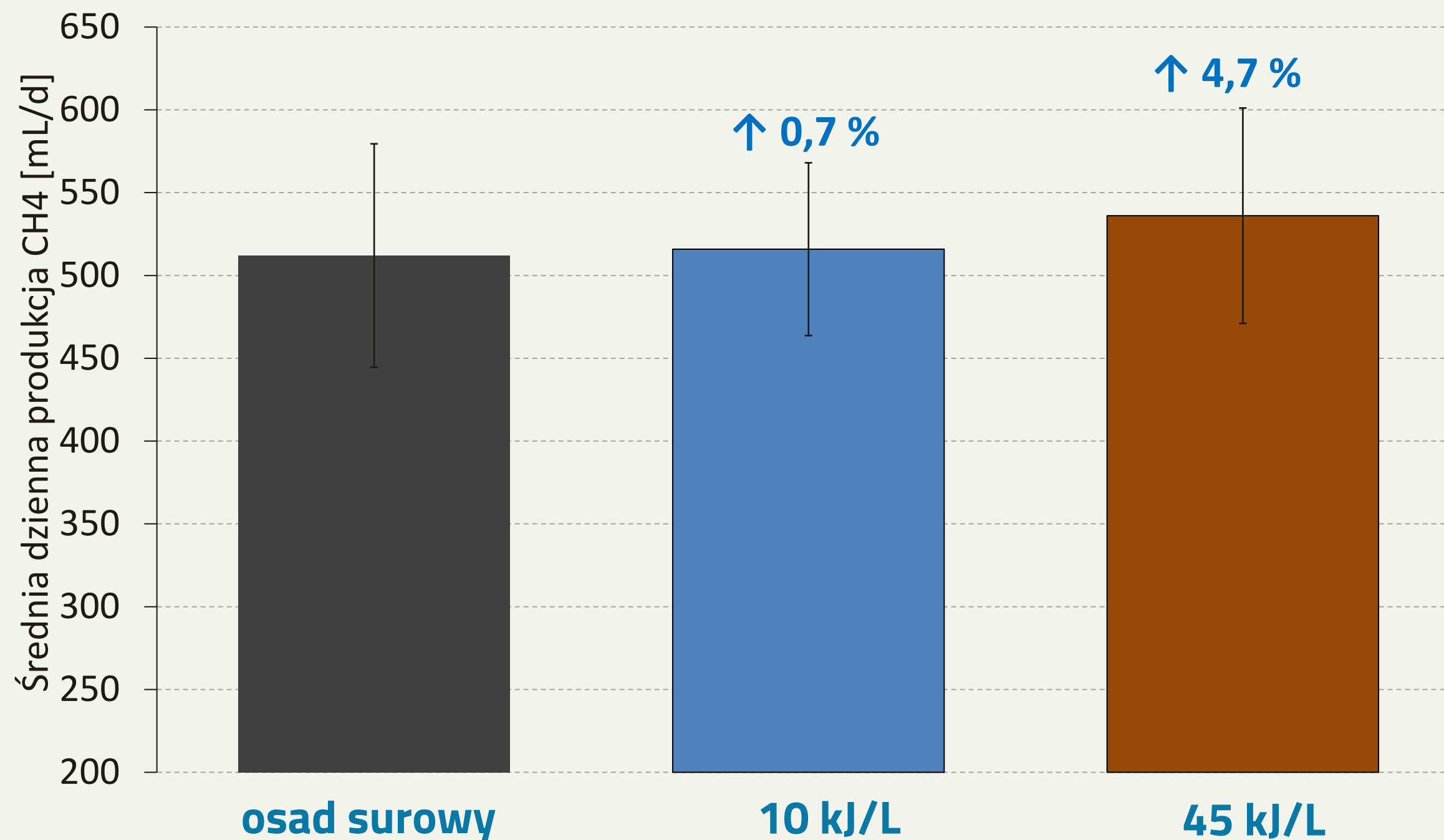


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Walczak et al. 2023. Effects of various rotational speeds of hydrodynamic disintegrator on carbon, nutrient, and energy recovery from sewage sludge. Water Research 243, 120365

WYNIKI – wpływ gęstości energii na produkcję metanu w warunkach półciągłych (BRS)



Sytek-Szmeichel et al. 2025. Searching for a Method of Sewage Sludge Pretreatment to Improve the Efficiency of the Anaerobic Digestion Process. 12th IWA International Symposium on Waste Management Problems in Agro-Industries - AGRO'2025, 10-12 September, İstanbul, Türkiye

WYNIKI – wpływ dezintegracji na uwalnianie N i P do cieczy osadowej

Gęstość energii	kJ/L	osad surowy	10	45	70	105	140
ChZT	mgO ₂ /L	430	1019	1707	3910	4560	5222
LKT	mg/L	121	258	266	383	420	517
NH ₄	mgN/L	54,7	58,7	71,7	75,5	82,8	98,6
PO ₄	mgP/L	252	268	296	304	294	314
pH	-	6,73	6,96	6,77	6,9	6,83	6,85

Projekt pt. "Analiza możliwości uzyskania przez oczyszczalnie ścieków dodatniego bilansu energetycznego w wyniku zastosowania obróbki wstępnej wsadu kierowanego do komór fermentacyjnych" finansowanego ze środków „Inicjatywa Doskonałości – Uczelnia Badawcza” (IDUB), CPR-IDUB/214/Z01/2023.

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PODSUMOWANIE

Przed podjęciem decyzji o wdrożeniu dezintegracji na oczyszczalni ścieków należy przeprowadzić badania wstępne, które będą obejmowały dobór właściwych parametrów dezintegracji i analizę ekonomiczną inwestycji

Organizator:



DZIĘKUJĘ ZA UWAGĘ!

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