CO-FERMENTATION OF BIOMASS WITH HIGH CONTENT OF LIGNOCELLULOSES FOR BIOGAS PRODUCTION

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Abstract
More than 20 biogas plants started working in recent time in Latvia. There is need to investigate the suitability of various biomass for energy production. This paper shows results from the co-fermentation of waste water sludge with milk processing whey and different plant biomasses. The co-fermentation process was investigated for biogas production in 50 l digesters, operated in continuous mode at temperature 38±1.0°C. The average methane yield per unit of volatile solids added (VS) from co-fermentation with young willow was 115 $l \cdot kg_{VSa}^{-1}$ and the average methane (CH_4) content was 51.81%. The average methane yield from co-fermentation with chopped barley straw was 284 $l \cdot kg_{VSa}^{-1}$ and the average methane content was 61.47%. 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 to obtain a significant amount of energy. One of the most advanced methods of energy production from biomass is anaerobic digestion. The 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 need to use different raw materials in biogas plants. Results of co-fermentation investigation on these materials are very important for 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, then stable performance of the equipment was reached (beneficial bacteria association was grown for providing a good bioconversion process). Then bacteria were tamed to use co-fermentation 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 a 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 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 Bioenergy Laboratory of Latvia University of Agriculture determined the composition of the substrate using ISO 6496:1999. The substrates from each type of raw materials were analyzed for 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°C. The raw materials were carefully weighed and thoroughly mixed. All digesters were run using one inoculum – digestate from the cow manure digester.

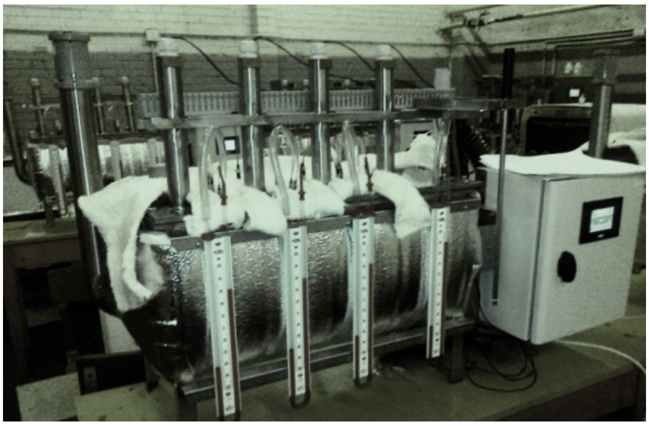
Every day digesters were filled with a specific raw material quantity shown in the research table (the accuracy of the measurements was ±0.2 g for weight). All data were entered into the research journal and computer.

All digesters were connected to the gas storage facilities and taps; the digesters were operating in continuous mode at temperature 38 + 0.5°C. Data of 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



Pic.1. **Laboratory equipment**

was determined by the "Nabertherm" drying oven at temperature 550°C. The laboratory equipment was used for the research (Picture 1).

The automated heating system obtained a 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, pressure and normal calculated volume of gas was measured. The weighing scales "Kern 16KO2 FKB" were used to determine raw materials 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. YW – young willow; S - sludge; W - whey; TS – total solids; DOM - dry organic matter.

Table 1

Filled in raw materials

Days	Filled material kg				PS, %	DOM from PS %	Ash from PS %	DOM kg
	S	W	YW	Total				
1	0.600	1.003	0.104	1.707	1.707	86.14	13.86	0.1505
2	0.601	1.004	0.102	1.707	1.707	84.30	15.70	0.1480
3	0.602	0.998	0.103	1.703	1.703	84.80	15.20	0.1499
4	0.600	1.002	0.102	1.704	1.704	85.28	14.72	0.1490
5	0.592	1.003	0.100	1.695	1.695	84.84	15.16	0.1487
6	0.603	1.001	0.102	1.706	1.706	86.12	13.88	0.1546
7	0.603	1.002	0.100	1.804	1.804	84.46	15.54	0.1546
8	0.600	1.010	0.100	1.805	1.805	85.67	14.33	0.1536
9	0.610	0.998	0.099	1.807	1.807	85.39	14.61	0.1516
10	0.605	1.003	0.099	1.810	1.810	86.10	13.90	0.1519
11	0.599	1.004	0.099	1.804	1.804	83.90	16.04	0.1455
12	0.601	0.997	0.098	1.796	1.796	84.30	15.70	0.1489
13	0.610	0.999	0.098	1.814	1.814	84.98	15.10	0.1528
14	0.603	1.002	0.097	1.809	1.809	84.30	15.70	0.1449
15	0.601	0.998	0.097	1.799	1.799	84.88	15.12	0.1453
16	0.605	1.008	0.096	1.815	1.815	84.98	15.02	0.1514

Table 2

Biogas and methane yield

Day	Biogas l	Methane l	Average methane content %	Biogas l/kg DOM	Methane l/kg DOM
1	24.30	18.18	74.83	161.42	120.79
2	43.20	24.11	55.82	291.81	162.89
3	50.30	24.49	48.69	335.50	163.36
4	43.40	22.75	52.43	291.21	152.68
5	41.70	21.90	52.52	280.43	147.27
6	43.20	22.29	51.59	279.43	144.17
7	41.60	23.79	57.20	269.02	153.86
8	42.80	23.03	53.81	278.56	149.88
9	41.30	21.11	51.12	272.52	139.30
10	35.60	18.32	51.47	234.32	120.60
11	23.50	12.15	51.71	161.53	83.52
12	25.80	12.54	48.59	173.27	84.20
13	19.00	9.09	47.86	124.31	59.49
14	20.90	10.21	48.84	144.25	70.45
15	10.50	4.31	41.09	72.26	29.70
16	18.50	7.65	41.37	122.19	50.56
Average	$32.85^{+17.45}_{-22.35}$	$17.25^{+12.93}_{-7.25}$	$51.81^{+23.02}_{-10.02}$	$218.21^{+117.25}_{-145.99}$	$114.55^{+48.81}_{-84..85}$

This year yield of young willow was used in the investigation. Young willows with green leaves were chopped in less than 1 cm pieces.

The investigation started on reduced organic load and the principle of gradualness was observed. As the result, the process of co-fermentation was successful and the biogas yield was adequate (Table 2).

2. Investigation of raw materials: sludge, whey and barleys straw.

Barley straw was used as raw material. The straw was carefully shredded and its size did not exceed 1 cm. The amount of filled in raw materials is shown in Table 3.

The C/N ratio of sludge and whey shows that a proportion of nitrogen is greater than a proportion of the carbon. Therefore, the

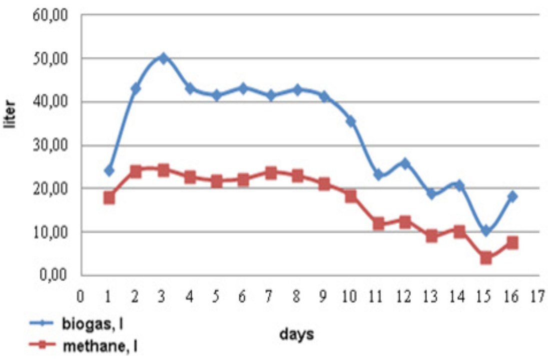


Fig. 1. **Biogas and methane, l**

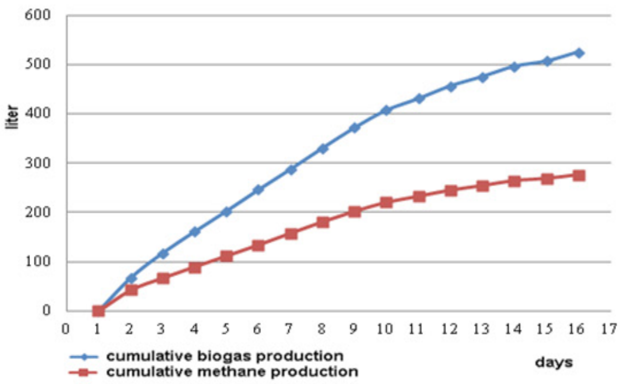


Fig. 2. **Biogas and methane in total, l**

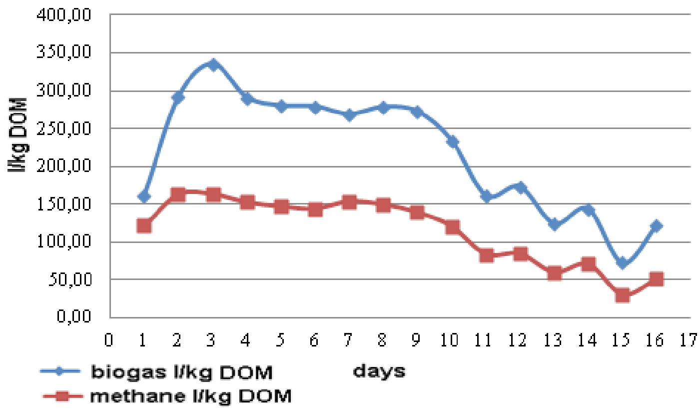


Fig. 3. **Biogas and methane l/kg DOM**

Table 3

Filled in raw materials

Days	Filled in kg					PS %	DOM from PS %	Ash from PS %	DOM kg
	Sludge	Straw	Whey	H_20	Total				
1	0.3	0.05	0.5		0.85	11.48	84.77	15.23	0.0827
2	0.301	0.051	0.503		0.855	11.75	84.93	15.07	0.0853
3	0.304	0.05	0.507		0.861	11.53	84.86	15.14	0.0842
4	0.300	0.051	0.502		0.853	11.31	84.15	15.85	0.0812
5	0.309	0.048	0.5		0.857	11.44	85.01	14.99	0.0833
6	0.300	0.05	0.501		0.851	11.29	85.18	14.82	0.0818
7	0.302	0.046	0.501		0.849	11.37	84.73	15.27	0.0818
8	0.302	0.05	0.499		0.851	11.46	85.07	14.93	0.0830
9	0.301	0.101	0.502		0.904	11.82	85.93	14.07	0.0918
10	0.300	0.099		0.503	0.902	6.57	76.22	23.78	0.0452
11	0.300	0.100		0.51	0.91	6.39	74.32	25.68	0.0432
12	0.300	0.098		0.503	0.901	616	74.26	25.74	0.0412
13	0.300	0.091		0.501	0.892	7.31	71.12	28.88	0.0464
14	0.306	0.097		0.501	0.904	07.11	69.36	30.64	0.0446
15	0.306	0.100		0.51	0.916	6.26	66.50	33.50	0.0382
16	0.305	0.101		0.502	0.908	6.86	68.74	31.26	0.0428

Table 4

Biogas and methane yields

Days	Biogas l	Methane l	Average methane content %	Biogas l/kg DOM	Methane l/kg DOM
1	8.08	4.06	46.13	106.38	49.07
2	23.03	11.23	48.20	273.08	131.61
3	14.5	6.65	45.86	172.12	78.93
4	24.6	10.45	46.55	302.99	141.05
5	37.3	20.48	54.91	447.54	245.74
6	29.3	17.88	61.04	358.02	218.52
7	31	19.10	61.62	379.01	233.57
8	44.6	26.88	60.27	537.58	323.97

Continue of Table 4

Days	Biogas l	Methane l	Average methane content %	Biogas l/kg DOM	Methane l/kg DOM
9	51.1	34.31	67.14	556.53	373.66
10	46.3	31.79	68.66	1025.04	703.79
11	30.4	21.50	70.72	703.44	497.49
12	30.5	21.84	71.60	740.21	530.01
13	21.7	15.80	72.79	468.17	340.80
14	13.2	9.30	70.48	296.15	208.73
15	11.2	7.94	69.67	298.78	208.16
16	16.8	11.39	67.80	392.34	266.00
Average	$27.2^{+23.9}_{-18.4}$	$16.98^{+17.34}_{-12.92}$	$61.47^{+11.33}_{-15.61}$	$441.09^{+583.95}_{-334.71}$	$284.44^{+419.35}_{-235.37}$

straw with a great concentration of carbon improves this ratio. The mode of filling in raw materials was gradually increased and maintained. The results were good and there was no need to correct it. The average organic load of kg·/m^3 was maintained a slightly above the theoretical optimum.

This is explained by the fact that the elements of straw composition have a long decomposition period. Cellulose and hemicelluloses decompose slower and therefore its amount in digestate and dry matter content was increasing.

The yield of methane and biogas is shown in Table 4 and Figures 4 and 5.

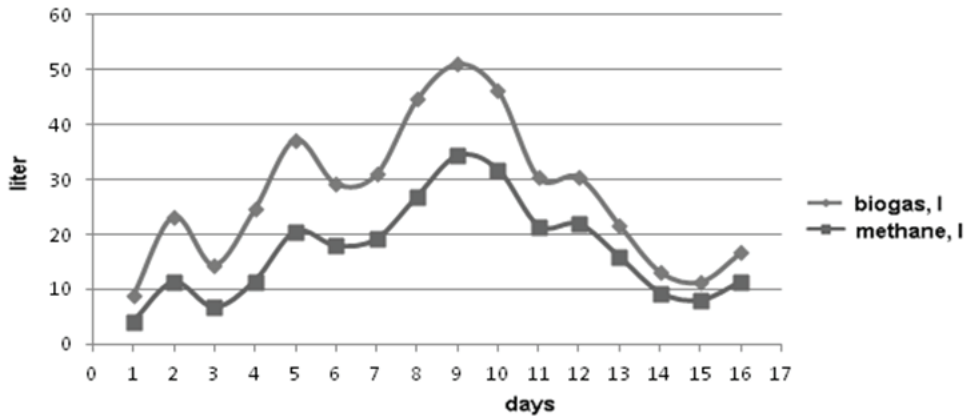


Fig. 4. **Biogas and methane, l**

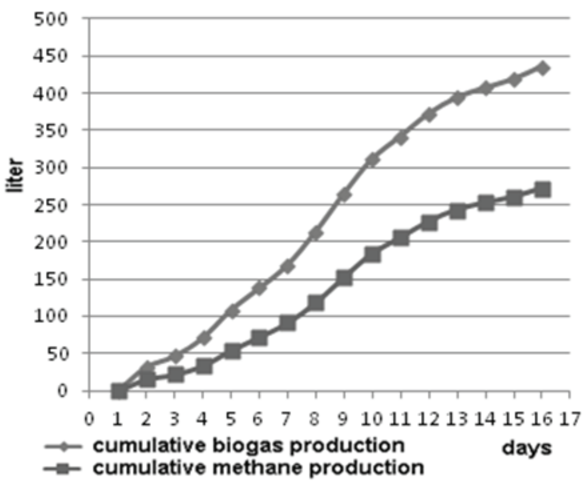


Fig. 5. **Biogas and methane in total, l**

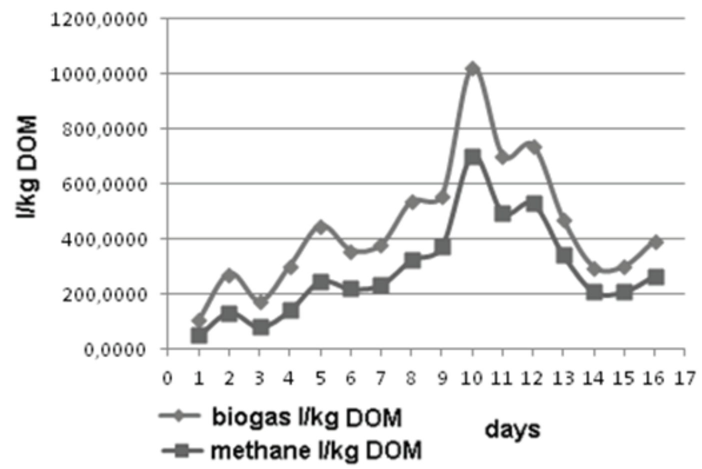


Fig.6. **Biogas and methane, l/kg DOM**

Conclusions

In the sludge, whey and young willow co-fermentation, an average 114.55 $l \cdot kg_{VSa}^{-1}$ methane yield was obtained.

The level of bioconversion could be greater if the increase of raw materials amount is insignificant but stable, yet, it requires a long period of investigation.

Methane yield 284.44 $l \cdot kg_{VSa}^{-1}$ was obtained from sludge, whey and barleys straw.

The process was stable and showed an increasing gas output trend.

The bioconversion level on average was over 60%, but in the final stage of the investigation, it decreased.

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