BIOGAS POTENTIAL FROM UNDERWOOD PLANTS

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Abstract. Adherence to the principles of sustainable forest management and increasing economic efficiency is one of the most important tasks of forest management. Therefore, new forest products are being developed in the world and also in Latvia, which are in demand in the market and increase the income of the landowner. In many European countries, in addition to growing valuable timber in stands, attention is being paid to the possibilities of developing the cultivation of ground cover plants and undergrowth biomass by creating cultivated plantations under tree crowns. The forest growing cycle is long, timber production per unit area is cyclical, it repeats every 20 years. Regular production of biomass through the cultivation of undergrowth and ground cover plants can ensure regular production of hitherto little-used biomass, which has an additional economic effect. For example, in fertile growing conditions, clearings and young stands are often overgrown with wild raspberries, which are heavily devoted to harvesting and shading future trees. Biomass from caring for young plants can be used for energy. At the same time, due to the reduction of mandatory procurement, cheaper raw materials are needed to survive in biogas plants. In this study, the biogas production potential from three Latvian underwood plants was tested: ferns (filice), thistles (carduus) and wild raspberries (silva amet) leaves and stalks. These plants were treated in 16 laboratory bioreactors at 38 ºC for 40 days under anaerobic conditions. From ferns 0.274 $L \cdot g^{-1}_{DOM}$ biogas, 0.06 $L \cdot g^{-1}_{DOM}$ methane was obtained. 0.703 $L \cdot g^{-1}_{DOM}$ biogas (0.256 $L \cdot g^{-1}_{DOM}$ methane) was obtained from thistle and 0.511 $L \cdot g^{-1}_{DOM}$ biogas (0.191 $L \cdot g^{-1}_{DOM}$ methane) from raspberry leaves and stalks. The study shows that thistle and raspberry leaves and stalks are suitable as a raw material for biogas production. Further research is needed to find out why bacteria make poor use of fern biomass.

Keywords: anaerobic digestion, biogas, fern, thistle, wild raspberries.

Introduction

The implementation of the EU Green Deal brings with it new opportunities to scale-up biogas and biomethane in Europe. "At the end of 2019, we have reached a total of 18,943 biogas plants and 725 biomethane plants across Europe. Biogas and biomethane are accessible sources of renewable energy: the sector is ready for expansion and perfectly placed to make a significant and sustainable contribution to the EU Green Deal. A supportive and consistent legislative framework will accelerate ongoing progress and encourage investment, helping sector to reach a minimum of 380 TWh by 2030, with further growth in the years thereafter" [1].

In Latvia, the state's initial support for biogas production is constantly being reduced. Even previously accepted aid conditions are not taken into account. Restrictions on the use of maize silage as a feedstock in biogas plants and new requirements for the use of larger quantities of manure were developed. Prices for raw material also increased. The financial situation of the producers of biogas has deteriorated and some owners have already ceased operation of biogas plant. Therefore, the use of new, inexpensive raw biomass would be very important for them [2]. Undergrowth biomass could be cheap, as it is not yet fully utilized. Adherence to the principles of sustainable forest management and increasing economic efficiency is one of the most important tasks of forest management. Therefore, new forest products are being developed in the world and also in Latvia, which are in demand in the market in the future and increase the income of the landowner. Much attention is paid to the use of biomass for energy. In many European countries, in addition to growing valuable timber in stands, attention is being paid to the possibilities of developing the cultivation of ground cover plants and undergrowth biomass by creating cultivated plantations under tree crowns. The forest growing cycle is long, timber production per unit area is cyclical, it repeats every 20 years. Regular production of biomass through the cultivation of undergrowth and ground cover plants can ensure regular production of hitherto little-used biomass, which has an additional economic effect. For example, in fertile growing conditions, clearings and young stands are often overgrown with wild raspberries, which are heavily devoted to harvesting and shading future trees. Biomass from caring for young plants can be used for energy.

Information on the use of undergrowth plants used in our study for biogas production could not be found in the literature. We found an article that wetland ferns were good for biogas production.

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"Consequently, the results of our study depicted that this fern, which is known as threat, can be used as an alternative biomass feedstock for efficient power generation and indicates that biogas from Azolla fern biomass had excellent and considerable ability in order to generate power and less NOX emission" [3].

In this study, the biogas production potential from three Latvian underwood plants was tested: fern (filice), thistle (carduus) and wild raspberry (silva amet) leaves and stalks. An extended study is needed to assess the cost-effectiveness, but this is not the aim of this work.

Materials and methods

The methodologies, similar with German VDI 4630 (VDI 4630, 2006) [4], (Angelidaki et.al. 2009) [5] guideline and the German Methodenhandbuch Energetische Biomassenutzung (Thran, 2010) [6] were used for the present study. An average sample for each group of raw materials was taken and the total dry matter, organic dry matter and content of ashes were measured. The analysis was performed according to standard methods. Each group's raw material was thoroughly weighed carefully. These plants were treated in 16 laboratory bioreactors at 38 ºC for 40 days under anaerobic conditions. All bioreactors (volume of 0.75 L) were filled with the same amount (500.0 g) of inoculums. Inoculums were digestate from a continuous working laboratory bioreactor with almost finished cow manure. Two bioreactors were filled with inoculums only as control [7]. The others bioreactors were filled in with inoculum and biomass sample (20.0 g). Chopped fern (20.0 g) were filled in bioreactors R2-R5. Chopped thistle 20 g as raw material was filled in bioreactors R6 to R10. Chopped wild raspberries 20 g were filled in bioreactors R11 to R15. The working methods, equipment and their accuracy are the same as described in the article [7]. Total biogas and methane production values were calculated using the biogas normal volumes and quality parameters obtained from gas collected in the gas storage bag for each bioreactor as described [8]. Data of study were recorded in the experimental log and also stored in the computer.

Results and discussion

The data of raw material sample analysis and amount of biogas and methane produced were estimated for all 16 bioreactors, and average results were calculated. The results of raw material analyses before anaerobic digestion are shown in Table 1. As substrates in control bioreactors (R1, R16) the same digestates were used as were used for inoculums. Weight of total solids (TS) and dry organic matter (DOM) of raw materials samples in Table1 is provided with accuracy ± 0.001 g, but for inoculum (500 g) with accuracy ± 0.02 g. As it can be seen from Table 1, most dry matter and dry organic matter are in wild raspberries.

Table 1

Analyses of raw material samples

Bio-reactors	Raw material	pH	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weight, g
R1; R16	IN	7.80	1.74	8.700	29.39	70.61	6.143	500
R2-R5	F	-	36.76	7.352	8.26	91.74	6.745	20
R2-R5	20 F + 500 IN	7.75	3.09	16.052	19.71	80.29	12.888	520
R6- R10	20 T	-	21.45	4.290	15.76	84.24	3.614	20
R6-R10	20 T + 500 IN	7.76	2.50	12.990	24.89	75.11	9.757	520
R11-R15	20 R	-	40.57	8.114	5.55	94.45	7.664	20
R11- R15	20 R + 500 IN	7.78	3.23	16.814	17.88	82.12	13.807	520

Note: IN – inoculum; F – fern; T – thistle; R – wild raspberries; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R16 – bioreactors.

Biogas and methane yield from ferns, thistles and wild raspberries are shown in Table 2. Biogas and methane values for bioreactors R2-R15 with fresh source biomass are provided with already subtracted average biogas and methane values obtained from reactors 1 and 16. The low methane content in the produced biogas is surprising. As it is low from all biomass and all bioreactors, it is possible that there was a bad inoculum with a low methane-forming bacteria content. Methane-producing bacteria could not multiply so quickly to use all the products produced in the first stages of the process. This is evidenced by the relatively large amount of biogas produced, with the exception of ferns, with a very high carbon dioxide content. However, our studies before and after this study, when a similar inoculum was used, suggest that there is another explanation for the low methane production. There may be a substance in the undergrowth that inhibits the rapid growth of methane bacteria. More research is needed.

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	0.2	0.033	1.10	0.002	0.0003
R16 500 IN	0.3	0.049	5.33	0.016	0.0030
Average R1, R16	0.25	0.041	3.22	0.009	0.0017
R2 500 g IN + 20 g F	1.4	0.208	24.71	0.346	0.0510
R3 500 g IN + 20 g F	2.1	0.311	28.14	0.591	0.0880
R4 500 g IN + 20 g F	1.8	0.267	13.22	0.238	0.0350
R5 500 g IN + 20 g F	2.1	0.311	21.10	0.443	0.0660
Average R2- R5 ± st.dev.	**1.850 0.332**	**0.274 0.049**	**21.890 6.397**	**0.405 0.15**	**0.0600 0.0230**
R6 500 g IN + 20 g T	2.5	0.692	32.52	0.813	0.2250
R7 500 g IN + 20 g T	2.5	0.692	39.84	0.996	0.2760
R8 500 g IN + 20 g T	2.5	0.692	32.12	0.803	0.2220
R9 500 g IN + 20g T	2.4	0.664	39.42	0.946	0.2620
R10 500 g IN + 20 g T	2.8	0.774	38.14	1.068	0.2960
Average R6-R10 ± st.dev.	**2.540 0.152**	**0.703 0.042**	**36,42 3,787**	**0.925 0.115**	**0.2560 0.0320**
R11 500 g IN + 20 g R	4.0	0.522	36.55	1.462	0.1910
R12 500 g IN + 20 g R	4.4	0.574	39.89	1.755	0.2290
R13 500 g IN + 20 g R	3.8	0.496	35.79	1.360	0.1770
R14 500 g IN + 20 g R	4.0	0.522	40.68	1.627	0.2120
R15 500 g IN + 20 g R	3.4	0.444	32.91	1.119	0.1460
Average R11- R15 ± st.dev.	**3.920 0.363**	**0.511 0.047**	**37.370 3.168**	**1.465 0.246**	**0.1910 0.0320**

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

The specific biogas and methane yields from ferns, thistles and wild raspberries from every bioreactor are shown in Figure 1.

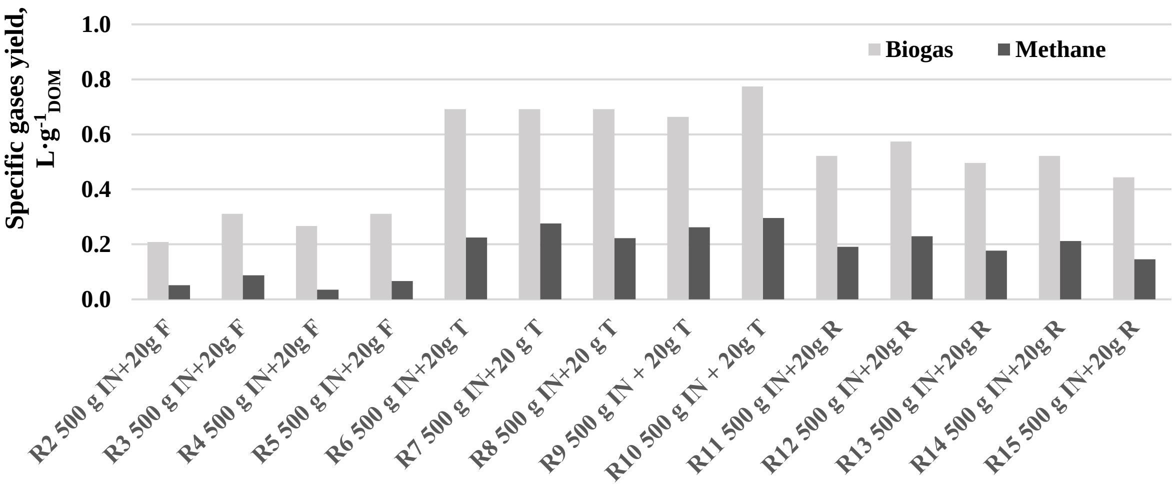

Fig. 1. **Specific biogas and methane yield from ferns, thistles and wild raspberries from every bioreactor**

The best methane potential was from thistle, then from wild raspberries and small from ferns. This could be partly explained by the fact that this difference between thistles and ferns is due to the large number of stalks in the chopped ferns. The ferns were also drier.

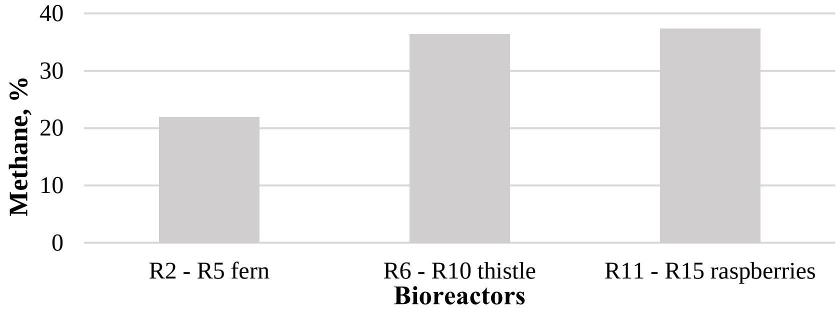

Fig. 2. **Average methane content from ferns, thistles and wild raspberries**

We could not compare with the results of other researchers, because they could not be found in the literature. Comparing the methane extraction potential with the methane extraction potential of other raw materials, it can be seen that for thistle it is somewhat similar to pig manure (0.250 $L \cdot g^{-1}_{DOM}$), but for wild raspberries it is somewhat similar to that of cow manure (0.185 $L \cdot g^{-1}_{DOM}$) [8].

Conclusions

1. The average yield of biogas (methane) from the bioreactors with fern was 0.274 ± 0.049 $L \cdot g^{-1}_{DOM}$ (0.06 ± 0.023 $L \cdot g^{-1}_{DOM}$).
2. The average yield of biogas (methane) from the bioreactors with added thistle was 0.703 ± 0.042 $L \cdot g^{-1}_{DOM}$ (0.256 ± 0.032 $L \cdot g^{-1}_{DOM}$) .
3. The average yield of biogas from the bioreactors with added raspberry was 0.511 ± 0.047 $L \cdot g^{-1}_{DOM}$ (0.191 ± 0.032 $L \cdot g^{-1}_{DOM}$).
4. The average yields of biogas and methane from the bioreactors with added fern were low.
5. Using fern as raw material alone for methane production is not acceptable.
6. Thistle and wild raspberries can be usable raw materials for biogas production, but better together with other raw materials.

Acknowledgements

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