Analysis of possibilities of obtaining positive energy balance in anaerobic digestion systems with hydrodynamic disintegration

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Introduction

One method of intensifying the anaerobic digestion process is the preliminary processing of substrate supplied to digestion chambers via disintegration methods. Own research in technical installations showed that excess biogas obtained after the introduction of disintegration of the stream of excess sludge supplied to digestion chambers would allow for producing an amount of electricity higher than that used for pre-processing. This justifies the application of the analysed process in practice (Żubrowska-Sudoł *et al,* 2018).

Considering the positive results obtained in the case of mono-digestion, a hypothesis was stated that the disintegration process can also be used for facilitating co-digestion. The report will present study results regarding the possibility of increasing the methane potential of selected co-substrates and obtaining a positive energy balance via hydrodynamic disintegration pre-treatment.

Methods

The experiment covered the determination of the methane potential yield (Y_{CH4}) for the following substrates: cow manure, pig manure, maize stillage, remains of fruits, beetroot pulp, and beetroot pulp in the form of pellets.

The disintegration process employed a newly designed hydrodynamic disintegrator [patent application: WP-84/JW l3766l18, 27.12.2018]. The device is powered by an electric 5.5 kW engine with rotational speed of 3000 rpm. The aforementioned substrates were subject to the process of hydrodynamic disintegration at different levels of energy density: 10, 20, 35, 70, and 140 kJ/L.

The influence of hydrodynamic disintegration parameters on specific methane production was assessed in biochemical methane potential tests (Holliger *et al*, 2016) which were conducted in a AMPTS II device (Automatic Methane Potential Test System) composed of 15 test reactors with a working volume of 400 ml each. The digestion process was conducted at a temperature of 37°C at a constant load of the inoculum with organic compounds reaching 5.0 g VS/L. All tests were conducted until the daily gas production over three consecutive days reaches one percent of total gas production. Each test was conducted in three repetitions.

Results

Data presented in Figure 1 show that the hydrodynamic disintegration process contributed to an increase in the methane potential yield of maize stillage and beetroot pulp in the form of pellets. The maximum increase in the value of Y_{CH4} (48.2%) also occurred for beetroot pulp in the form of pellets subject to the disintegration process conducted at an energy density of 35 kJ/L. It was not equivalent to the highest net energy production (Table 1), however. Such a result was obtained for maize stillage disintegrated at energy density at a level of 10 kJ/L (Table 1). An increase in Y_{CH4} for this sample was 34.4%. In the report, a similar analysis will be conducted for all selected co-substrates.

Conclusion

To sum up, hydrodynamic disintegration as pre-treatment of substrates subject to the digestion process allows for increasing the amount of produced methane in the case of obtaining positive energy balance. Implementation works should be preceded with tests aimed at the selection of: i) substrate/substrates subject to pre-treatment and ii) parameters of the disintegration process (including the amount of energy supplied in the process).

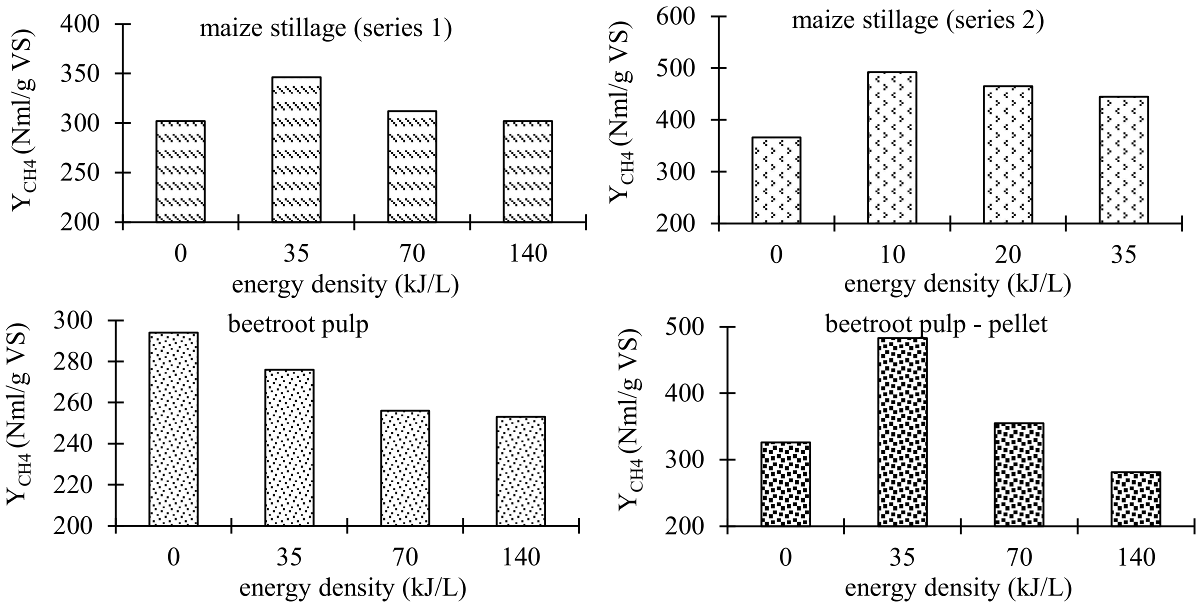

Figure 1. Influence of hydrodynamic disintegration pretreatment on methane potential yield (Y_{CH4}) of selected co-substrate.

Table 1. Energy balance.

Parameter	**unit**	**maize stillage**								**beetroot pulp - pellet**			
		Series 1				**Series 2**							
		0	35 kJ/L	70 kJ/L	140 kJ/L	0	10 kJ/L	20 kJ/L	35 kJ/L	0	35 kJ/L	70 kJ/L	140 kJ/L
Methane energy content[1]	(Wh)	3.13	3.46	3.12	3.02	7.32	9.84	9.30	8.90	9.54	12.7	9.75	8.64
Electricity[2]	(Wh)	1.25	1.38	1.25	1.20	2.93	3.94	3.72	3.56	3.82	5.06	3.90	3.45
Extra electricity[3]	(Wh)	-	0.13	0.00	0,00	-	1.01	0.79	0.63	-	1.25	0.08	-0.36
Energy applied for HD	(Wh)	-	0.23	0.42	0.91	-	0.17	0.31	0.58	-	1.23	2.47	4.94
Net energy production	(Wh)	-	-0.10	-0.42	-0.91	-	0.84	0.48	0.05	-	0.01	-2.38	-5.30
Relative energy profit	(%)	-	-	-	-	-	599	253	108	-	101	-	-

[1]Methane energy content calculated by assuming methane calorific value equal to 36 MJ/m[3];
[2]Electricity calculated by assuming electrical efficiency of engine equal to 40%;
[3]Extra electricity = electricity dez.—electricity untreated, (Wh): Electricity dez., amount of electricity produced in a disintegrated sample at a predefined energy density level (Wh); Electricity untreated, amount of electricity produced in an untreated sample (Wh).

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