METHANE PRODUCTION FROM BIRCH AND MAPLE LEAVES AND MISCANTHUS GRASS

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Abstract. Global warming is increasingly affecting life in the world. We have to experience drastic temperature fluctuations, floods and drought periods more and more. The European Union has decided to achieve climate neutrality by 2050. To achieve this, it is important to stop using fossil energy sources. Renewable energy resources should be used instead. Instead of fossil natural gas, biogas obtained from various organic residues and waste can be used well. In order to make biogas production more profitable, cheap raw materials are needed. These could be tree leaves, which are collected in large quantities in the autumn and deposited in piles and garbage dumps. The piles also produce harmful gases. If the gas from these piles is not collected, then it escapes into the atmosphere and also pollutes the environment. Such practices should not be allowed in the future. The aim of this study was to find out the potential of biomethane production from maple and birch leaves compared to grass miscanthus, which gives a high biomass yield. The study was conducted in a laboratory facility with 16 bioreactors. The study lasted for 32 days. Anaerobic fermentation took place in an oven at 38 ºC. On average, grass miscanthus yielded 0.474 $L \cdot g^{-1}$DOM of biogas and 0.236 $L \cdot g^{-1}$DOM of methane. 0.542 $L \cdot g^{-1}$DOM biogas and 0.262 $L \cdot g^{-1}$DOM methane were obtained from maple leaves. Birch leaves yielded 0.467 $L \cdot g^{-1}$DOM biogas and 0.219 $L \cdot g^{-1}$DOM methane. All biomasses tested in the study can be used as raw materials for biogas production. Only the average content of methane in this biogas is lower than that obtained from animal manure.

Keywords: anaerobic fermentation, biogas, methane, maple leaves, birch leaves, grass miscanthus.

Introduction

Methane causes 32-45 times more radiative forcing in a century than CO_2 on a mass basis. CH_4 is more responsive than CO_2 to changes in sources or sinks, forest CH_4 budgets are a meaningful aspect of management directed at slowing the pace of global climate change (UNFCCC, 2016). Fallen leaves from trees also release carbon dioxide and methane as they decompose [1]. It would be better to collect them rather than allow harmful emissions. Biogas producers are looking for the cheapest possible raw material. They do not always have access to cheap waste. Plants that give large yields are also sought. One of such is grass miscanthus. Miscanthus is a rhizomatus, perennial C4 grass species, which originates from South-East Asia. The sterile clone *Miscanthus x giganteus* is a high-yielding genotype, which is currently the standard cultivar in commercial utilization. This high yield potential has led to miscanthus being identified as a promising energy crop in several studies [2-5]. As its fertilizer and pesticide requirements are low, miscanthus can be also characterized as a low-input crop [3]. *Miscanthus x giganteus* has a good environmental profile with the potential to increase soil carbon, soil fertility and biodiversity and to reduce nutrient run-off and leaching. Despite these benefits, miscanthus cultivation and the utilization of its biomass are still not widespread in Europe (approx. 38.300 ha in Europe) [5].

Opening up the biogas sector as a new market for miscanthus biomass could encourage the introduction of this environmentally beneficial crop into European agriculture and thereby help reduce the ecological burden of biogas production. The average dry matter yield of the winter control (18.7 t DM ha^{-1}) was about 28% lower than the yield of the late green harvest in October [4] (26.0 t $DM \cdot ha^{-1}$). Similar biomass losses over winter have been reported in the literature [5; 6]. Therefore, the utilization of green biomass has the potential to substantially increase the biomass yield per unit area and to exceed that of maize.

German researchers compared yields from 2 fields and time of harvests. "The comparison of different old Miscanthus fields showed that there is no significant difference in terms of biomass yield, specific BMP and BMP per hectare. Only the influence of repeated autumn harvest showed differences in the methane production per hectare between both stand ages. The methane yield of the younger stand did not change considerably, while in the older stand, the productivity decreased about 15% after 1 year" [5].

R. Wahid & et.al. [6] evaluated the methane yields from stems and leaves of Miscanthusx giganteus and Miscanthus sinensis harvested green. They reported that after 90 days of anaerobic digestion, the methane production for Miscanthus x giganteus varied for stems from 285-333 $NL \cdot kg^{-1}$ VS and for leaves from 286-314 $NL \cdot kg^{-1}$ VS and for Miscanthus sinensis from 291-312 $NL \cdot kg^{-1}$ VS for stems and from 298-320 $NL \cdot kg^{-1}$ VS for leaves.

Romanian researchers studied biogas production from anaerobic co-digestion of cow manure and leaves of Miscanthus x giganteus. The results showed that the maximum yield of biogas, after 15 days of anaerobic digestion, was of 0.420 $Nm^3 \cdot kg^{-1}$ dry matter, and the biogas started to form on the second day of incubation [7].

German researchers studied the possibilities of biogas extraction from fallen leaves of trees determining the extraction from three different trees. Data were collected from 15 biogas plants near Berlin. Maple leaves had the following results: C/N ratio 48.6; DM 0.51; DOM 0.87; methane yield 0.193 $L \cdot g^{-1}_{DOM}$; methane content 58.0% [8].

Chinese scientists [9] studied co-fermentation of straw and leaves and found the following: "The comparison of the experiment results show that: the volatile solids (VS) gas production of the straw is higher than that of the fallen leaves. The fermentative materials of the leaves have the most accumulation and the longest retention time of gas production. When the raw materials of straw and leaves are at a ratio of 2:1 in the test of SS-AD, the biogas production will be increased". We confirm in our previous study that the differences are significant [10].

Data on biogas (methane) extraction from maple (*Acer platanoides* L.) leaves can be found in literature. Lithuanian researchers studied the C:N ratio in fallen maple leaves in the park. It was 45.0 ± 0.6 for newly fallen, 34.7 ± 2.4 after 92 days and 21.5 ± 2.3 after 275 days [11]. This proves that maple leaves are suitable for biogas production. Maple leaves collected in a park in Jelgava produced biogas of 0.526 $L \cdot g^{-1}_{DOM}$ (0.280 $L \cdot g^{-1}_{DOM}$ methane) [12].

In literature, there is little data on anaerobic fermentation of only birch leaves. We studied the co-fermentation of birch leaves and molasses in a ratio of 1:1. The average yield of biogas (methane) was 0.737 (0.369) $L \cdot g^{-1}_{DOM}$, which can be evaluated as very good [10; 12]. We made pellets from birch leaves and found their biogas (methane) potential - 0.565 (0.214) $L \cdot g^{-1}_{DOM}$.

The aim of this study was to determine the methane potential of chopped miscanthus grass, maple and birch leaves collected in October.

Materials and methods

The raw materials used in the study were collected at the end of October. All raw material samples were analysed to clear up the general elements before anaerobic fermentation. Data were used for organic loading rate calculation. The raw material was prepared, mixed and distributed between reactors (R2-R15), and accuracy of substrate dose in every reactor equals to measurement accuracy of the scales used. The study was conducted using a widely used methodology as in other studies [13; 14]. 500 g of inoculum was filled in bioreactors R1 and R16. The inoculum was digestate from a 110-liter bioreactor continuously operating in the laboratory. In bioreactors R2 to R5, 500 g of inoculum and 20 g of grass miscanthus were filled in each. 500 g of inoculum and 20 g of maple leaves were filled in bioreactors R6 to R10. Bioreactors R11 to R15 were filled with 500 g of inoculum and 20 g of birch leaves each. Both the grass and the leaves were crushed before filling into the bioreactors. Gasholders with taps were added to all bioreactors. The bioreactors were placed in the SNOL dryer and the operating temperature was set to 38 ± 1 ºC. Gas composition was measured with a GA 2000 gas analyzer – the content of CH_4, carbonic acid gas CO_2, oxygen O_2 and hydrogen sulfide H_2S was determined. Gas volumes were measured using a flow meter (Ritter drum-type gas meter). The anaerobic fermentation process was carried out in single batch mode and was stopped after 32 days.

A Shimazu dry balance was used to determine dry matter, and a Nabertherm drying oven was used to determine organic dry matter. The substrate pH values were measured before and after finishing the anaerobic digestion, using the pH meter (model PP-50).

Results and discussion

The results of analyses of raw material samples before anaerobic digestion are shown in Table1.

Table 1

Results of 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	7.16	2.54	12.7	19.42	80.58	10.23	500 ± 0.2
R2-R5	20g M		88.78	17.76	3.21	96.79	17.19	20 ± 0.005
R2-R5	20g M + 500gIN	7.16	5.86	30.46	9.98	90.02	27.42	520 ± 0.2
R6-R10	20g ML		36.9	7.38	9.03	90.97	6.71	20 ± 0.005
R6-R10	20g ML + 500g IN	7.15	3.86	20.08	15.64	84.36	16.94	520 ± 0.2
R11-R15	20gBL		60.44	12.09	15.07	84.93	10.27	20 ± 0.005
R11-R15	20gBL + 500gIN	7.14	4.77	24.79	17.31	82.69	20.50	520 ± 0.2

Note: IN – inoculum; M - grass miscanthys; BL – birch leaves; ML – maple leaves; ASH – ashes; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R16 – bioreactors.

The results of the analyses show that miscanthus grass and birch leaves have a high dry matter and organic dry matter content. Maple leaves were less withered. Specific biogas and methane yields are shown in Table 2.

Table 2

Production of biogas and methane

Bioreactor/Raw material	Biogas, L	Biogas, $L \cdot g^{-1}_{DOM}$	Methane, aver.%	Methane, L	Methane, $L \cdot g^{-1}_{DOM}$
R1 500IN	0.30	0.029	7.4	0.022	0.002
R16 500IN	0.26	0.025	7.6	0.020	0.002
Average R1, R16	**0.28**	**0.027**	**7.5**	**0.021**	**0.002**
R2 500 g IN + 20g M	7.80	0.454	53.74	4.195	0.244
R3 500 g IN + 20g M	7.96	0.463	46.87	3.735	0.217
R4 500 g IN + 20g M	8.76	0.510	47.65	4.191	0.243
R5 500 g IN + 20g M	8.05	0.468	51.18	4.120	0.240
Average R2- R5 500 g IN + 20g M ± st. dev.	**8.14 ± 0.7**	**0.474 ± 0.037**	**49.86 ± 3.97**	**4.060 ± 0.426**	**0.236 ± 0.023**
R6 500 g IN + 20g ML	3.60	0.537	44.86	1.615	0.240
R7 500 g IN + 20g ML	4.12	0.614	50.18	2.067	0.308
R8 500 g IN + 20g ML	2.80	0.417	47.14	1.320	0.197
R9 500 g IN + 20g ML	3,95	0.589	51.22	2.023	0.302
R10 500 g IN + 20g ML	3.70	0.551	48.15	1.782	0.265
Average:R6-R10 500 g IN + 20gML ± st. dev.	**3.63 ± 1**	**0.542 ± 0.053**	**48.31 ± 1.33**	**1.761 ± 0.394**	**0.262 ± 0.021**
R11 500 g IN + 20 g BL	5.00	0.487	48.14	2.407	0.234
R12 500 g IN + 20 g BL	4.80	0.467	50.06	2.403	0.233
R13 500 g IN + 20 g BL	4.70	0.457	47.22	2.243	0.218
R14 500 g IN + 20 g BL	4.60	0.448	47.13	2.168	0.211
R15 500 g IN + 20 g BL	4.90	0.477	41.51	2.034	0.198
Average R11-R15 500 IN + 20 g BL ± st. dev.	**4.8 ± 0.5**	**0.467 ± 0.024**	**46.81 ± 1.50**	**2.251 ± 0.075**	**0.219 ± 0.004**

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

The best specific yield of methane is obtained from maple leaves. It is 19.63% higher than that of birch leaves and 11.02% higher than that of miscanthus grass. Compared to many raw materials, they are rated as good. Specific biogas and methane yields from each bioreactor are shown in Figure 1.

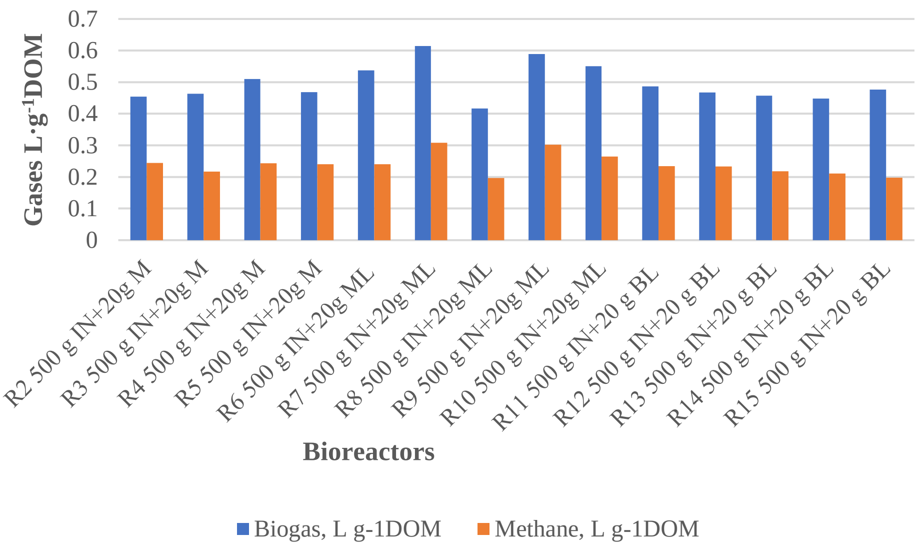

Fig. 1. **Specific biogas and methane yields from each bioreactor**

The average methane content from each bioreactor is shown in Figure 2. On average for each raw material, it is low compared to many other raw materials. This could be explained by the fact that the C:N ratio is not so good. It was the best for maple leaves, also the methane content was the highest among them. The release of methane was inhibited by the large predominance of C.

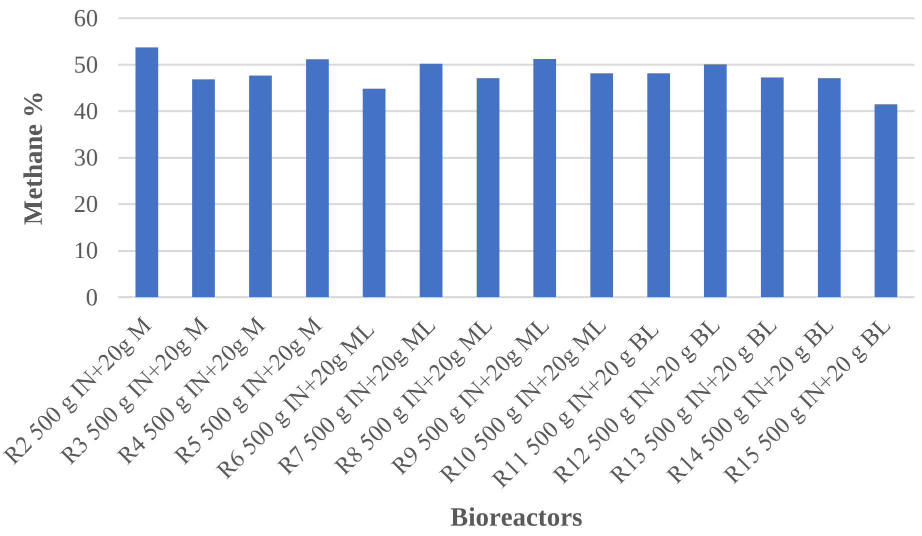

Fig. 2. **Average methane content in each bioreactor**

Methane content varies little for all raw materials. The results of the study show that these raw materials can be well used in co-fermentation with raw materials with a higher N content.

Conclusions

1. Specific biogas (methane) average yield from grass miscanthus is 0.474 (0.236) $L \cdot g^{-1}_{DOM}$
2. Specific biogas (methane) average yield from maple leaves is 0.542 (0.262) $L \cdot g^{-1}_{DOM}$
3. Specific biogas (methane) average yield from birch leaves is 0.467 (0.219) $L \cdot g^{-1}_{DOM}$
4. The raw materials tested in the study can be well used in the anaerobic fermentation process for methane production.

Author contributions

Conceptualization, V.D.; methodology, V.D. and D.D.; software, V.D.; validation, D.D. and V.D; formal analysis, V.D and D.D.; investigation, V.D., and D.D.; data curation, V.D. and D.D.; writing – original draft preparation, V.D.; writing – review and editing, D.D. and V.D.; visualization, V.D.; project administration, V.D.; funding acquisition, D.D. All authors have read and agreed to the published version of the manuscript.

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