ANAEROBIC DIGESTION OF SUNFLOWERS AND AMARANTHS SILAGES WITH CATALYST METAFERM

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***Abstract**. Fifty-fourbiogas plants are working today in Latvia. There is need to investigate the suitability of various biomasses for energy production. Maize is the dominant crop for biogas production in Latvia. The cultivation of more varied crops with good economics and low environmental impact is thus desirable. One of the way for improving biogas yield in Latvia conditions is using biological catalysts. This paper shows results from anaerobic digestion of sunflowers and amaranths silagesusing new biological catalyst Metaferm. The digestion process was investigated for biogas production in sixteen 0.7 l digesters, operated in batch mode at temperature 38±1.0°C. The average methane yield per unit of dry organic matter added (DOM) from digestion of sunflower silage was 0.267 $l{\cdot}g_{DOM}^{-1}$ with Metaferm1 ml- 0.307 $l{\cdot}g_{DOM}^{-1}$ and with Metaferm 2 ml-0,434 $l{\cdot}g_{DOM}^{-1}$. Average methane yield from digestion of amaranth silage was 0,403 $l{\cdot}g_{DOM}^{-1}$ with Metaferm1 ml- 0,602 $l{\cdot}g_{DOM}^{-1}$ and with Metaferm 2 ml-0,484 $l{\cdot}g_{DOM}^{-1}$. Both investigated silages can be successfully cultivated for energy production under agro ecological conditions in Latvia. Addition of catalyst Metaferm increased methane yield.*

Key words: *anaerobic digestion, sunflower, amaranth, biogas, methane, biological catalyst.*

INTRODUCTION

One of the most promising renewable energy sources is biogas. Biogas production must be developed, ensuring that methane collection also helps to implement the Kyoto Protocolprovisions. Latvian Action Plan envisages total electricity generation capacity of 92 MW [1] for the biogas plants in 2020. Number of working biogas cogeneration plants increase up to 54 in Latvia in 2014 [2]. There are around 369,000 ha of available land suitable for energy crops growing and the production of biogas in Latvia [3]. However, many of biogas plants are built in areas, e.g. in sub region Zemgale, with less or no free additional land areas for growing of biomass (mainly maize) for biogas plants. High cereals yields and increasing prices on grain in market can cause further decrease of maize areas, potentially limiting this traditional source for biogas production. Therefore it is necessary to find new biomass sources to stabilise or increase biomethane production in biogas plants in Latvia.

Common sunflower (*Helianthus annuus* L.) is annual plant, attached to *Asteraceae* family. *Helianthus annuus* ssp. *Sativus* Wenzl. is used for biomass production. In Latvia, the average biomass of this plant varies from 15.0 to 30.0 t ha^{-1}, but higher yield from 40.0 to 50.0 t ha^{-1} is possible to be grown in optimal agrometeorological conditions. The cultivation of forms and hybrids of this subspecies provides the raw material for biogas production during the whole season

Amaranth (*Amaranthus* L.) is annual or perennial plant, attached to *Amaranthaceae* family. There are more than 65 genus and about 900 species of amaranth in the world. About 17 species are used for food production. The most significant species are *Amaranthus. cruentus* L., *Amaranthus hybridus* L., *Amaranthus caudatus* L. Amaranth is one of the most productive plants. In fertile soils, the average fresh biomass is about 100 t ha^{-1}, the average seed yield varies from 2 t ha^{-1} to 5 t ha^{-1} (for seed varieties). The fresh biomass or silage of amaranth can be used for biogas production. [4].

Additional way to increase biogas production is improvement of anaerobic fermentation process itself. Currently, the biogas sector within some European countries is faced with the rapid development and innovation in usage of a variety of specific additives [5]-[8] aiming to increase the biogas yield.The aim of the study is to evaluate biogas and methane production from different energy crops silages, clarify whether the addition of biocatalyst Metaferm (made in Latvia) in substrates causes any positive effect, establish effective doses for optimised fermentation.

MATERIALS AND METHODS

In order to achieve greater statistical confidence the heated camera (Memmert incubator) and number of the small bioreactors were used. Small bioreactors were filled with substrate and placed in a heat chamber, and gas from each bioreactor was directed into separate storage bag located outside the camera. For obtaining of results the widely applied methods were used [9]. Dry matter was determined by investigation of initial biomass sample weight and dry weight by using scales Shimazu at 120°C temperature and by investigation of ashes content help by furnace Nabertherm burnt the samples at 550°C. All mixtures were prepared, carefully mixed and all sealed bioreactors were put in heated camera within same time period before starting of anaerobic digestion.Collected in storage bag gas composition was measured with the gas analyser GA 2000. Help by this instrument oxygen, carbon dioxide, methane and hydrogen sulphide were registered. Substrate pH value was measured before and after finishing of anaerobic fermentation process, using pH meter (PP-50) with accessories. Scales (Kern KFB 16KO2) was used for weighting of substrate before anaerobic processing and for weighting of digestate after finishing of fermentation process.Dry matter contents and ashes contents were measured for digestate from every bioreactor, to determine dry organic matter (DOM) content.
Each bioreactor with volume of 0.7 l was filled in with biomass sample 20 ± 0.05g and with 500.0 ± 0.2 g inoculum (fermented cattle manure from 120 l bioreactor working in continuous mode). For calculation purposes control bioreactors were filled only with inoculum. All data were recorded in the journal of experiments and into computer. All bioreactors were placed into incubator at operating temperature 38 ± 0.5°C, and every bioreactor have flexible pipe connected to gas storage bag positioned outside the heated camera. Every gas bag is provided with port, normallyclosed with tap, for gas measurement. Quantity and composition of gases were measured every day. Bioreactors were also gently shaked to mix the floating layer regularly. Fermentation process was provided with single filling in batch mode until biogas emission ceases. Final digestate was weighed, and dry matter and ashes were investigated to evaluate organic dry matter content. 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.

RESULTS AND DISCUSSION

Results of raw material samples analyses for investigation of sunflowers and amaranths silages anaerobic digestion are shown in Table 1.

Table 1

Results of analyses of raw material samples before anaerobic digestion

Bioreactor/Raw material	pH substrate	TS, %	TS, g	Ash, %	DOM, %	DOM, g	Weight, g
R1, R16 only inoculum (Ie) 500g	7,52	5,09	25,45	19,62	80,38	20,46	500
R2,R3 20gSS	4,5	16,45	3,29	10,42	89,58	2,95	20
500g Ie + 20g SS	7,35	5,53	28,74	18,57	81,43	23,4	520
R4,R5 20gSS	4,5	16,45	3,29	10,42	89,58	2,95	20
500g Ie +20gSS + 1ml MF	7,46	5,53	28,74	18,57	81,43	23,4	521
R6,R7 20gSS	4,5	16,45	3,29	10,42	89,58	2,95	20
500g Ie +20gSS + 2ml MF	7,49	5,52	28,81	18,52	81,48	23,47	522
R8,R9 20g AS	4,3	16,18	3,24	14,41	85,59	2,77	20
500g Ie +20gAS	7,3	5,51	28,69	19,03	80,97	23,23	520
R10,R11,R12 20g AS	4,3	16,18	3,24	14,41	85,59	2,77	20
500g Ie +20gAS + 1ml MF	7,39	5,51	28,7	19,03	80,97	23,24	521
R13,R14,R15 20g AS	4,3	16,18	3,24	14,41	85,59	2,77	20
500g Ie +20gAS + 2ml MF	7,42	5,5	28,71	18,97	81,03	23,26	522

Abbreviations: Ie – inoculum; SS – sunflowers silage; AS – amaranths silage; MF – biocatalyst Metaferm; TS – total solids; Ash – ashes; DOM – dry organic matter; R1-R16 numbers of bioreactors.

Results of digestate analysis after finishing of anaerobic digestion process are shown in Table 2.

Table 2

Results of digestate analysis for sunflowers and amaranths silages

Bioreactor/Raw material	pH	TS, %	TS, g	Ash, %	DOM, %	DOM, %	Weight, g
R1Ie	7,30	4,18	20,62	24,30	75,7	15,61	493,2
R16 Ie	7,24	4,16	20,48	24,24	75,76	15,52	492,4
R2 SS+Ie	7,23	4,25	21,69	21,17	78,83	17,10	510,4
R3 SS+Ie	7,24	4,28	21,84	21,28	78,72	17,19	510,2
R4 SS+Ie+1ml MF	7,20	4,27	21,90	23,91	76,09	16,59	510,6
R5 SS+Ie+1ml MF	7,19	4,54	22,98	22,17	77,83	17,89	506,2
R6 SS+Ie+1ml MF	7,22	4,20	21,30	24,68	75,32	16,04	507,2
R7 SS+Ie+2ml MF	7,17	4,73	23,84	20,30	79,70	19,00	504,0
R8 SS+Ie+2ml MF	7,18	4,66	23,59	21,84	78,16	18,43	506,2
R9 ZS+Ie+2ml MF	7,16	4,52	22,97	23,12	76,88	17,66	508,2
R10 AS+Ie	7,19	4,10	20,80	25,14	74,86	15,57	507,2
R11 AS+Ie	7,23	4,26	21,53	25,16	76,84	16,11	505,4
R12 AS+Ie+1ml MF	7,14	4,58	22,92	21,41	78,59	18,01	500,4
R13 AS+Ie+1ml MF	7,26	4,63	23,24	21,91	79,09	18,38	502,0
R14 AS+Ie+2ml MF	7,20	4,64	23,51	22,71	77,29	18,17	506,6
R15 AS+Ie+2ml MF	7,23	4,61	23,08	24,16	75,84	17,51	500,7

The production of biogas and methane from sunflowers and amaranths silages and from control bioreactors is presented in Table 3.

Table 3

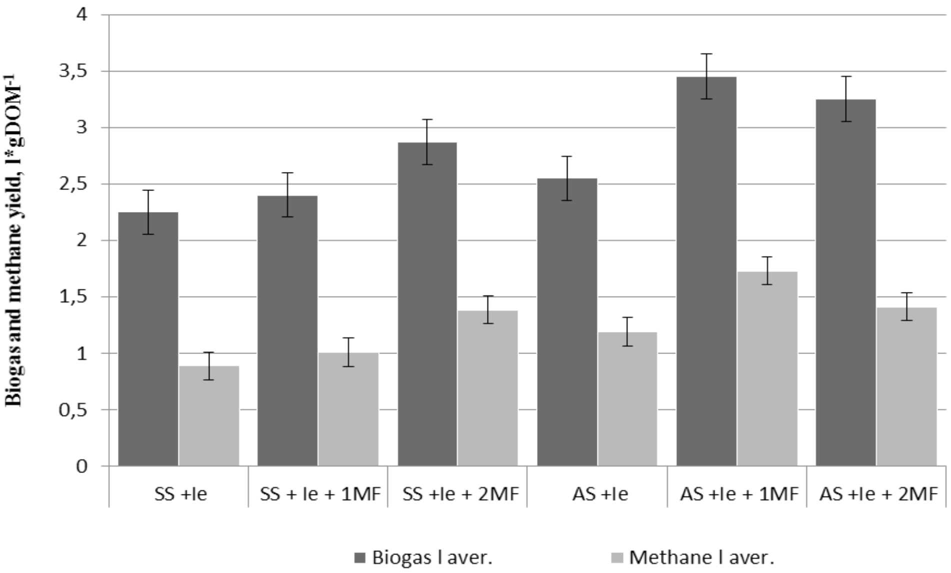
Production of biogas and methane in bioreactors from sunflowers and amaranths silages

Bioreactor/Raw material	Biogas, l	Biogas, l g_{DOM}^{-1}	Methane average, %	Methane, l	Methane, l g_{DOM}^{-1}
R1 Ie	0,9			0,110	
R2 SS +Ie	2,2	0,423	62,88	0,886	0,266
R3 SS +Ie	2,3	0,457	58,42	0,889	0,267
R4 SS + Ie + 1MF	2,1	0,389	62,46	0,819	0,243
R5 SS + Ie + 1MF	2,4	0,492	62,19	1,006	0,306
R6 SS + Ie + 1MF	2,7	0,593	62,90	1,202	0,373
R7 SS +Ie + 2MF	2,8	0,627	63,48	1,275	0,398
R8 SS +Ie + 2MF	2,8	0,627	69,22	1,382	0,434
R9 SS +Ie + 2MF	3,0	0,695	67,63	1,488	0,470
R10 AS +Ie	2,7	0,648	65,74	1,253	0,426
R11 AS +Ie	2,4	0,537	70,76	1,127	0,380
R12 AS +Ie + 1MF	4,0	1,129	59,34	1,913	0,670
R13 AS +Ie + 1MF	2,9	0,722	73,82	1,541	0,533
R14 AS +Ie + 2MF	2,8	0,685	60,72	1,226	0,416
R15 AS +Ie + 2MF	3,7	1,019	54,17	1,593	0,552
R16Ie	1,0			0,093	

Note: Biogas and methane values for biorectors R2-R15 with fresh source biomass are provided with already substracted average biogas and methane values obtained from reactors R1 and R16.

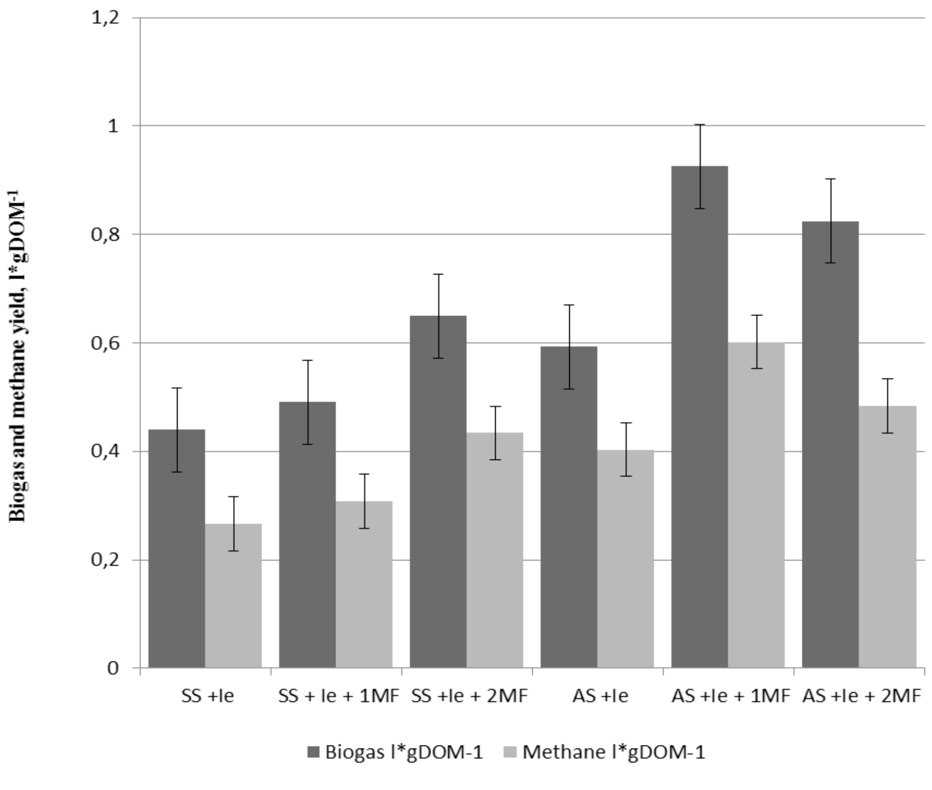
Abbreviation: l g_{DOM}^{-1} – litres per 1 g dry organic matter added (added fresh organic matter into inoculum)

Addition of biocatalyst Metaferm resulted in considerably higher methane production compared to control reactors (with sunflowers or amaranths silages only) in all bioreactors .
Average biogas and methane yield in liters from sunflowers and amaranths silages when added MF 1 ml and 2 ml shown in figure 1.



Abbreviations: Ie – inoculum; SS – sunflowers silage; AS – amaranths silage; MF – biocatalyst Metaferm; DOM – dry organic matter.

Figure 1. **Average biogas and methane yield in l from sunflowers and amaranths silages when added MF 1 ml and 2 ml**



Abbreviations: Ie – inoculum; SS – sunflowers silage; AS – amaranths silage; MF – biocatalyst Metaferm; DOM – dry organic matter.

Figure 2. **Specific biogas and methane yield (l*gDOM^{-1}) from sunflowers and amaranths silages when added MF 1ml and 2 ml.**

Specific biogas and methane production $l*gDOM^{-1}$volumes calculated for added sunflowers and amaranths silages is shown in figure 2. Very high methane yield when added 1 ml MF was surprise. Maybe it is explained with more amaranth seeds in these samples. There more research are needed.
Results show that for sunflowers silage higher yield with addition 2 ml Metaferm, but for amaranths silage 1ml Metaferm addition is good enough. It can be explained with higher fiber content in sunflower silage.

CONCLUSIONS

Addition of biocatalyst Metaferm have positive impact on fermentation process in all substrates compare to control without MF addition.

Addition of biocatalyst Metaferm in doses of 1 ml and 2ml gives rise methane production by 15.11%, and 16.25% in substrates with sunflowers and by 49.37%, and 20.09% in substrates with amaranths silages compare to control substrates respectively.

Methane yield from amaranths silage was 50.94% higher than from sunflowers silage.

ACKNOWLEDGEMENTS

The research was supported by the grant of the Ministry of Agriculture of the Republic of Latvia, Agreement No. 270314 /S70.

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