METHANE POTENTIAL FROM HOUSEHOLD GARDEN LEAVES

Vilis Dubrovskis, Imants Plume
Latvia University of Life Sciences and Technologies, Latvia
vilisd@inbox.lv, imants.plume@llu.lv

Abstract. Every year a huge amount of different tree leaves is collected in Latvian household gardens. They are taken away to landfills or stored in large piles, most often in municipal areas, as transportation to sparse landfills has now become expensive. Large piles are called compost piles, but in fact the composting process in them is weak because there is no good oxygen supply. Anaerobic processes begin in the lower layers of the heap and, in fact, there is more pollution than if the leaves were left under the trees and decomposed by aerobic bacteria. The problem could be solved if these leaves were recycled in biogas plants. What is the potential of some leaves for methane extraction was clarified in this study. Maple, grape, apple, cherry and pear leaves were anaerobically processed in 16 laboratory bioreactors at 38 ºC. After 32 days of processing, 0.526 $L \cdot g^{-1}{}_{DOM}$ biogas was obtained from maple leaves (0.28 $L \cdot g^{-1}{}_{DOM}$ methane), 0.471 $L \cdot g^{-1}{}_{DOM}$ biogas from grape leaves (0.214 $L \cdot g^{-1}{}_{DOM}$ methane), 0.723 $L \cdot g^{-1}{}_{DOM}$ biogas was obtained from apple leaves (0.262 $L \cdot g^{-1}{}_{DOM}$ methane) and from a mixture of cherry and pear leaves 0.769 $L \cdot g^{-1}{}_{DOM}$ biogas (0.338 $L \cdot g^{-1}{}_{DOM}$ methane). It has been concluded that chopped garden leaves are a good raw material for methane production.

Keywords: anaerobic digestion, methane, maple, grape, apple, cherry and pear leaves.

Introduction

Every year a huge amount of different tree leaves is collected in Latvian household gardens. They are taken away to landfills or stored in large piles, most often in municipal areas, as transportation to sparse landfills has now become expensive. Large piles are called compost piles, but in fact the composting process in them is weak because there is no good oxygen supply. Anaerobic processes begin in the lower layers of the heap and, in fact, there is more pollution than if the leaves were left under the trees and decomposed by aerobic bacteria.

During the growth process, leaves accumulate a large number of toxic substances that enter the air with exhaust gases. When foliage is burned, carbon monoxide and carbon dioxide, benzapyrene with carcinogenic properties, and dioxins are released. From one ton of burnt leaves up to 30 kg of toxic compounds enter the air. The problem could be solved, if these leaves were recycled in biogas plants. Fallen leaves can bring considerable benefits and save money on gasoline, natural gas and other energy resources. But most importantly, leaf recycling using anaerobic fermentation technology can improve the ecological situation in the city. Other researchers write about the usefulness of tree leaves for energy production. "Using urban fallen leaves as potential resource of energy could not only benefit in environmental and economical aspects, but also improve the efficiency of urban energy systems, introducing using of new renewables and encouraging utilizing other urban green waste in biomass-for-energy consumption" [1; 2].

Biogas yields from leaves depends on many parameters: composition of the substrate; type of technology and equipment used; compliance with technological conditions (heating, etc.).

According to reports, the biogas yield from 1 ton of leaves is 2.85-3 cubic meters. Consequently, from 120 thousand tons (we take the data for Kiev), you can get 342 thousand cubic meters of gas. It is a gas mixture with a methane content of up to 60%. In terms of natural gas, this is about 210 000 m^3 [3].

In our 2012 study with mixed city park tree leaves, we obtained the following results. The average specific biogas production yield 377 ± 22 $L \cdot kgVSA^{-1}$ with the average methane content 50.2% was obtained from fallen leaves [1]. Further improvement of biogas output from fallen leaves can be achieved through different pre-treatment techniques, e.g., fine shredding, steam heating and/or chemical treatment, improving lignin biodegradability.

Another study showed that the biogas yield reached 321 $mL \cdot g^{-1}$ VS for poplar leaf co-digestion with swine manure [4]. However, few studies have investigated the anaerobic digestion characteristics of poplar leaf as the sole feedstock. „In this study, the effect of combined pretreatment on the anaerobic digestion of poplar leaves as the sole substrate is conducted. The objective of the study is to: (1) test the anaerobic digestion performance when poplar leaves are used as the sole substrate after combined pretreatment and (2) determine the best combination of pretreatment condition parameters and the optimal condition for anaerobic digestion'' [4].

What is the methane potential of maple leaves, grape leaves, apple leaves and cherry leaves mixed with pear leaves for methane extraction was clarified in this study. Data on the biogas yield from such leaves could not be found in literature. Therefore, the yield of biogas from poplar leaves is shown.

Materials and methods

The study used methodologies similar to those in Germany and Denmark [5-7]. Fallen leaves were collected in the garden of one household. Grape leaves were collected in a greenhouse. All leaves were determined for total dry matter and dry organic matter content.

Dry organic matter (DOM) content was determined by weighting of the initial biomass samples, drying in dry matter weights Shimazu at 105 ºC and then placed for ashing in the oven ("Nabertherm" type) at 550 ºC. Gas volumes were measured using a water batch. The composition of gases, including oxygen, carbon dioxide, methane, and hydrogen sulphide was measured by help of a gas analyser (model GA2000). The substrate pH value was measured before and after finishing off the AD process, using a pH meter (model PP-50) with accessories. Scales (Kern, model KFB 16KO2) was used for weighting of the total weight of substrates before and after the AD process [6; 7]. Sixteen 0.75 liter bioreactors were used for the study. Bioreactors R2-R4 were filled in with inoculum 500 g and 20 g chopped maple leaves, bioreactors R5-R7 were filled in with 500g inoculum and 20 g chopped grape leaves. Bioreactors R8-R11 were filled in with 500 g inoculum and 20 g chopped apple leaves, bioreactors R12-R15 were filled in with 500 g inoculum and 20 g chopped mixed cherry with pear leaves (proportions 1:1). Bioreactors R1 and R16 were filled in with 500 g inoculum only.

Fermented cattle manure (from 110 L bioreactor working in continuous mode) was used as the inoculum. Batch mode AD process was ongoing at temperature 38 ± 0.5 ºC. Biogas released was collected in gas bags for further measurements of the gas volume and elemental composition. Biogas and methane volumes and gas composition were measured during the AD process at regular time intervals. The AD process was provided until biogas emission ceases (32 days). The obtained experimental data were processed using appropriate statistical methods [6; 7].

Results and discussion

The results of investigation of sample substrates, including inoculums, maple leaves, grape leaves, apple leaves and cherry and pear leaves mixture, 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	7.68	3.8	19.0	26.48	73.52	13.969	500
R2-R4	ML	-	77.49	15.498	21.08	78.92	12.231	20
R2-R4	20 ML + 500IN	7.67	6.63	34.498	24.05	75.95	26.20	520
R5- R7	20 GL	-	61.0	12.2	14.67	85.33	10.41	20
R5-R7	20 GL + 500IN	7.65	6.0	31.2	21.86	78.14	24.375	520
R8-R11	20 AL	-	31.79	6.358	30.94	69.06	4.39	20
R8- R11	20 AL + 500IN	7.67	4.88	25.358	27.60	72.40	18.359	520
R12-R15	CHPL 20	-	39.44	7.888	11.39	88.61	6.99	20
R12-R15	CHPL 20 + 500 IN	7.67	5.17	26.888	22.05	77.95	20.959	520

Note: IN – inoculum; ML – maple leaves; GL – grape leaves; AL – apple leaves; CHPL –cherry and pear leaves; TS – total solids; DOM – dry organic matter (on raw substrate basis);
R1 – R16 – bioreactors.

As it can be seen from Table 1, the maple and grape leaves have a high dry matter content. This is due to the fact that these leaves were collected and stored for a long time in the greenhouse. The remaining garden leaves were collected in the morning of the study start day and were therefore less dry. The content of cherry and pear leaves in the sample is similar.

Table 2

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 500 IN	0.4	0.029	6.75	0.027	0.002
R16 500 IN	0.4	0.029	8.50	0.034	0.002
Average R1, R16	**0.4**	**0.029**	**7.63**	**0.031**	**0.002**
R2 500 g IN + 20 g ML	7.0	0.572	54.0	3.78	0.309
R3 500 g IN + 20 g ML	7.0	0.572	55.01	3.851	0.315
R4 500 g IN + 20 g ML	5.3	0.433	49.85	2.642	0.216
Average R2- R4 ML	**6.433**	**0.526**	**52.95**	**3.424**	**0.280**
± st.dev.	**0.981**	**0.08**	**2.375**	**0.678**	**0.056**
R5 500 g IN + 20 g GL	6.0	0.576	45.9	2.754	0.264
R6 500 g IN + 20 g GL	2.9	0.279	45.09	1.307	0.126
R7 500 g IN + 20 g GL	5.8	0.557	45.21	2.622	0.252
Average R5-R7 GL	**4.4**	**0.471**	**45.4**	**2.228**	**0.214**
± st.dev.	**1.735**	**0.166**	**0.437**	**0.8**	**0.076**
R8 500 g IN + 20 g AL	3.2	0.729	53.94	1.086	0.247
R9 500 g IN + 20 g AL	3.1	0.706	37.65	1.167	0.266
R10 500 g IN + 20 g AL	3.1	0.706	36.61	1.135	0.259
R11 500 g IN + 20 g AL	3.3	0.751	36.45	1.203	0.274
Average R8-R11 AL	**3.175**	**0.723**	**41.16**	**1.148**	**0.262**
± st.dev.	**0.096**	**0.022**	**8.535**	**0.05**	**0.011**
R12 500 g IN + 20 g CHPL	5.4	0.773	42.22	2.28	0.326
R13 500 g IN + 20 g CHPL	5.6	0.801	46.13	2.583	0.370
R14 500 g IN + 20 g CHPL	5.0	0.715	41.72	2.086	0.298
R15 500 g IN + 20 g CHPL	5.5	0.787	45.69	2.513	0.360
AverageR12-R15 CHPL	**5.375**	**0.769**	**43.94**	**2.366**	**0.338**
± st.dev.	**0.263**	**0.038**	**2.291**	**0.227**	**0.035**

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

Most of the methane from dry organic matter came from a mixture of cherry and pear leaves. This could be explained by the fact that the mixture also had recently fallen leaves that contained more juice. Specific average biogas and methane yields from maple leaves, grape leaves, apple leaves and mixed cherry with pear leaves are shown in Fig. 1 and the average methane content in Fig. 2.

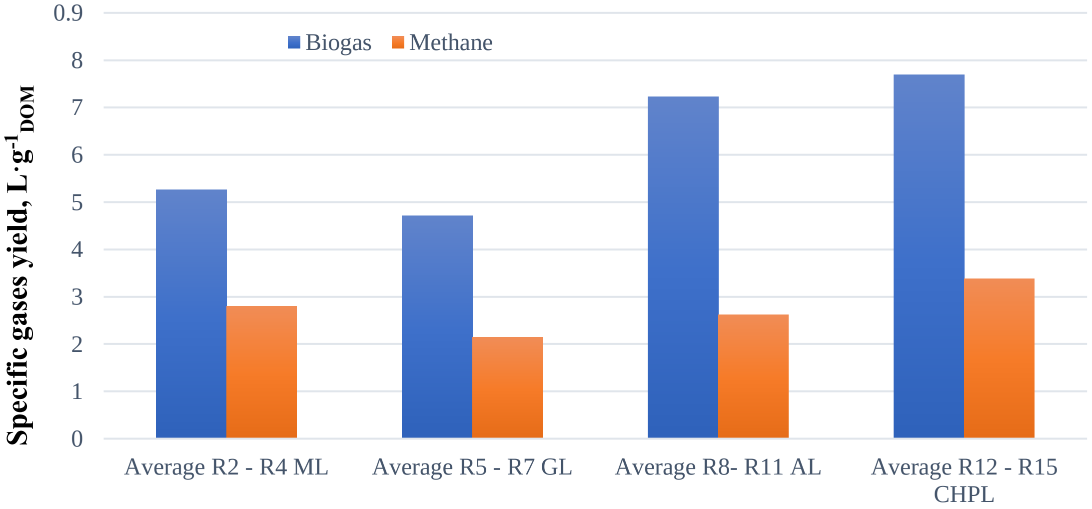

Fig. 1. **Specific average biogas and methane yields from maple leaves, grape leaves, apple leaves and mixed cherry with pear leaves**

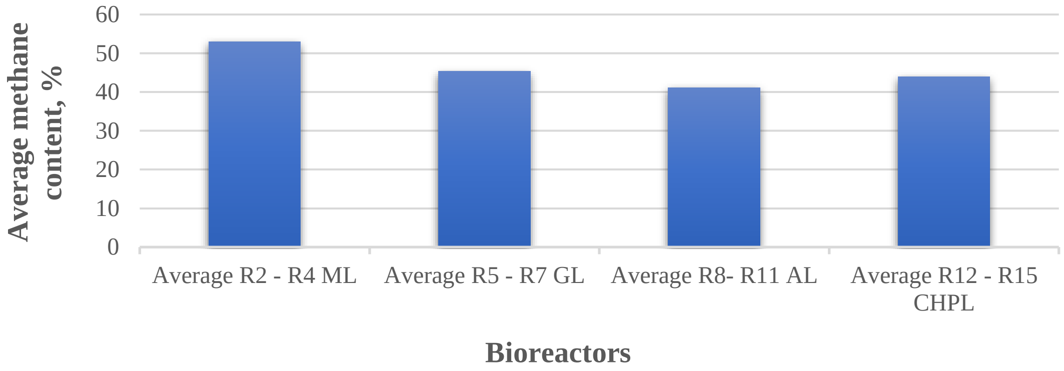

Fig. 2. **Average methane content**

It was not possible to compare our results with the data of other researchers, because we did not find studies on the potential of methane from such leaves in the literature.

Compared to other feedstocks used in biogas plants, the lower methane content could be explained by the fact that the leaves were already dry and contained a lot of cellulose, hemicellulose, as well as lignin. The leaves have a high carbon content, so it is desirable to use them in co-fermentation with raw materials with a higher nitrogen content in order to have a better C/N ratio.

Conclusions

1. The average yield of biogas (methane) from the bioreactors with added maple leaves was 0.526 $L \cdot g^{-1}_{DOM}$ (0.280 $L \cdot g^{-1}_{DOM}$).
2. The average yield of biogas (methane) from the bioreactors with added grape leaves was 0.471 $L \cdot g^{-1}_{DOM}$ (0.214 $L \cdot g^{-1}_{DOM}$) .
3. The average yield of biogas from the bioreactors with added apple leaves was 0.723 $L \cdot g^{-1}_{DOM}$ (0.262 $L \cdot g^{-1}_{DOM}$).
4. The average yield of biogas from the bioreactors with added apple leaves was 0.769 $L \cdot g^{-1}_{DOM}$ (0.338 $L \cdot g^{-1}_{DOM}$).
5. Household garden leaves can be a good raw material for biogas production.

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