EXTRACTION OF DIGESTATE FROM VARIOUS RAW MATERIALS AND ITS MIXTURES WITH ASH

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Abstract. Within the framework of the LAD- 29 project, it was necessary to obtain digestates from various raw materials used by the project partners and to test the possibility of granulating their mixture with ash. Raw materials were taken from the biogas plants of the project partners and analyzed in laboratory. Partner LatdanAgro feedstocks were charged in the same proportions, as in the biogas plant were filled, in two 110 liter bioreactors A and B, which operated in continuous operation mode. How much digestate can be obtained from each feedstock and how much of it can be obtained biogas was tested in 16 bioreactors in the batch mode. The operating temperature in all bioreactors was kept the same as in the bioreactors of the biogas plant. The digestates with different moisture contents obtained in the laboratory and also brought from four biogas plants were mixed with wood ash, the condition of each mixture was determined and the possibility of granulation was assessed. The granulation test revealed that when using a digestate with a high moisture content, it is cementing the added ash, but the ash, added to the dry digestate, puts in the air. Granules can only be formed, if the moisture content of the digestate is 20-30%. The thick fractions of digestates from the biogas plants of the four project partners, obtained from their fractionation plants, were tested. Different stability granules were made from them.

Keywords: anaerobic digestion, digestate, wood ash, granules.

Introduction

The key condition of a viable and sustainable anaerobic digestion (AD) project is the uninterrupted supply of qualitative biomass feedstock [1; 2]. Digester liquor (digestate) can be used as a fertiliser supplying vital nutrients to soils. The solid, fibrous component of the digested material can be used as a soil conditioner to increase the organic content of soils. The liquor can be used instead of chemical fertilisers that require large amounts of energy to produce and transport. The use of manufactured fertilisers is, therefore, more carbon-intensive than the use of anaerobic digester liquor fertiliser [3]. Italian researchers studied the mass balance of digestate. The results obtained indicated that unexpectedly on a mass balance the liquid fraction still contains the majority of dry matter (DM), i.e. 67% of the total of digestate. Liquid fraction also contained 87% and 71% of TKN and P_2O_5, respectively. Dry matter contents were in line with a typical natural product (NP) – organic fertilizers. Chemical characterization suggested that the light fraction can be used as a substitute for mineral N fertilizers because of its high N content, while the solid fraction can be proposed as a NP-organic fertilizer [4].

The digestate needs to be environmentally friendly and useful. Anaerobic digestion (AD) is a suitable process for it. In the literature data were found [5; 6] on its use for biogas production. For biogas plant operator proper control of the anaerobic digestion process they need to know the following raw material methane potential [7; 8].

Latvia biogas plants every year produce 1.1-1.2 bn tons of digestate. It can be used as fertilizer. Wood ash also was used for improving soils. This study is an attempt to mix both for use as fertilizer. A study also was aimed to find out the potential of biogas from different biomass, which is usable for biogas plants of Latvian pigs farms and to investigate what digestate it is possible to produce.

Materials and methods

Methods and equipment are similar as described in our article [9]. Sixteen 0.75 l bioreactors were charged with raw material and 500 g of inoculum (its weight was recorded to the nearest 0.2 g). All data were recorded in an experiment log and on a computer. Bioreactors R2-R4 were filled with 40 g of pig manure each, R5-R7 with 20 g of thick recirculate each, R8-R10 with 20 g of maize silage each, and bioreactors R11-R13 each with 20 g of sludge and R14-R15 each with wheat straw. In this study, digestate was obtained from each raw material in a mixture with inoculum.

In order to form mixtures of digestate and ash, it is important to find out the optimal moisture content of the digestate and the proportions of the mixture. First, the digestate naturally obtained in the AD process was added to Fortum ash in 5 different proportions. 4 out of 5 jars formed a product that cemented. This convinced that mixtures should be made with drier digestate. It was further experimented and already at 20% humidity the digestate with ash no longer settled. The drier the digestate, the more granular the mixture and after about 23-24% the digestate did not form pronounced ash. Therefore, when the digestate thick fraction was examined after separation, it proved to be suitable for mixing. The completely dried digestate from both our laboratory equipment and the Pampali drying equipment was also tested. Both digestates had to be further crushed before mixing, as they were in lumps. The mixture came out very loose, but the ash very rose in the air. It is light, but must be transported in closed containers. We tried to granulate this mixture, but failed, an ash cloud formed. In mixtures with a moisture content of 25-30% granulation was successful.

Results and discussion

Results of investigation of sample substrates, including inoculums, pig manure, thick recirculate, maize silage, sludge and chopped straw before starting of the AD process are shown in Table 1.

Table 1

Analyses of raw material samples before anaerobic digestion

Bio-reactors	Raw material	pH	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weight, g
R1; R16	In 500g	8.00	5.53	27.65	10.48	89.52	24.752	500
R2-R4	PM 40g	7.5	5.4	2.16	21.2	78.8	1.702	40
R2-R4	40g PM + 500g In	7.82	5.51	29.81	11.12	88.88	26.495	520
R5- R7	20g TR	-	26.09	5.218	14.26	85.74	4.474	20
R5-R7	20g TR + 500g In	7.9	6.32	32.868	11.08	88.92	29.226	520
R8-R10	20g MS	-	43.64	8.728	11.47	88.53	7.727	20
R8- R10	20g MS + 500g In	7.85	6.995	36.378	10.72	89.28	32.479	520
R11-R13	20g S	-	14.38	2.876	15.69	84.31	2.425	20
R11-R13	20g S + 500g In	7.86	5.87	30.526	10.98	89.02	27.177	520
R14-R15	10g ST	-	80.73	8.073	10.77	89.23	7.204	10
R14-R15	10g ST + 500g In	7.9	70.04	35.723	10.55	89.45	31.956	510

Note: In – inoculum; PM – pig manure; TR – thick recirculate; MS – maize silage ; S –sludge; ST – straw; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R16 – bioreactors.

Digestate from every bioreactor is shown in Table 2. The best contents of DOM are from MS and TR.

Table 2

Digestate from every bioreactor

Bioreactor	pH	TS%	TS g	Ash%	DOM%	DOM g	Weight g
R1	8.05	3.34	16.352	31.61	68.39	11.184	489.6
R16	7.92	3.49	17.122	33.78	66.22	11.338	490.6
Aver. R1-R16	**7.98**	**3.415**	**16.737**	**32.69**	**67.31**	**11.261**	**490.1**
R2	7.96	3.32	16,858	35,41	64.59	10.889	507.6
R3	7.93	4.46	22.423	25,62	74.38	16.680	502.8
R4	8.08	3.19	16.045	35,53	64.47	10.345	503.0
Aver R2-R4 ± st.dev	**7.99 0.79**	**3.657 0.699**	**18.442 3.472**	**32.187 5.687**	**67.213 5.687**	**12.638 3.511**	**504.5 2.715**
R5	7.88	4.17	21.334	31.01	68.99	14.718	511.6
R6	7.80	4.67	23.807	26.54	73.46	17.489	509.8
R7	7.87	4.13	21.162	28.41	71.59	15.150	512.4
Aver. R5-R7 ± st.dev	**7.85 0.44**	**4.323 0.301**	**22.101 1.48**	**28.653 2.245**	**71.35 2.245**	**15.786 1.491**	**511.3 1.332**
R8	7.82	3.78	19.112	32.26	67.64	12.927	505.6
R9	7.78	3.82	19.268	29.52	70.48	13.580	504.4
R10	7.71	3.74	19.096	32.21	67.79	12.945	510.6
Aver.R8-R10 ± st.dev	**7.77 0.557**	**3.78 0.04**	**19.159 0.095**	**31.363 1.568**	**68.64 1.598**	**13.150 0.372**	**506.9 3.288**

Table 2 (continued)

Bioreactor	pH	TS%	TS g	Ash%	DOM%	DOM g	Weight g
R11	8.06	3.72	18.912	33.95	66.05	12.492	508.4
R12	7.88	3.08	15.622	38.80	61.20	9.561	507.2
R13	7.90	3.76	19.011	31.59	68.41	13.005	505.6
Aver.R11-R13 ± st.dev	**7.95 0.099**	**3.52 0.382**	**17.848 1.929**	**34.78 3.676**	**65.22 3.676**	**11.685 1.858**	**507.1 1,405**
R14	7.96	3.43	17.458	28.57	71.43	12.471	509.0
R15	7.93	3.45	17.498	33.90	66.10	11.566	507.2
Aver.R14-R15 ± st.dev	**7.95 0.21**	**3.44 0.14**	**17.478 0.028**	**31.24 3,769**	**68.77 3.769**	**12.019 0.64**	**508.1 1.273**

The production of biogas and methane from each bioreactor is shown in Table 3.

Table 3

Biogas and methane yields

Bioreactor/Raw material	Biogas, L	Biogas, $L \cdot g^{-1}_{DOM}$	Methane, aver.%	Methane, L	Methane, $L \cdot g^{-1}_{DOM}$
R1 500g In	2.0	0.081	19.05	0.381	0.015
R16 500g In	2.1	0.085	33.33	0.7	0.028
Average R1, R16	**2.05**	**0.083**	**26.415**	**0.54**	**0.022**
R2 500 g In + 40g PM	0.95	0.558	56.12	0.533	0.313
R3 500 g In + 40g PM	0.85	0.499	58.42	0.497	0.292
R4 500 g In + 40g PM	1.05	0.617	56.05	0.589	0.345
Average R2- R4 PM ± st.dev.	**0.95 0.1**	**0.558 0.059**	**56.86 1.349**	**0.540 0.046**	**0.317 0.027**
R5 500 g In + 20g TR	1.875	0.419	53.94	1.012	0.226
R6 500 g In + 20g TR	2.23	0.498	60.36	1.346	0.301
R7 500 g In + 20g TR	2.05	0.458	50.15	1.028	0.230
Average R5-R7 TR ± st.dev.	**2.053 0.178**	**0.458 0.04**	**54.82 5.161**	**1.129 0.188**	**0.252 0.042**
R8 500 g In + 20g MS	5.03	0.650	64.62	3.247	0.420
R9 500 g In + 20g MS	4.53	0.586	64.51	2.923	0.378
R10 500 g In + 20g MS	4.33	0.560	63.11	2.733	0.354
Average R8-R10 MS ± st.dev.	**4.63 0.361**	**0.599 0.046**	**64.08 0.841**	**2.968 0.26**	**0.384 0.033**
R11 500 g In + 20g S	1.03	0.424	61.26	0.631	0.260
R12 500 g In + 20 g S	1.33	0.548	60.45	0.804	0.332
R13 500 g In + 20 g S	0.83	0.342	59.28	0.492	0.203
Average R11-R13 S ± st.dev.	**1.063 0.252**	**0.438 0.104**	**60.33 0.995**	**0.642 0.156**	**0.265 0.065**
R14 500 g IN + 10 g ST	3.23	0.448	63.00	2.035	0.282
R15 500 g IN + 10 g ST	3.13	0.434	57.32	1.794	0.249
Average R14-R15 ST ± st.dev.	**3.18 0.071**	**0.441 0.01**	**60.16 4.016**	**1.915 0.17**	**0.266 0.023**

Note: $L \cdot g^{-1}_{DOM}$ – litres per 1 g dry organic matter added (added fresh biomass into inoculums).

The best methane yield is from MS, then from PM. These biomasses are favourable as raw materials.

Filling of 110 liter bioreactors was done as follows. By 17.02, both bioreactors A and B were filled with 50 liters of inoculum (liquid digestate). From 17.02, bioreactors were started to be filled with the same raw materials and in the same proportions as at the biogas plant. In bioreactor A alone, 13 batches of 3.903 kg of feedstock were filled, but in bioreactor B, six batches of 8.042 kg plus 2.487 kg. Each bioreactor then contained 100.74 kg of biomass. Subsequently, 3.903 kg of raw materials were filled into each bioreactor daily in appropriate proportions and 3.739 kg of digestate was poured. The results obtained from 1.03 to 1.04 are shown in Fig. 1 and 2.

Although at the beginning of the period the feedstock filling regimes were different, the biogas production from the two bioreactors on average leveled off and did not differ much.

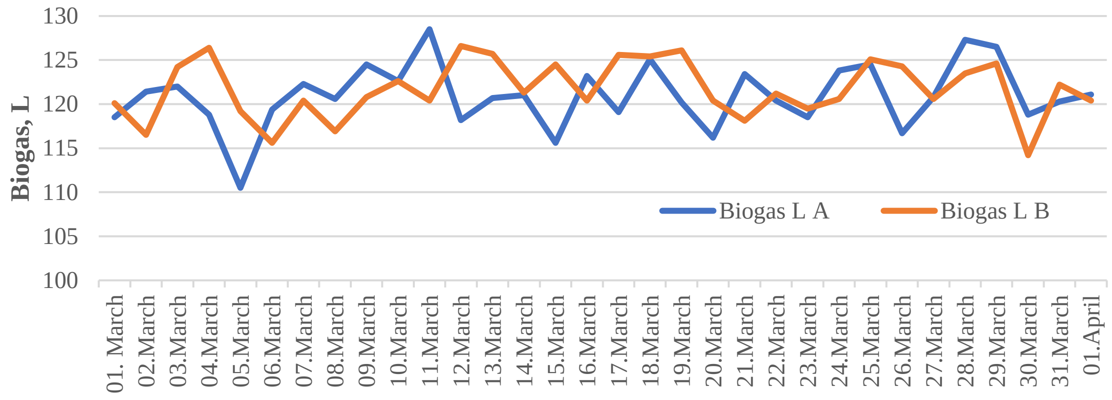

Fig. 1. **Biogas production in bioreactors A and B**

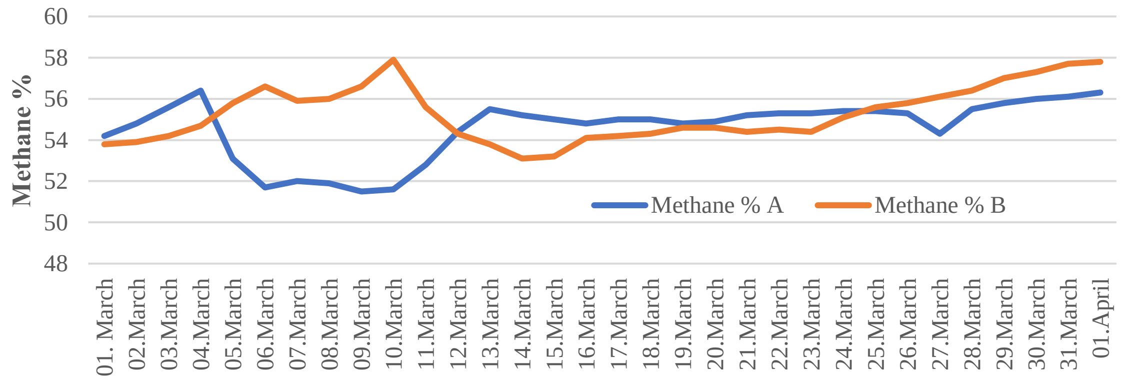

Fig. 2. **Methane contents % in biogas from bioreactors A and B**

The methane content in both bioreactors was quite similar. The biggest differences in the period from 4.03 to 11.03 can be explained by the unequal filling regime of raw materials. The results obtained in the last period of stable filling of raw materials and digestate removal are shown in Table 4. The digestate obtained in biogas plant bioreactors in the filling period and 110 liter bioreactors did not differ very much. The digestates with different moisture contents obtained in the laboratory and also brought from four biogas plants were mixed with wood ash, the condition of each mixture was determined and the possibility of granulation was assessed.

Table 4

Digestate from 110 litres bioreactors A and B

Bioreactor	PS%	P%	DOM%
A	5.62	20.58	79.42
A	5.61	20.47	79.53
A	5.82	20.68	79.32
A	5.59	20.13	79.87
A	5.60	20.49	79.51
A	5.53	19.95	80.05
A	5.66	20.51	79.49
A average ± st.dev.	**5.63 ± 0.09**	**20.40 ± 0.26**	**79.60 ± 0.26**
B	5.67	22.86	77.14
B	5.68	22.88	77.12
B	5.70	23.02	76.98
B	5.65	22.43	77.57
B	5.69	22.58	77.42
B	5.72	21.12	78.88
B	5.68	22.85	77.15
B average ± st.dev.	**5.68 ± 0.02**	**22.53 ± 0.66**	**77.47 ± 0.66**
A + B average ± st.dev.	**5.655 ± 0.035**	**21.465 ± 1.506**	**78.535 ± 1.506**

The condition of the different mixtures is shown in Table 5.

Table 5

Condition of various mixtures

Digestate source	PS%	P%	SOV%	State of the mixture	Suitable for granulation
A bioreactor	3.44	31.24	68.76	cementing	no
B bioreactor	3.52	25.14	74.86	cementing	no
Pampali recirculate	5.40	24.10	75.90	cementing	no
LatDanAgro recirculate	5.53	10.48	89.52	cementing	no
A bioreactor	5.63	20.40	79.60	cementing	no
B bioreactor	5.68	22.53	77.47	cementing	no
A bior., little dried	11.92	24.52	75.48	cementing	no
A + B bior., little dried	18.44	7.91	92.09	Slightly cemented	no
Bioziedi thick fraction	22.75	10.04	89.96	Does not cement, does not dust	yes
LatDanAgro thick fraction	24.24	9.63	90.37	Does not cement, does not dust	yes
LatDanAgro thick fraction	24.25	10.3	89.70	Does not cement, does not dust	yes
A + B bioreactor, semi - dried	25.23	8.21	91.79	Does not cement, does not dust	yes
Pampali thick fraction	26.52	10.90	89.10	Does not cement, does not dust	yes
Pampali thick fraction	28.43	7.35	92.65	Does not cement, does not dust	yes
Mezaciruli thick fraction	28.58	12.74	87.26	Does not cement, does not dust	yes
A bioreactor, semi - dried	47.38	5.31	94.69	Dust rises in the air	no
B bioreactor, semi - dried	49.33	12.32	87.68	Dust rises in the air	no
Pampali completely dried	85.87	8.90	91.10	Very much dust rises in the air	no
A + B bioreactors completely dried	97.14	13.38	86.62	Very much dust rises in the air	no

Conclusions

1. For digestate from pig manure, the TS had an average of 3.657 ± 0.699% with a DOM of 67.213 ± 5.687%.
2. For digestate from thick recirculate, the TS had an average of 4.323 ± 0.301% with a DOM of 71.35 ± 2.245%.
3. For digestate from maize silage, the TS had an average of 3.78 ± 0.04% with a DOM of 68.04 ± 1.598%.
4. For digestate from sludge, the TS had an average of 3.52 ± 0.382% with a DOM of 65.22 ± 3.676%.
5. For digestate from straw, the TS had an average of 3.44 ± 0.14% with a DOM of 68.77 ± 3.76%.
6. The average digestate from 110 liter bioreactors was TS 5.65 ± 0.035% with a DOM of 78.535 ± 1.506%
7. It is the best to use the thick fraction of digestate after separation to form mixtures, no more drying is required.

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