BIOMETHANE PRODUCTION FROM PELLETS OF HORSE MANURE AND LITTER MIXTURE

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Abstract. Climate change caused by global warming forces more and more attention to the use of renewable energy resources. Biogas production from organic waste is considered one of the most correct and environmentally friendly technologies. Various organic wastes are used as raw materials. If this waste has to be transported over longer distances, it is advantageous to granulate it. It has been proven that more gas can be obtained from granules than from non-granulated raw materials during anaerobic fermentation. In this study, it was determined how much biogas (biomethane) can be obtained from pellets of horse manure and three different bedding mixtures. The amount of biogas (biomethane) production was studied in a laboratory device with 16 bioreactors. Their volume was 0.75 liters each. Three different mixtures of horse manure and litter were prepared: a) with fine sawdust (<1mm) and hay and straw residues (M1) b) with a large amount of hay and straw (also long) (M2) c) with coarse sawdust and hay and straw residues (M3). The bioreactors were placed in a thermostat and the operating temperature was set to 38ºC. The study lasted for 30 days. The following results were obtained: 0.451 (0.203) $L \cdot g^{-1}$DOM of biogas (biomethane) was obtained from mixture M1; mixture M2 yielded 0.494 (0.212) $L \cdot g^{-1}$DOM of biogas (biomethane) and mixture M3 yielded 0.468 (0.253) $L \cdot g^{-1}$DOM of biogas (biomethane). In two bioreactors with M3 mixture pellets the enzyme concentrate Metha Plus was added. Its addition improved biogas (biomethane) production: 0.497 (0.278) $L \cdot g^{-1}$DOM. The study showed that all three mixtures are well suited for biogas (biomethane) production.

Keywords: anaerobic fermentation, biogas, biomethane, enzymes, horse manure, pellets.

Introduction

Climate change is being observed all over the world. They are manifested both in global warming and in strong storms and large floods. In order to stop global warming, it is necessary to rapidly reduce harmful emissions. The use of fossil energy resources should be stopped and alternative energy sources should be used instead. Biogas production from organic waste (including agricultural waste) is considered as one of the most correct and environmentally friendly technologies [1-4]. If this waste has to be transported over longer distances, it is advantageous to granulate it [5; 6]. It has been proven that more gas can be obtained from granules than from non-granulated raw material [7]. A lot of manure is also produced in horse farms and it should be used efficiently.

Horse manure was used as substrate for biogas production from which nanolignocellulose fibres (LCNF) were extracted [8]. A biogas yield of 207 $L_N\ kg_{VS}^{-1}$ with a methane concentration of 65% was achieved. From the fermentation residue LCNFs, in yields of up to 41%, with lignin contents between 23 and 29 wt% depending on the fermentation time were obtained.

Swedish researchers [9], studying the extraction of biogas from horse manure, have found that according to national statistics the number of horses in Sweden is continually increasing and is currently approximately 360,000. This in turn leads to increasing amounts of horse manure that have to be managed and treated. Current practices could cause local and global environmental impacts due to poor performance or lack of proper management. Horse manure with its content of nutrients and organic material can however contribute to fertilisation of arable land and recovery of renewable energy following anaerobic digestion. At present anaerobic digestion of horse manure is not a common treatment. Two crucial factors are the type and amount of bedding material used, which has strong implications for feedstock characteristics, and the type of digestion method applied (dry or wet process). Straw and waste paper are identified as the best materials in the energy point of view. While the specific methane yield decreases with a high amount of bedding, the bedding material still makes a positive contribution to the energy balance.

The aim of this study is to determine how much biogas (biomethane) can be obtained from pellets of horse manure and three different bedding mixtures.

The book written by German researchers [4] contains data on the biogas yield from a mixture of horse manure and straw litter 300 $L \cdot kg^{-1}$DOM with a methane content of 65%. The high methane% raises doubts, but since there was no more information, there was no way to check it.

Materials and methods

Raw materials brought from a horse breeding farm were used in the research. The research used a methodology similar to that shown in the following literature [1; 10; 11]. An average sample was taken and the chemical composition determined in the LBTU laboratory according to standardized methodologies ISO 6496:1999. Total dry matter, organic dry matter, ash and major element content were determined for each group of raw materials for the average sample and inoculum. Analyses were performed according to standard methods. The raw materials of each group were carefully weighed, the inoculum was also weighed and thoroughly mixed. One inoculum – digestate from a continuous bioreactor was used for all samples.

10 g of raw material pellets and 0.5 kg of inoculum were filled into 0.75 l bioreactors (the weight was recorded to the nearest 0.2 g). All data were recorded in an experiment logbook and computer. In bioreactors R1 and R16, 500 g of inoculum was filled in each. Bioreactors R2-R5 were filled with 500 g of inoculum and 10 g of horse manure and litter M1 pellets, where the horse manure litter consisted of fine sawdust (<1 mm) and hay and straw residues. Bioreactors R6-R9 were filled with 500 g of inoculum and 10 g of horse manure and litter M2 pellets, where the litter consisted of a large amount of hay and straw (also long). Bioreactors R10-R13 were filled with 500 g of inoculum, 10 g of horse manure and litter M3 pellets, where the horse manure litter consisted of coarse sawdust. In bioreactors R14-R15, 500 g of inoculum, 10 g of horse manure and litter mixture M3 granules were filled and 1ml of enzyme concentrate Metha Plus (MP) was added. All bioreactors were connected with gas storage bags and taps, placed in a drying oven and set to a working temperature of 38 ± 0.5 ºC. The amount and composition of the gas released was measured daily. Fermentation took place in single filling mode and lasted until biogas was no longer released (28 days). The digestate was also weighed and its dry matter, ash and organic dry matter content was determined. The measurement accuracy was ± 0.02 for pH, ± 0.025 l for gas volume and ± 0.1 ˚C for temperature. The composition of the produced biogas was periodically measured - the content of CH_4, carbonic acid gas CO_2, oxygen O_2 and hydrogen sulfide H_2S was determined.

A Shimazu dry balance and a Nabertherm organic dry oven were used to determine the total dry matter%. A special program at 550 ºC was used for drying the samples. A gas analyzer GA 2000 was used to measure the gas composition. The content of methane, oxygen, carbonic acid gas and hydrogen sulphide in the biogas was determined, as well as the pressure and the normal volume of the gas was calculated.

Results and discussion

When calculating the amounts of biogas and methane obtained, the amount of biogas and methane obtained from all 16 bioreactors was evaluated. Mean results were calculated. The results were tabulated and presented in figures. The results of raw material analyses are shown in Table 1.

Table 1

Raw material analysis results

Raw material/bioreactor	pH	DM, %	DM, g	Ash, %	DOM, %	DOM, g	Weight, g
R1, R16 only inoculum	7.82	3.90	19.50	25.41	74.59	14.55	500
R2-R5 with 10g M1	-	89.29	8.929	8.17	91.83	8.200	10
R2-R5 with 500gIn + 10gM1	7.80	5.57	28.429	19.98	80.02	22.75	510
R6 - R9 with 10gM2	-	89.03	8.903	9.61	90.39	8.047	10
R6-R9 with 500gIn + 10gM2	7.80	5.57	28.403	20.44	79.56	22.597	510
R10-R13 with 10gM3	-	91.39	9.139	6.45	93.55	8.550	10
R10-R13 with 500gIn + 10gM3	7.80	5.62	28.639	19.34	80.66	23.100	510
R14-R15 M3 + In + 1ml MP	7.79	5.61	28.642	19.34	80.66	23.103	511

Designations: DM – total dry matter; DOM– dry organic matter; M1 – pellets of the first mixture of horse manure and litter; M2 – pellets of the second mixture of horse manure and litter; M3 – pellets of the third mixture of horse manure and litter; MP – enzyme concentrate Metha Plus; In – Inoculum.

As it can be seen from the table, the raw materials had a high dry matter and organic dry matter content. Such feedstock, which contains a lot of dry matter, is also well suited for biogas production. Biogas and methane yields from all raw materials are shown in Table 2. The table shows the results, in which the results obtained from the inoculum have already been evaluated and deducted.

Table 2

Biogas and methane production

Bioreactor Raw material	Biogas, L	Biogas, $L \cdot g^{-1}DOM$	Methane, %	Methane, L	Methane, $L \cdot g^{-1}DOM$
R1 inoculum	0.2	0.014	8.8	0.018	0.001
R16 inoculum	0.4	0.028	8.2	0.033	0.002
R1, R16 average	0.3	0.021	8.5	0.026	0.0015
R2 M110g + In 500g	3.5	0.427	45.24	1.583	0.193
R3 M110g + In 500g	3.7	0.451	46.01	1.725	0.210
R4 M110g + In 500g	3.8	0.463	44.40	1.687	0.206
R5 M110g + In 500g	3.8	0.463	43.82	1.665	0.203
Average R2 –R5	3.7 ± 0.1	0.451 ± 0.012	45.02 ± 0.758	1.665 ± 0.041	0.203 ± 0.007
R6 500gIn + 10g M2	4.2	0.522	43.74	1.837	0.228
R7 500gIn + 10g M2	3.6	0.447	43.32	1.560	0.194
R8 500gIn + 10g M2	4.0	0.497	40.81	1.632	0.203
R9 500gIn + 10g M2	4.1	0.510	44.15	1.810	0.224
Average R6 – R9	3.975 ± 0.188	0.494 ± 0.024	43.01 ± 1.098	1.710 ± 0.114	0.212 ± 0.014
R10 500gIe + 10g M3	4.2	0.491	55.43	2.328	0.272
R11500gIe + 10g M3	4.1	0.479	54.09	2.218	0.259
R12 500gIe + 10g M3 +	3.9	0.456	52.42	2.044	0.239
R13 500gIe + 10g M3	3.8	0.444	54.12	2.057	0.241
Average R10 – R13	1.95 ± 0.7	0.468 ± 0.173	54.0 ± 2.563	2.162 ± 0.454	0.253 ± 0.116
R14 500gIn + 10gM3 + 1ml MP	4.2	0.492	55.28	2.322	0.272
R15 500gIn + 10gM3 + 1ml MP	4.3	0.502	56.62	2.435	0.284
Average R14-R15	4.25 ± 0.05	0.497 ± 0.0 05	55.95 ± 0.67	2.379 ± 0.057	0.278 ± 0.006

Designations: $Lg^{-1}DOM$ - litter applied to the initial amount of dry organic matter of the raw material.

The yield of biogas and methane from all three feedstocks from each bioreactor is shown in Figure 1.

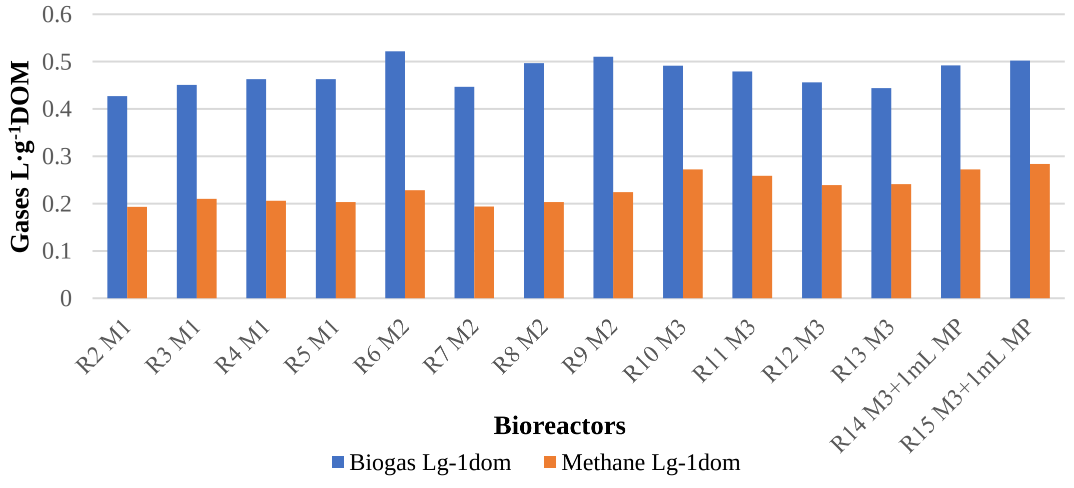

Fig. 1. **Specific biogas (methane) yields from each bioreactor**

The figure shows the biogas (methane) output (yield), which is applied to the unit of dry organic matter (g). It depends very much on the composition of this substance and is different for each substance. The highest methane yield was from the bioreactors containing mixture M3. It is 24.6% higher than from mixture M1. When another 1ml of enzyme was added to M3 mixture, the methane yield was 9.88% higher.

We were not able to find data in the literature directly on the use of horse manure and litter pellets in biogas production, and therefore there is no comparison. A comparison with a mixture of manure and litter would not be correct, because as we confirm in other studies, pelleting increases the yield of methane. The methane content in% from each bioreactor is shown in Figure 2.

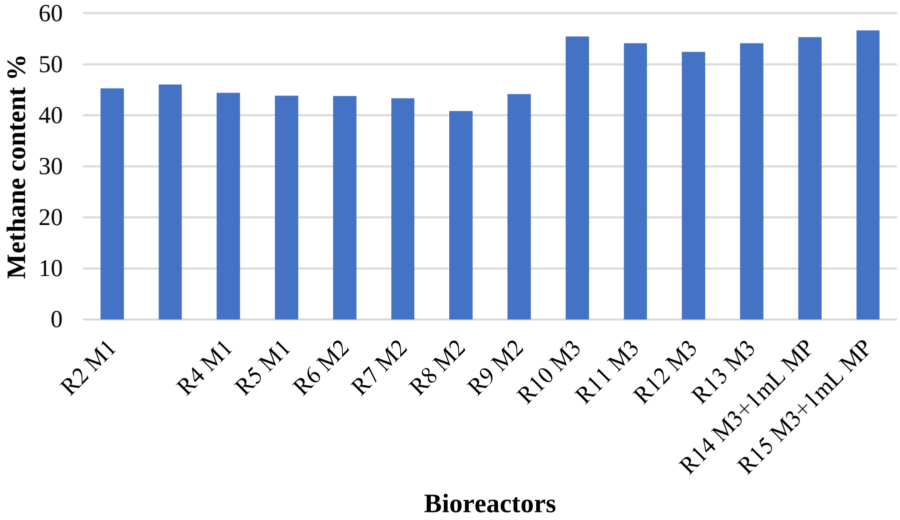

Fig. 2. **Methane content in each bioreactor**

The methane content of all three raw materials is considered to be relatively low. This can be explained by the large amount of litter in the mixtures. The fact that the yield is better from M3 can be explained by the higher SOV content. The highest methane content was from bioreactors with a small addition of enzyme concentrate.

Conclusions

1. All three pellets of different mixtures of horse manure and bedding can be well used as raw materials for biogas production.
2. The methane content in biogas from such pellets for M3 is a little higher than that produced from cattle manure (50%), but lower than that from pig (60%) and bird (58%) manure.
3. The amount of biogas produced from such pellets is greater than that produced from cattle manure (280-320 $L \cdot kg^{-1}$DOM) and quite similar to that from pig (500 $L \cdot kg^{-1}$DOM) and bird (490 $L \cdot kg^{-1}$DOM) manure.
4. The addition of the enzyme mixture significantly improved the methane yield.
5. Such pellets can also be used as fuel in furnaces.

Author contributions

Conceptualization, V.D.; methodology, P.I. and V.D.; software, V.D; validation, V.D; formal analysis, V.D and P.I..; investigation, V.D., P.I. data curation, V.D. and P.I.; writing – original draft preparation, V.D.; writing – review and editing, P.I. and V.D.; visualization, V.D.; project administration, V.D.; funding acquisition, V.D. Both authors have read and agreed to the published version of the manuscript.

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