INVESTIGATION OF BIOGAS PRODUCTION FROM MSW WITH GARAGE-TYPE BIOREACTOR

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Abstract. Over the past two decades the topical issue for the European Union countries as well as the rest of the word is usage of biomass for energy and biogas production. Dry fermentation is a new introduction in Latvia. The goal of the investigation was to identify how suitable the garage-type bioreactor and production technology for biogas production from MSW (municipal solid wastes) is and to identify the biogas obtaining potential. Biogas output was investigated at 37-38 ºC. The garage-type bioreactor and production technology is suitable for biogas production using MSW. The fermentation process was measured on pH 7.21-7.99 levels. The obtained biogas value of 1 ton waste in 4 weeks: Investigation A – average 23.21 Nm^3 biogas, Investigation B – average 34.23 Nm^3 biogas, Investigation C – average 40.89 Nm^3 biogas.

Keywords: biogas, biomass, municipal solid wastes, bioreactor.

Introduction

The topical issue is the agricultural sector and the related sectors waste products and other biomass usage for energy and biogas production. The main reason for this trend is fossil energy sources depletion threats and the need to replace these sources with renewable resources.

Dry fermentation is a new introduction in Latvia. Dry fermentation has several advantages [1] such as:

- supplementary income source for waste disposers, local governments, farmers;
- direct income source in rural areas and very valuable end products (electricity, heat, digestate);
- additional benefits for the countries with scarce water resources;
- low maintenance requirements;
- potential way to reduce fossil fuel consumption and thus to reduce climate changes;
- good option for the government in the matter of waste.

The goal of the investigation was to identify how suitable the garage-type bioreactor and production technology for biogas production from MSW is and to identify the biogas obtaining potential, invent and build garage-type bioreactor arrangement, the first dry-fermentation study in Latvia shown in Fig.1. In order to achieve the goal the following tasks were set:

1. To evaluate MSW products for three different investigations;
2. To determine the yield of biogas (per day);
3. To determine the biogas chemical composition taken from the leachate container and bioreactor (per day);
4. To maintain temperature for the leachate container and bioreactor (per day);
5. To compare the launcher technologies;
6. To calculate the biogas production potential and to show the results in tables and diagrams.

Materials and methods

Garage-type dry fermentation

1. The analysis was measured using standardized methods. The bioreactor operated in a single filling mode without substrate stirring. The raw material – MSW (municipal solid wastes) – was taken from the landfill “Daibe”. The landfill is located in Pargauja county, Stalbe municipality. The landfill started working in 2004 and is the only municipal solid waste disposal landfill in North Vidzeme region. The biomass shredding occurred in “Daibe” landfill; the bioreactor was filled using standard methods. Three investigations were made:

A. The fresh weight 159.6 kg, period of 100 days;
B. The fresh weight 134.65 kg + 40.395 kg old weight, in total 175.045 kg, period of 59 days;
C. The fresh weight 99.45 kg + 29.835 kg old weight, in total 129.285 kg, period of 49 days.

Fig. 1. **Invented and built garage-type bioreactor arrangement**

2. As inoculum the digestate from the FATEK operating bioreactor with cattle manure, the content of CH_4 – 55.1 % was used. The digestate was homogenised for normal circulation through the tubes. The inoculum is used for fresh substrate sowing with bacteria. The leachate container was filled with 90 litres of leachate.

3. The substrates were analysed for the dry matter, organic matter, ash content and moisture content. The dry matter was determined in auto mode by the "SHIMADZU" scales at the temperature 120 ºC.

4. The organic matter was determined in auto mode by the "NABERTHERM" drying oven at the temperature 550 ºC. Fig. 2 – on the right "SHIMADZU", on the left "NABERTHERM".

Fig. 2. **"NABERTHERM" oven and "SHIMADZU" scales**

The raw materials were analysed for the dry matter, organic matter, and ash content. The five average samples were taken from the landfill "Daibe". The results are shown in Table 1, Table 2, and Table 3.

Investigation A. DM – dry matter, *DOM* – dry organic matter, calculated from % of *DM*. Average DOM calculated from Table 1 is 21.6 %.

Table 1

Investigation A. Evaluation results of MSW 5 samples

Evaluation/ sample	**MSW 1**	**MSW 2**	**MSW 3**	**MSW 4**	**MSW 5**	**Average**
DM %	66.1	70.1	67.7	69.3	68.9	68.4
Ash %	77.5	80.6	73.5	80.6	79.8	78.4
DOM %	22.5	19.4	26.5	19.4	20.2	21.6

Investigation B. Average DOM calculated from Table 2 is 40.9 %.

Table 2

Investigation B. Evaluation results of MSW 5 samples

Evaluation/ sample	MSW 1	MSW 2	MSW 3	MSW 4	MSW 5	Average
DM %	52.3	55.2	61.0	46.7	53.7	53.8
Ash %	65.0	57.0	62.2	59.5	52.2	59.2
DOM %	35.0	43.1	37.8	40.5	47.8	40.9

Investigation C. Average DOM calculated from Table 3 is 36.9 %.

Table 3

Investigation C. Evaluation results of MSW 5 samples

Evaluation/ sample	MSW 1	MSW 2	MSW 3	MSW 4	MSW 5	Average
DM %	50.2	53.1	50.7	53.1	51.1	51.6
Ash%	61.9	64.2	62.7	63.5	63.3	63.1
DOM %	38.1	35.8	37.4	36.5	36.7	36.9

5. The bioreactor was sealed, then equipped with the temperature sensor and then the heating was turned on. The biogas output was practically tested at 37-38 ºC (mesophilic mode).

6. The bioreactor was connected to a circulating pump "TCL S04-2006" and the leachate container. The leachate container also was equipped with a temperature sensor and then the heating was turned on.

7. When the operating temperature of 38 ºC was reached the periodic leachate recirculation was turned on in automatic mode by ZAMEL PGM-04. This means that the temperature is maintained at 38 ºC and leachate recirculation starts every 15 minutes.

8. The fermentation process took as long as there were practically no emissions of biogas and the period was sufficient to indicate the yield of biogas. The composition of gas was determined every day by the gas analyzer GA 2000 plus. The concentration of methane (CH_4), oxygen (O_2), carbon dioxide (CO_2), and hydrogen sulphide (H_2S) in the biogas was measured. The garage-type bioreactor for dry fermentation, Fig. 3.

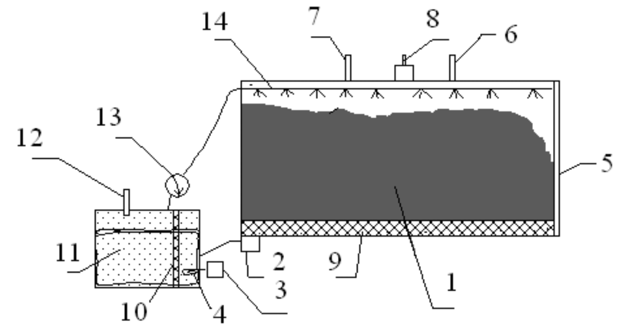

Fig. 3. **Invented and built garage-type bioreactor arrangement:** 1 – Biomass, "MSW"; 2 – leachate collection; 3 – automatic; 4 – heating device; 5 – door, biomass loading; 6, 7 – temperature gauge; 8, 12 – biogas output; 9, 10 – grid; 11 – container with leachate; 13 – leachate pump; 14 – injector

Results and discussion of A, B and C investigations

The fermentation process occurred at variable pH. Assuming the results of three investigations the process occurred at the optimal range of pH 7.21-7.99, as shown in Fig. 4, when the filling of the bioreactor with fresh weight was stopped.

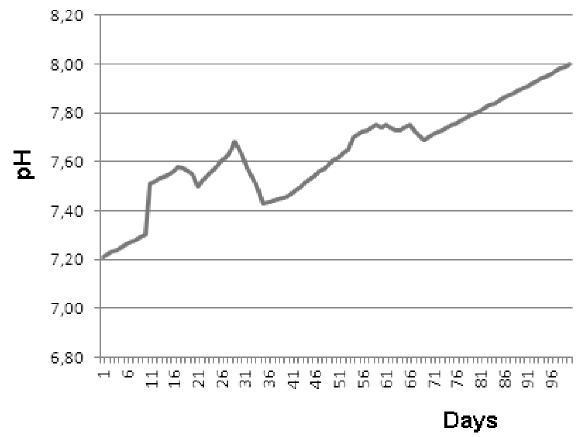

Fig. 4. **Change of pH value of MSW dry fermentation process**

The yield of biogas is calculated using formula 1 and formula 2.

$$B_{ie} = I_{gn} / A_m \cdot A_{DOM} \tag{1}$$

$$Am = Tm \text{ (kg)} \cdot DM \text{ (\%)} \tag{2}$$

where B_{ie} – yield of biogas, $l \cdot kg^{-1}{}_{DOM}$

I_{gn} – amount of the discharged gas by a specific time, l;

A_m – total dry weight of filled waste, kg;

T_m – total filled weight, kg;

A_{DOM} – organic matter mass in the dry matter determined by laboratory test for each raw material %.

Comparing the results of three investigations, the yield of biogas obtained from the Investigation B is 5992 litres; from the Investigation C 5854 litres; from the Investigation A 3705 litres. Investigation A has low *DOM* = 21.6 % and this explains the amount of the obtained gas. The higher is *DOM* %, the higher is the yield amount of biogas (Investigation B *DOM* = 40.9 %, Investigation C *DOM* = 36.9 %).

After the processing of the results it is seen that the methane content on Day 6 (Investigation B) and Day 7 (Investigation C) reached > 50 % and this biogas can be practically used for energy production. This factor shows that mixing and filling proportions used in the investigations are correct. The filling proportions used in Investigation B and C – 70 % of the fresh weight + 30 % (of the fresh weight) recycled waste - all proportions were taken from previous researches and literature sources.

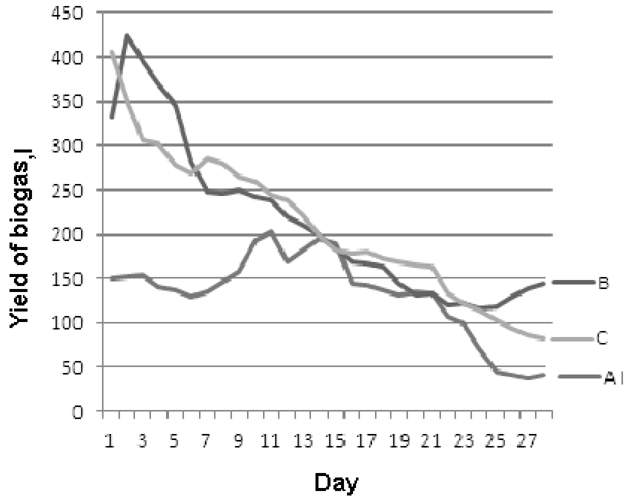

Fig. 5. **Yield of biogas in dry fermentation process using garage type bioreactor in Investigations A, B, C**

Table 4 shows $l \cdot kg^{-1}_{DOM}$ from Week 1 till Week 5.The obtained biogas value of 1 ton waste in 4 weeks: Investigation A – average 23.21 Nm^3 biogas, Investigation B – average 34.23 Nm^3 biogas, Investigation C – average 40.89 Nm^3 biogas.

Table 4

$L \cdot kg^{-1}_{DOM}$ from1 till 5 week

Week	Investigation A	Investigation B	Investigation C
	$l \cdot kg^{-1}_{DOM}$	$l \cdot kg^{-1}_{DOM}$	$l \cdot kg^{-1}_{DOM}$
1	42.41	62.23	89.25
2	95.34	103.95	158.59
3	138.34	132.41	207.95
4	157.13	155.57	237.81
5	167.01	177.66	256.90

One of the main factors affecting the fermentation process is the temperature. The temperature range selected for the investigation is mesophilic (31-42 ºC). The operating temperature of the leachate container and pulp container was 37 ± 1 ºC.

Table 5

Investigations A, B and C biogas yield

Day	A Yield, l	B Yield, l	C Yield, l	Day	A Yield, l	B Yield, l	C Yield, l	Day	A Yield, l	B Yield, l	C Yield, l
1	150	333	406	11	203	239	244	21	133	133	164
2	152	424	351	12	170	220	239	22	107	120	133
3	154	396	306	13	182	210	221	23	99	123	123
4	141	370	302	14	196	200	199	24	71	117	114
5	137	345	278	15	190	185	183	25	45	119	103
6	130	281	269	16	144	170	179	26	41	130	94
7	136	248	285	17	142	168	181	27	38	139	86
8	147	246	280	18	138	163	173	28	42	144	82
9	157	249	265	19	132	145	170	**Total**	**3705**	**5992**	**5854**
10	193	243	259	20	135	132	165				

The optimum retention time could be around 32 days, despite the fact that after Day 21 the value of the obtained gas is significantly lower; the methane content still is above 60 % and the gas is emitting.

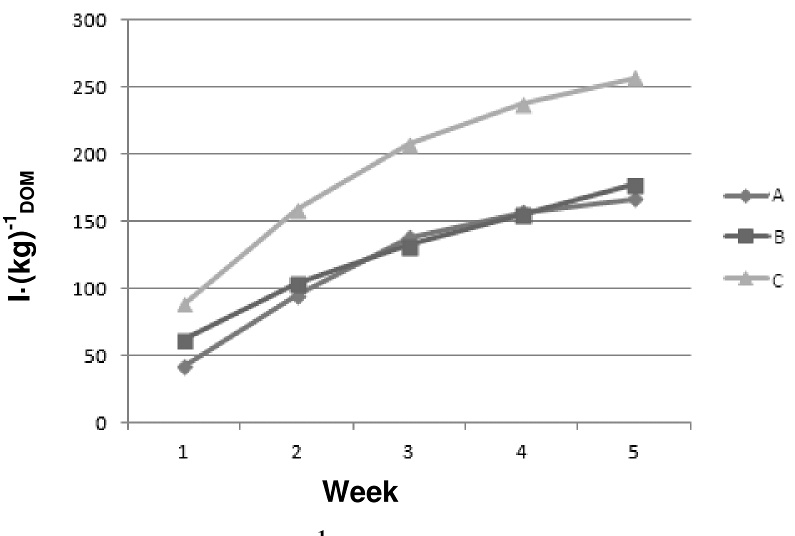

Fig. 6. **$l \cdot kg^{-1}_{DOM}$ Week 1 till Week 5**

Conclusions

1. The garage type bioreactor and production technology is suitable for biogas production using MSW (municipal solid wastes).
2. The average ash content: Investigation A 78.4 %; Investigation B 59.2 %; Investigation C 63.1 %.
3. The yield of biogas obtained from the Investigation B (5992 litres), the Investigation C (5854 litres), and the lower amount was obtained from the Investigation A (3705 litres), comparing the results it is necessary to point the difference of the waste composition and average *DOM* of three investigations.
4. The temperature range selected for the investigation was mesophilic. The operating temperature of the leachate bioreactor and pulp bioreactor was 37 ± 1 ºC.
5. The filling proportions used in Investigations B and C – 70 % of the fresh weight + 30 % (of the fresh weight) recycled waste. The methane content on Day 6 (Investigation B) and Day 7 (Investigation C) reached >50 % and this biogas can be practically used for energy production. This factor shows that mixing and filling proportions used in the investigations are correct.
6. The fermentation process was measured on pH 7.21-7.99 level.
7. The optimum retention time in the garage type bioreactor could be around 32 days, despite the fact that after Day 21 the value of the obtained gas is significantly lower; the methane content still is above 60 % and the gas is emitting.
8. The obtained gas value in 4 weeks: Investigation A – 157.13 $l \cdot kg^{-1}_{DOM}$ of biogas; Investigation B – 155.57 $l \cdot kg^{-1}_{DOM}$ of biogas; Investigation C – 237.81 $l \cdot kg^{-1}_{DOM}$ of biogas.
9. The obtained biogas value of 1 ton waste in 4 weeks: Investigation A – average 23.21 Nm^3 biogas, Investigation B – average 34.23 Nm^3 biogas, Investigation C – average 40.89 Nm^3 biogas.

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