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Co-digestion of by-products after biodiesel production and effective treatment of post-digestion liquors

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The aim of this study was to develop the technological concept ensuring: (1) high efficiency co-digestion of by-products from the production of biodiesel and sewage sludge as well as (2) an effective method of post-digestion effluents treatment, - to the level allowing its discharge to the natural reservoir.

MATERIALS AND METHODS

The digesters were fed with the following co-digestion mixtures:
- 3% waste glycerine (WG) + 97% sewage sludge (SS);
- 2% rapeseed cakes (RC) + 98% sewage sludge (SS);
- 2% rapeseed cakes (RC) + 1% waste glycerine (WG) + 97% sewage sludge (SS).

Characteristics of the raw materials

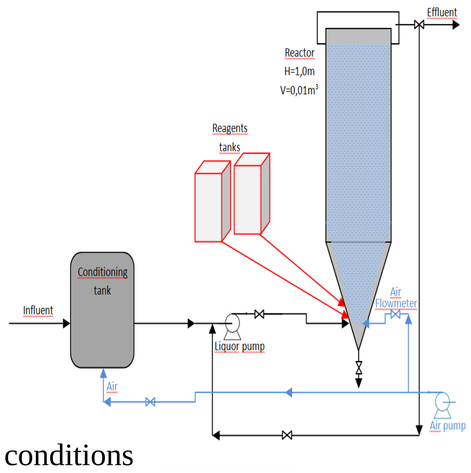
Indicator	Sewage sludge (SS)	Waste glycerine (WG)	Rapessed cake (RC)
pH	6.4 (0.4)	5.6 (0.3)	-
TS, %	5,17 (0.35)	55.9 (2.1)	95.6 (2.8)
VS, %	3.51 (0.27)	52.1 (1.7)	82.5 (2.4)
$C_{org.}$, % TS	33.0 (0.4)	48.4 (0.7)	51.6 (2.6)
N_{Total}, % TS	5.02 (0.38)	0.17 (0.01)	5.54 (0.42)
NH_4^+, mg/dm^3	15.8 (5.9)	254 (25)	-
COD, g O_2/dm^3	0.25 (0.10)	420 (66)	-

Anaerobic digestion

Detailed description of anaerobic digestion conditions:
- 3 dm^3 bioreactors, working in a semi-continuous mode
- Process conducted in mesophilic conditions (37°C)
- HRT in the range of 16-26 days

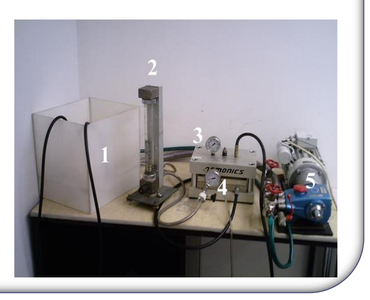
Struvite precipitation

Detailed description of conditions of struvite precipitation:
- 10 dm^3 crystallizer, working in a batch mode. The process was carried out at constant temperature of 20˚C and pH of 9.0-9.5; MgO used as Mg^{2+} source and H_3PO_4 used as PO_4^{3-} source;
- process was conducted for molar ratio of Mg^{2+} : NH_4^+: PO_4^{3-} as well as 25% and 50% excess amounts of magnesium and phosphorus (Mg^{2+} : NH_4^+ : PO_4^{3-} = 1.25:1:1.25; Mg^{2+} : NH_4^+ : PO_4^{3-} = 1.5:1:1.5)



Membrane filtration

Detailed description of the membrane apparatus used and process conditions during experiments:
- high-pressure in the device type GH-100-400, produced by a US-based company Osmonics;
- dead-end mode; trans-membrane pressure of 2 MPa;
- pH value of the liquors treated was adjusted to 6.5 by means of HCl, before the liquor underwent membrane treatment;
- RO: polyamide membrane type ADF.



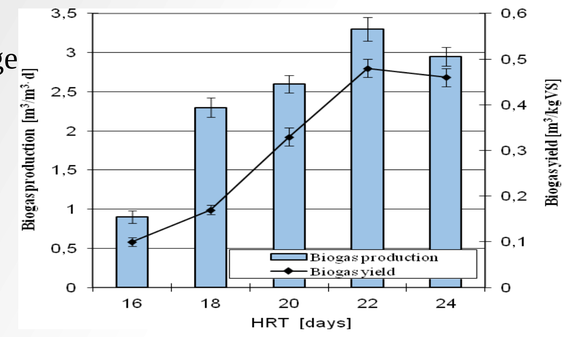
RESULTS AND DISCUSSION

I. Anaerobic co-digestion of waste glycerine/rapeseed cakes and sewage sludge
Characteristics of the post-digestion liquors – the most appropriate process conditions (tab. 1).

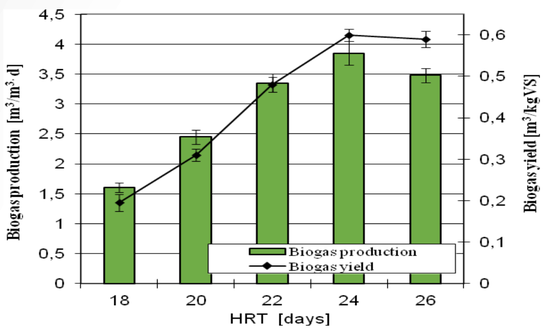
Oznaczenie	Co-digestion		
	GL + SS	RC +SS	GL+ RC+SS
	HRT [doby]		
	22	22	24
pH	7.4 (0.2)	7.4 (0.2)	7.8 (0.1)
ORP, mV	-446 (30)	-420 (25)	-332 (20)
COD, mg O_2/dm^3	1945 (452)	2745 (165)	3535 (305)
VFA, mg/dm^3	1155 (55)	1055 (55)	1735 (75)
PO_4^{3-}, mg/dm^3	345 (37)	485 (48)	825 (40)
NH_4^+, mg/dm^3	1660 (31)	2050 (150)	2810 (140)
Alkalinity, mg/dm^3	6554 (225)	7229 (252)	7690 (208)
CSK, s	90 (8)	120 (8)	410 (30)

Biogas production and yield:

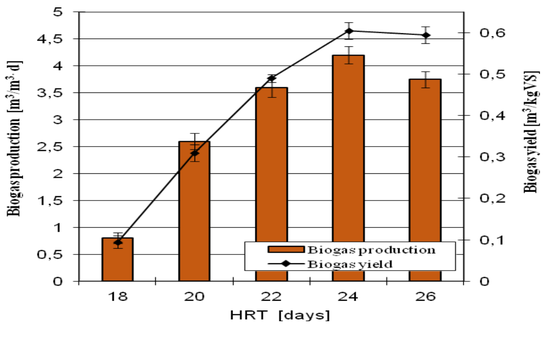
a) Waste glycerine + sewage sludge



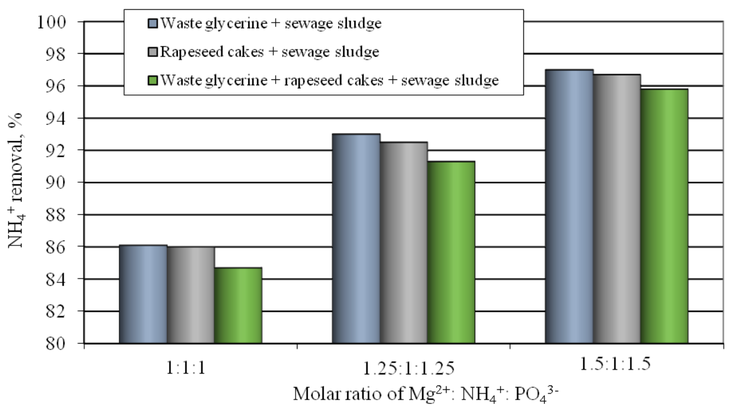
b) Rapeseed cake + sewage sludge

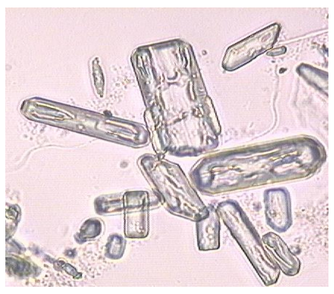


c) Waste glycerine + rapeseed cake + sewage sludge



II. Post-digestion effluents treatment
a.: Struvite precipitation as a pre-treatment before membrane filtration.
Influence of Mg^{2+} and PO_4^{3-} dosage on the NH_4^+ removal





b.: Membrane filtration (RO) without pre-treatment.
Concentrations and average removal degrees

Parameter	GL + SS	RC +SS	GL+ RC+SS	Permissible value*
pH	7.2	7.2	7.4	6.5-9.0
NH_4^+, mg/dm^3	198 (88%)	287 (86%)	656 (77%)	10^a-20^b
TN, mgN/dm^3	232 (86%)	349 (83%)	674 (76%)	
TP, mgP/dm^3	1.02 (>99%)	1.12 (>99%)	1.88 (>99%)	1^a-2^b
COD, mgO_2/dm^3	25 (98.7%)	35 (98.7%)	65 (98%)	125

% - removal; *EU Council Directive (91/271/EWG) concerning urban wastewater (10 000-100 000a– above 100 000b inhabitants and above), 21 May 1991.

c.: Struvite precipitation (pre-treatment) + membrane filtration (RO) as a post-treatment (average values)

Liquors Pretreatment	GL + SS	RC +SS	GL+ RC+SS	Permissible value*
Struvite precipitation Mg^{2+}: NH_4^+: PO_4^{3-}	1.25:1:1.25	1.5:1:1.5	1.25:1:1.25	-
pH	7.5	7.4	7.4	6.5-9.0
NH_4^+, mg/dm^3	6.4	7.0	8.0	10^a-20^b
TN., mgN/dm^3	7.0	7.8	9.1	
TP, mgP/dm^3	0.3	0.3	0.4	1^a-2^b
COD, mgO_2/dm^3	9.5	12	14	125

*EU Council Directive (91/271/EWG) concerning urban wastewater (10 000-100 000a– above 100 000b inhabitants and above), 21 May 1991.

CONLUSIONS

The addition of glycerol fraction /rapeseed cakes to sewage sludge influenced positively the degree of organic matter biodegradation and the quantity and quality of biogas produced. The co-digestion mixtures performed in optimal conditions (HRT = 22-24 days) generated the double amounts of biogas - containing about 10-12% more CH_4, - compared to the samples including the only sewage sludge. Under these conditions, biogas yield increased by about 48-82%, - depending on the co-substrate used. Taking into account the high content of organic matter (COD) and nutrients (NH_4^+, PO_4^{3-}) in post-digestion effluents, an attempt was made to treat them by the application of chemical precipitation and membrane filtration. The treatment of post-digestion liquors with a struvite precipitation and a subsequent RO process turned out to be effective and allowed to decrease contaminants' concentration below discharge limits, allowing direct release of permeate to a natural receiver. However, it was necessary to apply an increased ratio of magnesium and phosphates during struvite precipitation (125-150% of stoichiometric ratio), preceding reverse osmosis treatment.