BIOMASS COFERMENTATION FOR BIOGAS PRODUCING

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Abstract. More than 20 biogas plants have started working during recent time in Latvia. There is a need to investigate the suitability of various biomass for energy production. The paper shows the results of cofermentation of waste water sludge with milk processing whey and different plant biomass. The cofermentation process was investigated for biogas production in 50 l digesters, operated in continuous mode at temperature 38±1.0 ºC. Average methane yield per unit of volatile solids added (VS) from cofermentation with sunflower silage was 247 $l \cdot kg_{VSa}^{-1}$ and average methane (CH_4) content was 59.39 %. Average methane yield from cofermentation with yellow leaves of trees was 260.83 $l \cdot kg_{VSa}^{-1}$ and average methane content was 64.17 %. All investigated wastes and plants have good biogas yields, and can be successfully cultivated for energy production under agro ecological conditions in Latvia.

Key words: agricultural wastes, anaerobic digestion, biogas, methane, sludge, whey.

Introduction

Latvia cannot provide the country with own produced energy and fossil energy resources are imported from other countries. There are 368500 ha of not used agriculture land in Latvia. Effective use of this land could help obtain a significant amount of energy. One of the most advanced methods of energy production from biomass is anaerobic digestion. Biogas is a product of great value and its production technology does not increase carbon dioxide emission and is environmentally friendly. In recent years the biogas production is booming also in Latvia. There is a need to use different raw materials in biogas plants. These material cofermentation investigation results are very important for the maintaining a stable anaerobic digestion process at any plant.

Materials and methods

Investigations on laboratory equipment with different raw materials were carried out using one method. At first the equipment was started using inoculum and cow manure, and then stable performance of the equipment was reached (beneficial bacteria association was grown for providing good bioconversion process). Then bacteria were tamed to use cofermentation products – sludge and whey and finally, the third test material was added in each digester**.** As test materials raw materials that could be used in biogas plants were selected. The first stage of the investigation – growing of beneficial bacteria association in each digester lasted up to two months, but the investigation of the addition of the third material – up to one month. This investigation shows the results obtained from the facilities after the third material was added.

The raw materials used for the investigation were sludge and whey and other raw materials. The average substrate was taken and the Latvia University of Agriculture, Bioenergy Laboratory determined the composition of the substrate using ISO 6496:1999. The substrates from each type of raw materials were analyzed for the dry matter, organic matter, ash content and chemical composition. The analysis was measured by using standardized methods. The dry matter was determined by "Shimazu" facility at temperature 120 ºC. The raw materials were carefully weighed and thoroughly mixed. All digesters were run using one inoculum – digestate from cow manure digester.

Every day digesters were filled with a specific raw material quantity shown in the research table (the accuracy of the measurements was ±0.2 g for weight). All data were entered into the research journal and computer.

All digesters were connected to the gas storage facilities and taps; the digesters were operating in continuous mode at temperature from 38 to 0.5 ºC. The data of the substrate pH value, gas volume and composition were registered every day.

Also the digestate was weighed and the pH value, dry matter, ash content and organic matter composition were determined.

Facilities

The dry matter was determined by the Shimazu facility at temperature 120°C, the organic matter was determined by the "Nabertherm" drying oven at temperature 550°C. The laboratory equipment was used for the research "Figure 1".

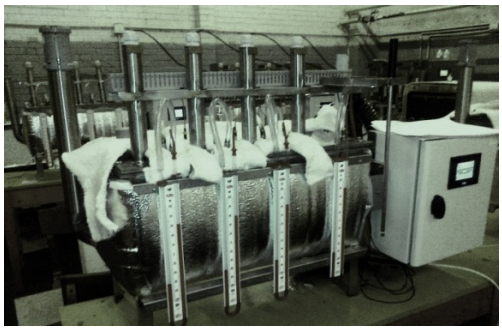

Fig.1. **Laboratory equipment**

The automated heating system obtained stable temperature. The composition of gas was determined by the gas analyzer "GA 2000". The concentration of methane, oxygen, carbon dioxide and hydrogen sulphide in the biogas, the pressure and normal calculated volume of gas were measured. The weighing scales "Kern 16KO2 FKB" were used to determine the raw material and digestate weight; the pH stationary meter "PP-50" was used to determine the pH value.

Results

1. Investigation of raw materials: sludge, whey and sunflower silage

The results are shown in Table 1. S.S – sunflower silage; S – sludge; W – whey; TS – total solids; DOM – dry organic matter.

Table 1

Filled in raw materials

Day	Filled material, kg				PS, %	DOM from PS, %	Ash from PS, %	DOM, kg
	S	W	S.S	Total				
1	0.600	1.003	0.104	1.707	10.32	81.35	18.65	0.1433
2	0.601	1.004	–	1.605	11.03	80.21	19.79	0.1420
3	0.602	0.998	0.103	1.703	10.41	81.27	18.73	0.1441
4	0.600	1.002	0.102	1.704	11.02	82.45	17.55	0.1548
5	0.592	1.003	0.100	1.695	10.81	83.07	16.93	0.1522
6	0.603	1.001	0.102	1.706	10.76	83.12	16.88	0.1526
7	0.603	1.002	0.199	1.804	10.54	82.91	17.09	0.1576
8	0.600	1.010	0.195	1.805	10.55	82.95	17.05	0.1580
9	0.610	0.998	0.199	1.807	10.69	83.02	16.98	0.1604
10	0.605	1.003	0.202	1.810	10.42	82.98	17.02	0.1565
11	0.599	1.004	0.201	1.804	10.70	83.13	16.87	0.1605
12	0.601	0.997	0.198	1.796	10.73	83.20	16.80	0.1604
13	0.610	0.999	0.205	1.814	10.81	82.98	17.02	0.1627
14	0.603	1.002	0.204	1.809	10.62	82.00	18.00	0.1575
15	0.601	0.998	0.200	1.799	10.87	82.98	17.02	0.1623
16	0.605	1.008	0.202	1.815	10.69	82.51	17.49	0.1601
17	0.601	1.005	0.201	1.807	10.65	82.01	17.99	0.1578
18	0.603	1.004	0.205	1.812	10.11	81.55	18.45	0.1494
19	0.602	1.001	0.203	1.806	10.21	81.68	18.32	0.1506
20	0.609	1.009	0.199	1.817	10.23	81.71	18.29	0.1519
21	0.602	0.999	0.190	1.791	10.07	81.49	18.51	0.1470

This year the yield of sunflower silage produced by farms was used in the investigation. For the first time sunflower silage was used not only for cattle feeding but for biogas producing.

The investigation started on reduced organic load and the principle of gradualness was observed. The quality of the silage was good. As the result the process of cofermentation was successful and the biogas yield was adequate.

The average bioconversion level is 57.14 % of the data calculated from the results of "Table 1" and extracted digestate.

Table 2

Biogas and methane yield

Day	Biogas, l	Methane, l	Average methane content, %	Biogas, $l \cdot kg^{-1}$ DOM	Methane, $l \cdot kg^{-1}$ DOM
1	40.2	23.75	59.09	280.50	165.75
2	46.6	23.38	50.16	328.18	164.62
3	41.9	21.27	50.77	290.82	147.65
4	51.0	26.25	51.48	329.40	169.57
5	59.9	32.85	54.84	393.53	215.83
6	58.7	32.67	55.66	384.72	214.12
7	50.6	29.12	57.54	320.97	184.70
8	48.5	28.76	59.30	307.04	182.08
9	56.6	32.81	57.96	352.94	204.58
10	53.4	30.13	56.43	341.21	192.55
11	55.0	33.94	61.71	342.76	211.52
12	59.8	36.14	60.44	372.82	225.33
13	72.4	43.63	60.26	444.94	268.11
14	72.4	43.48	60.05	459.58	275.98
15	84.5	54.58	64.59	520.74	336.37
16	84.0	53.00	63.10	524.71	331.09
17	89.8	59.09	65.80	568.99	374.38
18	82.6	53.99	65.36	552.90	361.38
19	74.7	49.10	65.73	495.98	326.00
20	76.0	48.53	63.86	500.39	319.53
21	73.7	46.46	63.03	501.46	316.09
Average	$63.4^{+26.4}_{-23.2}$	$38.23^{+20.86}_{-16.96}$	$59.39^{+6.41}_{-9.23}$	$410.22^{+158.77}_{-129.72}$	$247.01^{+127.37}_{-99.36}$

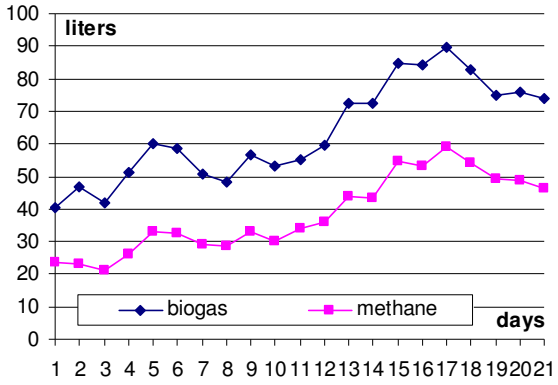

Fig. 1. **Biogas and methane**

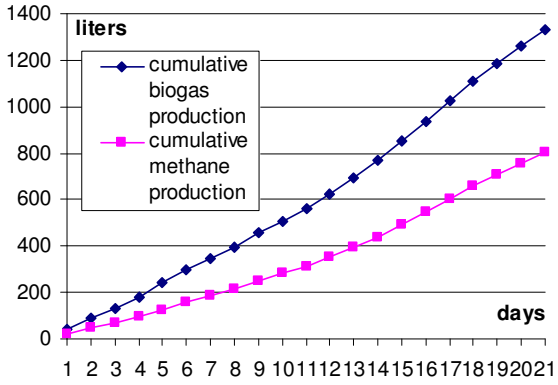

Fig. 2. **Biogas and methane in total**

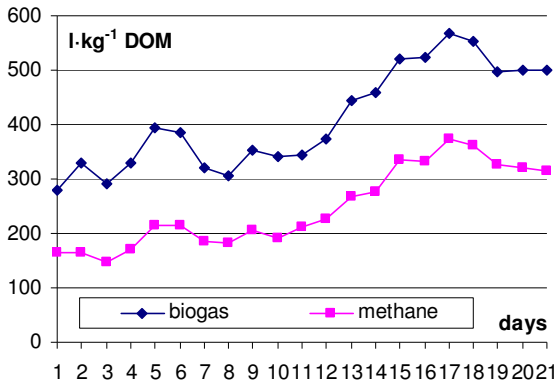

Fig. 3. **Biogas and methane l·kg^{-1} DOM**

2. *Investigation of raw materials: sludge, whey and leaves of the tree*

The tree leaves collected in the Yelgava Park were used as raw material. The leaves were carefully shredded and their size did not exceed 1 cm. The amount of filled in raw materials is shown in Table 3. T.L – tree leaves; S – sludge; W – whey.

Table 3

Filled in raw materials

Days	Filled material, kg				PS, %	DOM from PS, %	Ash from PS, %	DOM, kg
	S	W	T.L.	Total				
1	0.604	1.002	0.209	1.815	11.31	85.49	14.51	0.1755
2	0.601	0.999	0.201	1.801	10.85	89.54	10.46	0.1750
3	0.599	1.003	0.200	1.802	11.72	84.23	15.77	0.1779
4	0.598	1.007	0.197	1.802	11.00	84.23	15.77	0.1670
5	0.601	0.998	0.208	1.807	10.18	84.57	15.43	0.1555
6	0.593	0.999	0.195	1.787	11.43	84.11	15.89	0.1718
7	0.607	1.007	0.203	1.817	10.56	85.32	14.68	0.1637
8	0.600	1.010	0.299	1.909	10.93	84.33	15.67	0.1760
9	0.603	1.004	0.301	1.908	10.45	84.20	15.80	0.1679
10	0.601	1.001	0.299	1.901	11.25	86.21	13.79	0.1844
11	0.604	1.002	0.290	1.896	10.19	84.33	15.67	0.1629
12	0.598	1.003	0.301	1.902	10.25	83.74	16.26	0.1632
13	0.600	1.004	0.298	1.902	10.53	84.12	15.88	0.1685
14	0.606	1.001	0.295	1.902	10.98	85.23	14.77	0.1779
15	0.601	1.001	0.303	1.905	10.26	84.62	15.38	0.1654
16	0.605	1.002	0.300	1.907	10.20	84.42	15.58	0.1641
17	0.600	1.004	0.305	1.909	11.66	86.12	13.88	0.1917
18	0.603	1.001	0.301	1.905	10.54	84.11	15.89	0.1689
19	0.601	1.003	0.302	1.906	10.90	85.21	14.79	0.1769
20	0.604	1.007	0.289	1.900	10.38	84.16	15.84	0.1659
21	0.600	1.002	0.290	1.892	10.01	83.22	16.78	0.1576

The C/N ratio of sludge and whey shows that the proportion of nitrogen is greater than the proportion of carbon. Therefore, the tree leaves with a great concentration of carbon improve this ratio. The pH value of silage is low, but the pH value of the tree leaves is close to neutral. The raw materials filling in mode was gradually increased and maintained. The results were good and there was no need to correct them. The average organic load of 4.13 kg·m^{-3} was maintained slightly above the theoretical optimum.

The bioconversion level decreased from 72.27 % to 52.4 % of the data calculated from Table 3 and extracted digestate. This is explained by the fact that the elements of leave composition have a

long decomposition period. Cellulose and hemicelluloses decompose slower and therefore their amount in digestate and dry matter content was increasing.

The yield of methane and biogas is shown in Table 4 and figures.

Table 4

Biogas and methane yield

Days	Biogas, l	Methane, l	Average methane content, %	Biogas, $l \cdot kg^{-1}$ DOM	Methane, $l \cdot kg^{-1}$ DOM
1	50.7	29.770	58.718	289.38	169.92
2	55.1	31.927	57.944	314.86	182.44
3	56.5	31.842	56.357	317.58	178.98
4	65.4	39.637	60.607	391.33	237.17
5	74	47.537	64.239	475.88	305.70
6	70.9	45.839	64.653	412.90	266.95
7	70.7	45.657	64.579	432.01	278.99
8	76.4	48.968	64.094	434.09	278.23
9	72.1	46.388	64.338	429.31	276.21
10	69.3	44.991	64.922	375.34	243.68
11	69	45.396	65.791	423.64	278.71
12	71.4	45.563	63.814	437.41	279.13
13	74.7	48.360	64.739	443.54	287.14
14	76	48.855	64.283	426.49	274.16
15	77.6	51.519	66.391	469.41	311.65
16	68.7	46.399	67.539	418.56	282.69
17	74.2	50.777	68.433	387.12	264.92
18	72.6	48.692	67.069	429.83	288.28
19	67.3	44.249	65.748	380.14	249.93
20	67.1	44.465	66.267	404.43	268.01
21	64.5	43.281	67.102	409.17	274.56
Average	$66.8^{+8.8}_{-18.1}$	$44.29^{+7.23}_{-14.52}$	$64.17^{+4.26}_{-7.82}$	$404.88^{+71.00}_{-150.50}$	$260.83^{+50.82}_{-90.91}$

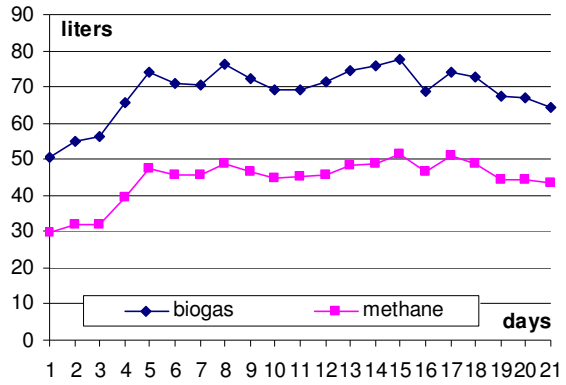

Fig. 5. **Biogas and methane**

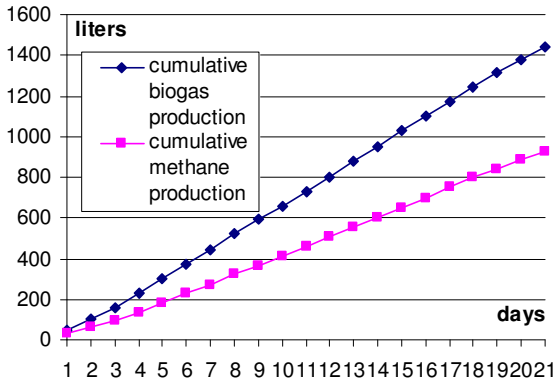

Fig. 6. **Biogas and methane in total**

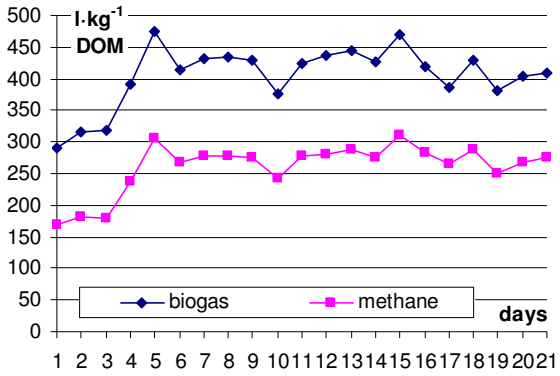

Fig. 7. **Biogas and methane, l·kg^{-1} DOM**

Conclusions

1. Sludge, whey and sunflower silage cofermentation obtained an average 247 l·kg$_{VSa}^{-1}$ methane yield and it is evaluated as a successful result.
2. The amount of the methane yield in the second investigation period is over the amount of the methane yield in the first investigation period due to the grown of the number of methane-forming bacteria.
3. The level of bioconversion could be greater if the increase of the raw material amount is insignificant but stable, yet it requires a long period of investigation.
4. The methane yield 260.83l l·kg$_{VSa}^{-1}$ was obtained from sludge, whey and leaves.
5. The process was stable and showed an increasing gas obtaining trend.
6. The bioconversion level on average was over 60 % but in the final stage of the investigation it decreased.

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