IMPACT OF MELAFEN-METAFERM ADDITIVE ON MAIZE SILAGE ANAEROBIC DIGESTION PROCESS

Vilis Dubrovskis, Imants Plume
Latvia University of Agriculture
vilisd@inbox.lv, imants.plume@inbox.lv

Abstract. Maize silage is widely used as the raw material in biogas plants, and its fermentation takes a long time. Different additives were used to achieve faster and better decomposition of silage biomass. The additive MM1 (composed of Melafen and Metaferm mixtures) was tested in this study at three different concentration levels of efficiency. The study was performed in 16 bioreactors filled with inoculums, added maize silage and additive MM1 in an amount of 1, 2 or 3 ml. Anaerobic fermentation was performed in 0.75 l bioreactors operating in batch mode at a temperature of 38 ºC. The higher average biogas yield improvement was obtained from bioreactors with 2 ml (by 3.8 %) or 3 ml (by 1.3 %) MM1 additive. The addition of MM1 at any concentration to maize silage substrate resulted in an increase in the methane content in biogas up to 3.7 % compared to maize silage substrate processed without MM1 additive. Usage of additive MMI for enhancement of the anaerobic fermentation process can be regarded as useful as the increased methane content in biogas can lower the carbon dioxide emissions and improve the overall efficiency of biogas cogeneration plants.

Keywords: biogas, anaerobic digestion, additives, methane.

Introduction

Energy production from renewable sources plays a major role in the Europe's energy policies. According to theDirective 2009/28/EK, Annex I, Part A, the goal for Latvia is to increase the share of energy produced from renewable energy sources (RES) in gross final energy consumption from 32.6 % in 2005 to 40 % in 2020 [1].

Biogas production must be developed, ensuring that biogas plants prevent methane release from manure storages and provide methane producing from energy plant biomass, so helping implement the Kyoto Protocol provisions. Latvian Action Plan envisages total electricity generation capacity of 92 MW for the biogas plants in 2020 [2]. The number of working biogas cogeneration plants increased up to 56, and more than 40 of them were using energy crops for biogas production in Latvia in 2015 [3]. There are around 369,000 ha of available land area suitable for energy crop growing for production of biogas in Latvia [4]. However, many of biogas plants are built in areas, e.g., in subregion Zemgale having high percentage of land usage for food products with less or no free additional land areas for growing of energy biomass (mostly maize) usable in biogas plants. Increasing prices on grain in the market can cause a further decrease of maize areas, potentially limiting this traditional source for biogas production. Therefore, it is necessary to improve biomethane yield from maize silage or to find new biomass sources to stabilise or increase biomethane production in biogas plants. A promising way to increase biogas production is improvement of the anaerobic fermentation process itself. Currently, the biogas sector within some European countries is faced with rapid development and innovation in the usage of a variety of specific additives [5-8] aiming to increase the biogas and methane yields.

The aim of this study was to evaluate the biogas and methane production from maize silage, to justify whether the addition of biocatalyst MM1 (composed from Melafen and Metaferm mixtures made in Latvia) in substrates can cause any positive effect, establish effective doses for advanced fermentation.

Materials and methods

Before fermentation, the raw material (maize silage) samples were analysed to clear up the trace elements. Data on deficiency of micronutrients Mo, Co and Ni were used by the mixture producer to create Melafen and Metaferm mixture called MM1.

Melafen is a mixture containing essential elements for the anaerobic fermentation process advancement. Metaferm is an innovative catalyst for the anaerobic digestion process. Metaferm contains multiple ferments, micronutrients, and B-group vitamins. The true composition both of Melafen or Metaferm is not known due to proprietary rights of the producing company.

To achieve greater statistical confidence, 16 small bioreactors were filled with the substrate and placed in a heated incubator, and the gas released from each bioreactor was collected into a separate storage bag located outside the incubator. For investigation of the fermentation process, widely applied methods were used [9].

Dry organic matter (DOM) content was determined by investigating of the weight and dry weight of the initial biomass samples and substrate samples before and after anaerobic fermentation by using electronic moisture balance (Shimazu Co. Ltd., model MOC-120H) at 105 ºC temperature, and by ashing in the oven ("Nabertherm" type) at 550 ºC. All mixtures were prepared, carefully mixed and all bioreactors were placed into the heated incubator at same time before starting of anaerobic digestion. Gas volume was measured by the flow meter (Ritter drum-type gas meter). The composition of gases, including oxygen, carbon dioxide, methane, and hydrogen sulphide was measured with the gas analyser (model GA 2000). The substrate pH value was measured before and after finishing the anaerobic fermentation 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 anaerobic fermentation process.

16 bioreactors with the volume of 0.75 l were filled with 500.0 ± 0.2 g inoculums (for control) or with mixtures of inoculums (500 g) and added biomass (20 ± 0.005 g). Fermented cattle manure obtained from 120 l bioreactor working in continuous mode was used as the inoculums. Bioreactors were placed into an incubator for batch mode anaerobic fermentation at temperature 38 ± 0.5 ºC. Biogas released was collected in the gas bag for further gas measurements. Biogas and methane volumes and gases composition were measured within regular time intervals. The fermentation process was provided until biogas emission ceases.

Results and discussion

The results of investigation of sample substrates, including inoculums, two types of maize silage with different doses of additive MM1, before anaerobic fermentation are shown in Table 1.

Table 1

Results of analyses of raw material sample before anaerobic digestion

Bio-reactors	Raw material	pH	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weight, g
R1; R16	IN	7.54	3.32	16.600	24.30	73.7	12.23	500
-	MS1	4.48	26.43	5.286	5.00	95.00	5.02	20
R2-R3	IN+MS1	7.35	4.20	21.886	21.27	78.73	17.23	520
-	MS2	4.51	23.97	4.794	5.47	94.53	4.53	20
R4-R5	IN+MS2	7.33	4.11	21.394	21.66	78.34	16.76	520
R6-R7	IN+MS1+1ml MM1	7.38	4.20	21.886	21.27	78.73	17.23	521
R8	IN+MS2+1ml MM1	7.39	4.11	21.394	21.66	78.34	16.76	521
R9-R10	IN+MS1+2ml MM1	7.42	4.19	21.886	21.27	78.73	17.23	522
R11	IN+MS2+2ml MM1	7.43	4.10	21.394	21.66	78.34	16.76	522
R12-R13	IN+MS1+3ml MM1	7.45	4.18	21.886	21.27	78.73	17.23	523
R14-R15	IN+MS2+3ml MM1	7.47	4.09	21.394	21.66	78.34	16.76	523

Note: IN – inoculum; MS1 – maize silage 1; MS2 – maize silage 2; ASH – ashes; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R16 – bioreactors.

The dry organic matter content in both maize silage samples (MS1 and MS2) does not differ substantially (Table 1). This is a good reason to divide all samples containing maize silage in four groups for calculation of average parameters. Each group contains both types of maize silage (MS1 and MS2), but the groups differ from each other by the dose of MM1 additive (see Tables 1-3).

The results of analysis of digestate from each bioreactor after finishing of the anaerobic digestion process are shown in Table 2.

Biogas and methane values for the bioreactors R2-R15 with added biomass are provided in Table 3 and Fig. 1-2 with already subtracted average values of biogas (0.7 l) and methane (0.102 l) obtained from the control reactors R1 and R16 filled in with pure inoculum.

Table 2

Results of analyses of finished digestate

Reactor	**Substrate**	**pH**	**TS %**	**TS g**	**ASH %**	**DOM %**	**DOM g**	**Weigh tg**
R1	500g IN	7.15	3.46	17.15	27.98	72.0	12.35	495.8
R16	500g IN	7.14	3.45	17.10	28.00	72.0	12.31	495.7
R2	500g IN+20g MS1	7.05	3.41	17.49	26.72	73.3	12.82	513.0
R3	500g IN+20g MS1	6.99	3.4	17.43	26.67	73.3	12.78	512.6
R4	500g IN+20g MS2	7.04	3.59	18.45	25.35	74.7	13.77	514.0
R5	500g IN+20g MS2	7.05	3.45	17.92	26.11	73.9	13.24	513.6
R6	500g IN+20g MS1+1ml MM1	7.02	3.5	17.97	21.26	78.7	14.15	513.6
R7	500g IN+20g MS1+1ml MM1	7.04	3.71	18.92	24.69	75.3	14.25	510.0
R8	500g IN+20g MS2+1ml MM1	7.05	3.65	18.72	24.89	75.1	14.06	513.0
R9	500g IN+20g MS1+2mlMM1	7.01	3.20	16.32	26.22	73.8	12.04	510.0
R10	500g IN+20g MS1+2mlMM1	7.02	3.45	17.66	25.22	74.8	13.21	512.0
R11	500g IN+20g MS2+2mlMM1	7.03	3.46	17.79	25.3	74.7	13.29	514.2
R12	500g IN+20g MS1+3ml MM1	7.04	3.39	17.40	27.42	72.6	12.63	513.3
R13	500g IN+20g MS1+3ml MM1	7.04	3.37	17.29	27.55	72.5	12.53	513.0
R14	500g IN+20g MS2+3ml MM1	7.05	3.40	17.44	27.11	72.9	12.71	513.0
R15	500g IN+20g MS2+3ml MM1	7.06	3.51	18.01	25.12	74.9	13.48	513.0

Production of biogas and methane from maize silage with MM1 and from the control reactors is presented in Table 3.

Table 3

Production of biogas and methane in bioreactors from maize silage with MM1 additive

Bioreactor/Raw material	**Biogas, l**	**Biogas, l g$^{-1}_{DOM}$**	**Methane, aver. %**	**Methane, l**	**Methane, l g$^{-1}_{DOM}$**
R2 500g IN+20g MS1	3.6	0.717	61.64	2.22	0.442
R3 500g IN+20g MS1	3.6	0.717	60.67	2.18	0.435
R4 500g IN+20g MS2	3.7	0.817	55.92	2.07	0.457
R5 500g IN+20g MS2	2.8	0.618	64.28	1.80	0.397
Average, MS	**3.43 ±0.42**	**0.717 ±0.08**	**60.63 ±3.49**	**2.07 ±0.19**	**0.433 ±0.03**
R6 500g IN+20g MS1+1ml MM1	3.0	0.662	61.63	1.85	0.408
R7 500g IN+20g MS1+1ml MM1	3.3	0.728	61.96	2.05	0.451
R8 500g IN+20g MS2+1ml MM1	2.8	0.618	65.07	1.82	0.402
Average, MS+1ml MM1 ±std.	**3.03 ±0.25**	**0.669 ±0.06**	**62.89 ±1.90**	**1.91 ±0.12**	**0.420 ±0.03**
R9 500g IN+20g MS1+2ml MM1	4.0	0.797	61.35	2.45	0.489
R10 500g IN+20g MS1+2ml MM1	2.9	0.640	60.52	1.75	0.387
R11 500g IN+20g MS2+2ml MM1	3.3	0.728	64.78	2.14	0.472
Average, MS+2ml MM1 ±std.	**3.4 ±0.56**	**0.721 ±0.08**	**62.22 ±2.26**	**2.12 ±0.35**	**0.449 ±0.05**
R12 500g IN+20g MS1+3ml MM1	3.7	0.737	60.70	2.25	0.447
R13 500g IN+20g MS1+3ml MM1	3.8	0.756	60.76	2.31	0.460
R14 500g IN+20g MS2+3ml MM1	3.3	0.728	65.21	2.15	0.434
R15 500g IN+20g MS2+3ml MM1	2.9	0.640	64.66	1.88	0.413
Average, MS+3ml MM1 ±std.	**3.43 ±0.41**	**0.715 ±0.05**	**62.83 ±2.44**	**2.15 ±0.19**	**0.439 ±0.02**
R16 IN 500g	0.7	-	-	0.12	-
R1 IN 500g	0.7	-	-	0.08	-
Average, R1; R16 ±std.	**0.7**	**-**	**-**	**0.10±0.03**	**-**

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

Average methane content in biogas for the maize silage samples with different doses of MM1 additive is shown in Fig. 1.

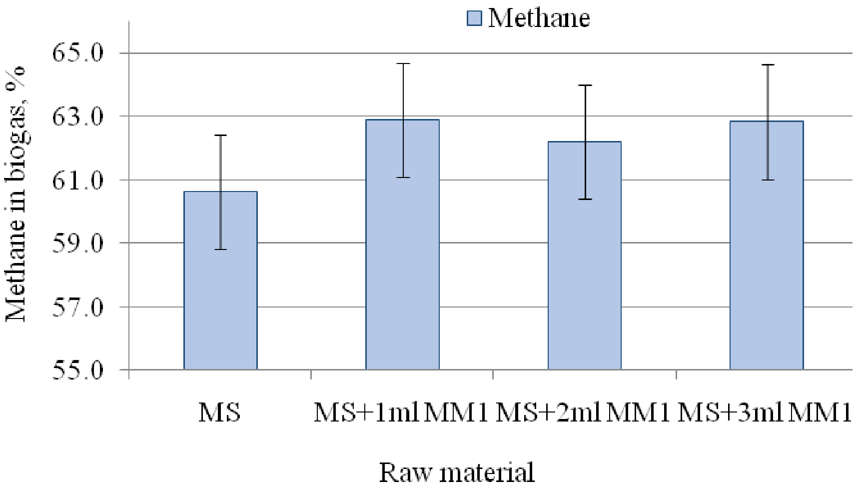

Fig. 1. **Average methane content in biogas without and with added MM1:** MS – maize silage; MM1 – mixture of Melafen concentration 1 + Metaferm

The methane content in biogas obtained from bioreactors with added MM1 was slightly higher (Fig. 1). Surprisingly high was the methane content in gases. Average methane percentage from maize silage normally is less than 60 %. High methane content can be explained by the fact that additive MM1 improves bioconversion of raw materials. Increasing of the methane content in biogas can lower carbon dioxide emissions and improve the efficiency of cogeneration engines. For more detailed investigations it is recommended to use more added biomass per sample substrate (to increase the organic load).

Specific average biogas and methane production yields ($l \cdot g^{-1}_{DOM}$) calculated for bioreactors without and with added MM1 into maize silage biomass are shown in Fig. 2.

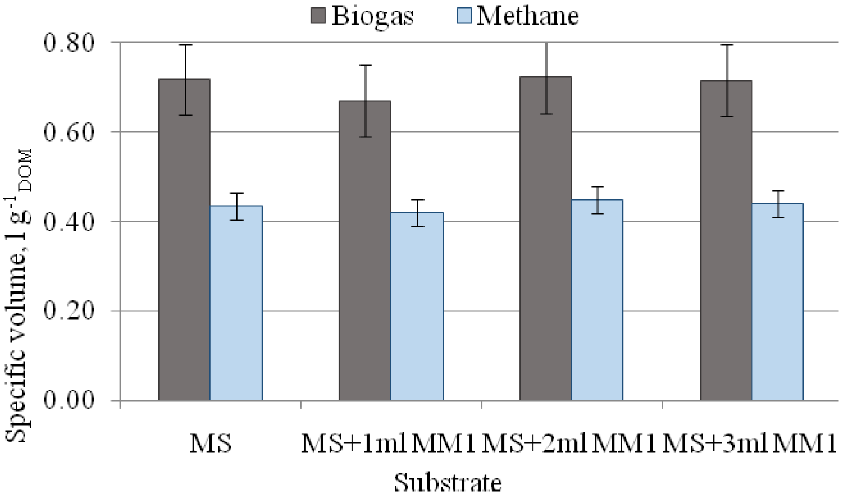

Fig. 2. **Specific average biogas and methane yields from maize silage samples without and with added MM1:** MS – maize silage; MM1 – mixture of Melafen concentration 1 + Metaferm

There are shown the average data calculated for all bioreactors containing maize silage biomass. Specific methane yield was higher from the samples provided with 2 ml and 3 ml MM1 additive, but less from the samples with 1 ml MM1. This evidence can be explained by lower methane yield obtained from the bioreactors R6 and R8.

As it can be seen from Fig. 2, usage of the additive MM1 in a dose of 2 ml or 3 ml increases the methane yield from maize silage samples up to 3.8 % in the anaerobic fermentation process.

Relatively high average biogas yield was obtained from a group of bioreactors (R2-R5) containing maize silage and from a group of bioreactors (R6-R8) with maize silage with MM1 additive. This evidence may be explained due to the following reason: maize silage has a good chopping degree. Comparison of the obtained results with other researcher's data would not be correct, as the additive used in this study has original composition, was composed for specific maize silage biomass in Latvia and was utilized for the first time for the given biomass.

Conclusions

1. Specific methane volumes from bioreactors with maize silage with additive MM1 in doses of 2 ml or 3 ml were slightly better compared to that obtained from maize silage without an additive. This could be explained by the fact that the additive MM1 improves the anaerobic fermentation process.
2. The recommended dose of additive for the anaerobic process improvement is 2 ml MM1 increasing the methane yield from maize silage by 3.8 % compared to control.
3. The average methane content in biogas increases by 3.7 %, if additive MM1 in a dose of 1 ml is added to maize silage.
4. The average methane content in biogas increases by 2.6 %, if additive MM1 in a dose of 2 ml is added to maize silage.
5. The average methane content in biogas increases by 3.26 %, if additive MM1 in dose of 3 ml is added to maize silage.
6. The average methane yield increase is relatively low, and investigations and calculations should be performed for every case, based on the individual substrate, anaerobic process conditions and desired criteria of effectiveness.

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