Somfai, D. - Czakó-Vér, K. - Suhajda, E. - Dolgos-Kovács, A. - Dittrich, E.

Department of Environmental Engineering,, University of Pécs, H-7624 Pécs, Boszorkány út 2., Hungary

EXPERIMENTS OF ANAEROB CO-FERMENTATION OF THE BIODEGRADABLE FRACTION OF THE MUNICIPAL SOLID WASTES (BIFMSW) AND SEWAGE SLUDGE(S)

ABSTRACT

Municipal solid waste collected at Pécs-Kökény Regional Waste Management Center possesses a significant portion of biologically degradable materials (26% in a 4-year average). Therefore, biological stabilization is required. Currently waste material is only treated in aerobic conditions, no energetic utilization is available yet. Measurements were performed using the organic fraction of municipal solid waste derived from mechanical separation (BiFMSW) as our primary substrate. BiFMSW was further disintegrated on a 10 mm sieve and stored in air-tight containers in refrigerator. Laboratory measurements were perfomed on BiFMSW to assess its potential as biogas substrate on 37 °C. The co-fermentation of BiFMSW and activated sludge in different proportions were also assessed. Biodegradation kinetics and biogas yield of different compositions (monosubstrate undergoing anaerobic degradation with BiFMSW's own microflora and with activated sludge) were compared. Average solid content of sewage sludge was 6% with a C/N ratio of 11. According to literature data, complementing it with organic substrates results in better biogas and methane yield. Average solid content of BiFMSW samples was 24 % with a C/N ratio of 36. According to our measurements, sewage sludge as a monosubstrate produced 0.34 Nm^{3}/kg volatile organic compound in 28 days. The co-fermentation of the 1:1 mixture of BiFMSW and sewage sludge resulted in 0.29 Nm^3/kg volatile organic compound.

INTRODUCTION AND AIM

In 2010 Mata Alvarez, J. et al composed a thorough summary titled „Codigestion of solid wastes: A review of its uses and perspectives including modeling". The review analyzes data from articles regarding co-fermentation of sewage sludges, OFMSW, industrial wastes and different agricultural products and by-products. The summary includes results from laboratory, semi-industrial and industrial circumstances. The most essential aspect is the distinct C/N ratio of substrates. The proper mixture of substrates ensures optimal C/N ratio for biogas production (optimal range: 10:1 – 25:1). [1]

Esposito et al (2008) established a model for the co-fermentation of sewage sludge and OFMSW. [2] Derbál et al (2009) tested this mathematical model by measuring the biogas production of fermenters with different substrate ratios. [3]

Li et al (2011) described that anaerobic digestation (AD) is an adequate method to treat substrates with a total solid content (TS) of 0.5% to 15%, for instance manure, sewage sludge and food industry waste. If the substrate has a TS higher than 15%, it is desirable to apply solid state anaerobic digestation (SS-AD). SS-AD is gaining popularity in treating substrates with high cellulose and lignocellulose content, for example energy crops and OFMSW. When

© SOMFAI, D., CZAKÓ-VÉR, K., SUHAJDA, E., DOLGOS-KOVÁCS, A., DITTRICH, E.

treating these substrates, applying pretreatment is desirable to achieve adequate hydrolysis and a proper amount of cellulase produced by cellulose degrading bacteria. [4]
Ponsa et al (2011) examined the co-fermentation of OFMSW in laboratory conditions with several co-substrates, like fat, oil, cellulose and protein. They found that the fermentation of the examined OFMSW as monosubstrate resulted in the following methane potential values: 80 liters/kg VS in 3 days; 382 liters/kg VS in 28 days. Continuing the fermentation for 138 days resulted in no further methane production. [5] In the co-fermentational experiments, the most prominent growth in methane yield was achieved by fat and oil co-substrates. [5] AbDullah J.J. et al (2019) summarized their results from laboratory experiments investigating OFMSW as a monosubstrate and in co-fermentation with kitchen waste. [6] Under mesophilic conditions, fermenting OFMSW as a monosubstrate resulted in a biogas of 0.661 m^3/kg VS. The produced biogas had a methane content of 70%. [6]

MATERIALS AND METHODS

The basis for all the calculations in the thesis is the ideal gas law [7]:

Ideal Gas Law:

$$n = p \times V / R \times T \qquad \mathbf{1}$$

n = number of moles of gases formed (mol)
p = gas pressure in Pascal (N/m^2)
V = gas volume (m^3)
R = gas constant (8,314 J/(mol*K))
T = incubation temperature (K)

Carbon (methane) content of the gaseous phase can be calculated with the following formula [7]:

$$n = (p \times Vg)/(R \times T) * 10^{-4} \qquad \mathbf{2}$$

n = number of moles of gas formed, CH_4 (mol)
Dp = the difference of the gas pressure in the sample bottle at the end of the experiment (plateau)
minus the pressure in the beginning of the experiment minus the difference of the blank values
(hPa)
Vg = gas volume of the headspace (ml)
10^{-4} = conversion factor Pa in hPa and m^3 into ml

RESULTS AND DISCUSSION

We used the results of the following tables (Table 1-3) to calculate the biomethane potential of the BiFMSW. Table 4 contains the calculated biomethane potential.

Table 1

Dry matter content of all substrates

Sample	Dry matter content (g/kg)

© SOMFAI, D., CZAKÓ-VÉR, K., SUHAJDA, E., DOLGOS-KOVÁCS, A., DITTRICH, E.

Notation	Content	Date	1.	2.	3.	Mean
1. Dss	Densified sewage sludge	2019.02.25	27,65	29,15	26,58	27,79
2. Dss	Densified sewage sludge	2019.02.25	27,85	28,68	28,89	28,47
3. Dss	Densified sewage sludge	2019.02.25	27,35	27,65	29,95	28,32
BiFMSW	Organic fraction of MSW	2019.05.31	595,15	523,54	518,14	520,84
Inoculum	Inoculum	2018.09.13	23,71	29,01	31,72	28,15

Table 2

Organic content of the whole sample

Sample			Organic content of the whole sample (g/kg)			
Notation	Content	Date	1.	2.	3.	Mean
1. Dss	Densified sewage sludge	2019.02.25	20,70	21,91	21,11	21,24
2. Dss	Densified sewage sludge	2019.02.25	21,00	21,72	21,72	21,48
3. Dss	Densified sewage sludge	2019.02.25	20,50	20,80	22,63	21,31
BiFMSW	Organic fraction of MSW	2019.05.31	451,16	391,89	375,84	383,87
Inoculum	Inoculum	2018.09.13	19,89	17,31	18,87	18,69

Table 3

Organic matter content of the dry content

Sample			Organic matter content of the dry content (g/kg)			
Notation	Content	Date	1.	2.	3.	Mean
1. Dss	Densified sewage sludge	2019.02.25	748,64	751,63	752,48	750,92
2. Dss	Densified sewage sludge	2019.02.25	754,04	757,53	751,92	754,50
3. Dss	Densified sewage sludge	2019.02.25	749,54	752,26	742,03	747,94
BiFMSW	Organic fraction of MSW	2019.05.31	751,30	748,55	725,36	736,96
Inoculum	Inoculum	2018.09.13	838,94	596,92	594,79	676,88

Table 4

Actual Biomethane potential

Measurement number	Ratio of the substrate	Duration of the measurement	(hPA)	Amount of gas (mol)	dm^3/kg TOS
17101302	50 g BiFMSW + 50 ml Densified sewage sludge	3 day	143	0,0055	7
17101601	50 g BiFMSW+ 50 ml Densified sewage sludge	3 day			
17101603	50 g BiFMSW+ 100 ml i Densified sewage sludge	3 day	163	0,0063	7,9
17101604	50 g BiFMSW+ 100 ml i Densified sewage sludge	3 day			

CONCLUSION

For biogas recovery a lot of potencial new substrates were analized. Organic fraction of the municipal solid waste may be a good substrate for anaerob fermentation. The C/N ratio of OFNSW was 35,8. The C/N ratio of the sewage sludge changes between 8,6 and 12.
In 2008 Esposito et al. worked the model for OFMSW and sewage sludge co-fermentation. [2]. Ponsa et al (2011) examined the co-fermentation of OFMSW in laboratory conditions with several co-substrates, like fat, oil, cellulose and protein. They found that the fermentation of the examined OFMSW as monosubstrate resulted in the following methane potential values: 80 liters/kg VS in 3 days; 382 liters/kg VS in 28 days. Continuing the fermentation for 138 days resulted in no further methane production. [5].
In our experiment, the specific biomethane yield was 0,00550 mol 1:1 BiFNSW : SS and 0,0063 mol 1:2 BiFNSW : SS ratio. From this the calculated specific Biomethane Potential 7,0 dm^3/ kg TOS and 7,9 dm^3/ kg TOS.
Biomethane Potential for 28 days can calculated from this data. Alrabashdeh et al. (2017) summarized the indicators of biogas production on a laboratory, semi-industrial and industrial scale, and they found that even scale up the co-fermentation results were good enough. [8]
As a result, anaerobic digestion has become one of the best alternative technology to treat the organic fraction of municipal solid wastes and can be an important source of bioenergy.

ACKNOWLEDGEMENT

The support of European Union and Hungarian State (grant agreement no. EFOP-3.6.2-16-2017-00010) is gratefully appreciated.

REFERENCES

1. **Mata-Alvarez, J., Dosta, J., Macé, S., Astals, S.:** "Codigestion of solid wastes: A review of its uses and perspectives including modeling." Critical Reviews in Biotechnology, 2010, pp. 1–13.

2. **Esposito, G., Frunzo, L., Panico Ad' Antonio, G.:** "Mathematical modelling of disintegration-limited co-digestionof OFMSW and sewage sludge." Water Science Technology, 58, 2008, 1513-1519

3. **Derbal, K., Bencheikh-Lehocine, M., Cecchi, F., Meniai, AH., Pavan, P.:** "Application of the IWA ADM1 model to simulate anaerobic co-digestion of organic waste with waste activated sludge in mesophilic condidion." Bioresour Technol 100, 2009, 1539-1543.

4. **Li, Y., Park, S. Y., Zhu, J.:** "Solid-state anaerobic digestion for methane production from organic waste." Renewable and Sustainable Energy Reviews 15, 2011, pp. 821-826.

5. **Ponsá, S., Gea, T., Sánchez, A.:** "Anaerobic co-digestion of the organic fraction of municipal solid waste with several pure organic co-substrates." Biosystems Engineering 108, 2011, pp.352-360.

6. **Abdullah, J. J., Tucker, G. A., Du, C.:** "Anaerobic Digestion of Food Processing and Municipal Solid Waste (MSW)." Journal of Environmental Science, Computer Science and Engineering & Technology Section A, Vol.9, No.1, 2019, pp.30-55.

7.**Pentilla, A**.: "Initialization of the Oxitop system for biogas production tests. " TAMK University of Applied Sciences. Tampore, 2009. pp.52.

8. Alrawashdeh, K. A., Pugliese, A., Slopiecka, K., Pistolesi, V., Massoli, S., Bartocci, P., Bidini, G., Fantozzi, F.: "Codigestion of untreated and treated Sewage Sludge with the Organic Fraction of Municipal Solid Wastes." Fermentation 3 (3), 2017, pp. 35.