ANAEROBIC DIGESTION OF VEGETABLE PROCESSING WASTES WITH CATALYST METAFERM AND MICROELEMENTS

Vilis Dubrovskis, Vladimirs Kotelenecs, Imants Plume
Latvia University of Agriculture
vilisd@inbox.lv

ABSTRACT. 54 biogas plants are working today in Latvia. There is a need to investigate the suitability of various biomasses for energy production. One of the ways for improving the biogas yield in Latvia conditions is adding biological catalysts and microelements. This paper shows results from anaerobic digestion of vegetable processing wastes using a new biological catalyst Metaferm and mix of microelements. The digestion process was investigated for biogas production in sixteen 0.75 l digesters, operated in batch mode at temperature 38 ± 1.0 ºC. The average methane yield per unit of dry organic matter added (DOM) from digestion of cucumbers was 0.282 $l \cdot g_{DOM}^{-1}$ with Metaferm 1 ml – 0.340 $l \cdot g_{DOM}^{-1}$ and with MEL1 – 0.337 $l \cdot g_{DOM}^{-1}$. The average methane yield from digestion of cucumbers with Metaferm 1 ml- and ME5 was 0.322 $l \cdot g_{DOM}^{-1}$. The average methane yield from digestion of leftovers and tops of tomatoes was 0.158 $l \cdot g_{DOM}^{-1}$ and with Metaferm 1 ml – 0.173 $l \cdot g_{DOM}^{-1}$. The average methane yield per unit of dry organic matter added from digestion of grass silage and MEL1 was 0.121 $l \cdot g_{DOM}^{-1}$. All investigated vegetable wastes can be successfully cultivated for energy production under agro ecological conditions in Latvia. Addition of the catalyst Metaferm increased the methane yield.

Key words: anaerobic digestion, cucumbers, leftovers of tomatoes, biogas, methane, biological catalyst.

Introduction

According to the Directive 2009/28/EC, 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 % (1918 toe) in 2020 [1].

One of the most promising renewable energy sources is biogas. Biogas production must be developed, ensuring that methane collection also helps implement the Kyoto Protocol provisions. The Latvian Action Plan envisages total electricity generation capacity of 92 MW for the biogas plants in 2020. The number of working biogas cogeneration plants increased up to 54 in Latvia in 2014 [2]. There are approximately 369,000 ha of available land suitable for energy crop growing and production of biogas in Latvia [3]. However, many of the 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 cereal yields and increasing prices on grain in the 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.

An additional way to increase biogas production is improvement of the anaerobic fermentation process itself [4]. 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. Trace element deficiency leads to reduced performance of involved bacteria, biocatalysts can improve it.

One of the available biomass sources is vegetable and fruit waste from food industry or/and households. Vegetable and fruit wastes have a high initial moisture content in the range of 60-93 %, and the wastes are easy degradable under anaerobic conditions.

Anaerobic processing of quickly degradable vegetable or fruit wastes can avoid carbon dioxide emissions and runoff from biomass, providing the biogas and fertilizer production in environmentally friendly way. Investigations should be provided for food industry processing wastes to evaluate the local or regional biogas potential. The aim of the study is to evaluate biogas and methane production from different vegetable residues, clarify whether the addition of biocatalyst Metaferm (made in Latvia) and deficit microelements in substrates cause any positive effect, establish effective doses for optimised fermentation and determine the highest doses capable to inhibit the anaerobic digestion process.

Materials and methods

Before fermentation raw material (cucumbers and tomato greens) samples were analysed for clear up of trace elements. Deficiency Mo, Co and Ni were used to create mixes ME5 and MEL1.

Metaferm is an innovative catalyst for the anaerobic digestion process. Metaferm contains multi ferments, micronutrients and B group vitamins.

In order to achieve greater statistical confidence the heated camera (Memmert incubator) and a number (16) of the small bioreactors were used. The small bioreactors were filled with substrate and placed in a heat chamber, and gas from each bioreactor was directed into a separate storage bag located outside the camera. For obtaining of the results widely applied methods were used [9].

Dry matter was determined by investigation of the initial biomass sample weight and dry weight by using the scales Shimazu at 105 ºC temperature and by investigation of ashes content by help of the furnace Nabertherm burnt samples at 550 ºC. All mixtures were prepared, carefully mixed and all sealed bioreactors were put in a heated camera within the same time period before starting of anaerobic digestion. Collected in the calibrated storage bag the gas volume was measured by help of the device Ritter and the composition was measured with the gas analyser GA 2000. By help of this instrument oxygen, carbon dioxide, methane and hydrogen sulphide were registered. Substrate pH value was measured before and after finishing of the anaerobic fermentation process, using pH meter (PP-50) with accessories. Scales (Kern KFB 16KO2) were used for weighting of substrate before anaerobic processing and for weighting of digestate after finishing the fermentation process. The dry matter content and ashes content were measured for digestate from every bioreactor to determine the dry organic matter (DOM) content.

Each bioreactor with volume of 0.7 l was filled with a biomass sample 20 ± 0.05 g and with 500.0 ± 0.2 g inoculum (fermented cattle manure from 120 l bioreactor working in continuous mode). For calculation purposes the control bioreactors were filled only with inoculum. All data were recorded in the journal of experiments and into the computer. All bioreactors were placed into the incubator at operating temperature 38 ± 0.5 ºC, and every bioreactor has a flexible pipe connected to the gas storage bag positioned outside the heated camera. Every gas bag is provided with a port, normally closed with a tap, for gas measurement. The quantity and composition of gases were measured every day. The bioreactors were also gently shaked to mix the floating layer regularly. The fermentation process was provided with single filling in batch mode until biogas emission ceases. Total biogas and methane production values were calculated using the biogas normal volumes and quality parameters obtained from the gas collected in the gas storage bag for each bioreactor. For statistical accuracy all final data values were obtained as average from two identical substrates positioned in the heat camera.

Results and discussion

The results of raw material sample analysis for investigation of cucumber processing waste and tops and leftowers of tomato waste anaerobic digestion are shown in Table 1.

As it can be seen in Table 1, the dry organic matter content in cucumber wastes was low (0.76 g), but the volume of the bioreactors (R) tolerated 20 g. The results of the analysis after finishing the anaerobic digestion process are shown in Table 2. Production of biogas and methane from cucumber and tomatoe wastes and from the control reactors is presented in Table 3.

Specific biogas and methane production volumes calculated for the added biomass in liters are shown in Figure 1and in l g_{DOM}^{-1} in Figure 2. There are shown average data calculated from the results of both bioreactors.

Too low methane content in gas was a surprise. Average low methane % can be explained due to the fact that the raw materials, especially cucumbers had few dry organic matter and total volume of gas contained a big proportion of warm air. For more detailed investigations it is recommended to use more biomass (more dry organic matter content). The specific methane yield was good from cucumbers, but near two times less from tomatoe leftovers.

Mixing cucumbers with tomatoe leftovers decreased the yield of biomethane, adding Metaferm to such mixed biomass increased the methane yield. As it can be seen from Figures 1 and 2, adding of microelements MEL1 to the mixture increased the methane yield from cucumber wastes.

Table 1

Results of analyses of raw material samples before anaerobic digestion

Bioreactor/Raw material	pH, substr	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weight, g
R1, R16 Ie only inoculum	7.52	3.9	19.50	22.70	77.30	15.07	500.00
20 g CU;		4.4	0.88	13.08	86.92	0.76	20.00
R2,R3 500 g Ie + 20 g CU	7.51	3.91	20.38	22.29	77.71	15.83	521.00
20 g CU;		4.4	0.88	13.08	86.92	0.76	20.00
R4,R5 500 g Ie + 20 g CU + 1ml MF	7.54	3.91	20.38	22.29	77.71	15.83	521.00
20 g CU;		4.4	0.88	13.08	86.92	0.76	20.00
R6,R7 500 g Ie +20 g CU+1ml MEL1	7.53	3.91	20.38	22.29	77.71	15.83	521.00
20 g CU;		4.4	0.88	13.08	86.92	0.76	20.00
R8,R9 500 g Ie +20 g CU +1ml MF+ME5	7.54	3.91	20.38	22.29	77.71	15.83	521.00
20 g CU;		4.4	0.88	13.08	86.92	0.76	20.00
20 g tom;		18.08	3.62	44.76	55.24	2.00	20.00
R10,R11 500 g Ie +20 g CU+20 g tom	7.52	4.44	24.00	25.68	74.32	17.84	540.00
20 g tom;		18.08	3.62	44.76	55.24	2.00	20.00
R12,R13 500 g Ie + 20 g tom +1ml MF	7.54	4.44	23.12	26.15	73.85	17.07	521.00
20 g ZS;		24.06	4.81	10.58	89.42	4.30	20.00
R14,R15 500 g Ie + 20 g ZS +1ml MEL1	7.50	4.67	24.31	20.30	79.70	19.38	521.00

Abbreviations: MEL1-melafen 1concentration, MF-metaferm; Ie-inoculum; CU-cucumbers; tom-tops and leftowers of tomatos; ZS-grass silage; ME 5-microelements(Ni, Mo, Co) mix.

Table 2

Results of digestate analysis

Bioreactor/Raw material	pH	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weig ht, g
R1Ie	7.45	3.89	19.31	22.94	77.06	14.88	496.4
R16 Ie	7.47	3.88	19.10	23.15	76.85	14.68	492.2
R2 500 g Ie + 20 g CU	7.36	3.69	18.94	21.73	78.27	14.83	513.4
R3 500 g Ie + 20 g CU	7.41	3.71	18.91	24.85	75.15	14.21	509.6
R4 500 g Ie + 20 g CU + 1 ml MF	7.28	3.88	19.98	23.65	76.35	15.26	515.0
R5 500 g Ie + 20 g CU + 1 ml MF	7.37	3.79	19.47	23.38	76.62	14.92	513.8
R6 500 g Ie + 20 g CU + 1 ml MEL1	7.20	3.80	19.50	20.69	79.31	15.47	513.2
R7 500 g Ie + 20 g CU + 1 ml MEL1	7.58	3.74	19.16	23.58	76.42	14.64	512.2
R8 500 g Ie + 20 g CU + 1 mlMF + ME5	7.12	3.70	19.03	21.92	78.08	14.86	514.4
R9 500 g Ie + 20 g CU + 1 mlMF + ME5	7.12	3.72	19.02	23.54	76.46	14.54	511.2
R10 500 g Ie + 20 gCU + 20 g tom	7.46	4.06	21.56	23.49	76.51	16.50	531.1
R11 500 g Ie + 20 g CU + 20 g tom	7.68	4.08	21.63	24.30	75.70	16.38	530.2
R12 500 g Ie + 20 g tom + 1 ml MF	7.28	4.15	21.24	26.99	73.01	15.51	511.8
R13 500 g Ie + 20 g tom + 1 ml MF	7.37	4.05	20.74	27.45	72.55	15.04	512.0
R14 500 g Ie + 20 g ZS + 1 ml MEL1	7.25	4.37	22.36	20.11	79.89	17.86	511.6
R15 500 g Ie + 20 g ZS + 1 ml MEL1	7.28	4.36	22.12	21.02	78.98	17.47	507.4

Relatively low gas yield was obtained from average of bioreactors containing fermentable grass silage and added MEL1 additive. This could have the following reasons: a) grass silage had a bad chopping degree; b) the process was relatively short (20 days) and grass silage had not enough time to decompose as evident from the high dry matter content of the digestate (see Table 2 R14, R15).

Comparing the results of other researchers with different additive data would not be correct because the additives used in this study are original, created in Latvia and for the first time the following biomass was used.

Table 3

Production of biogas and methane in bioreactors from cucumber and tomatoe wastes

Bioreactor/Raw material	Biogas, l	Biogas, l g_{DOM}^{-1}	Methane aver.%	Methane, l	Methane, l g_{DOM}^{-1}
R2 500 g Ie + 20 g CU	0.8	1.052	26.88	0.215	0.283
R3 500 g Ie + 20 g CU	0.8	1.052	26.63	0.213	0.280
R4 500 g Ie + 20 g CU + 1 ml MF	0.9	1.184	28.56	0.257	0.338
R5 500 g Ie + 20 g CU + 1 ml MF	0.9	1.184	28.89	0.260	0.342
R6 500 g Ie + 20 g CU +1 ml MEL1	0.9	1.184	26.22	0.236	0.311
R7 500 g Ie + 20 g CU +1 ml MEL1	0.8	1.052	34.38	0.275	0.362
R8 500 g Ie + 20 g CU +1 mlMF+ME5	1.0	1.315	25.10	0.251	0.331
R9 500 g Ie + 20 g CU +1 mlMF+ME5	0.8	1.052	29.63	0.237	0.312
R10 500 g Ie +20 g CU +20 g tom	1.2	0.435	34.83	0.418	0.151
R11 500 g Ie + 20 g CU + 20 g tom	1.1	0.398	41.27	0.454	0.164
R12 500 g Ie + 20 g tom + 1 ml MF	1.1	0.550	35.82	0.394	0.197
R13 500 g Ie + 20 g tom + 1 ml MF	1.0	0.500	30.00	0.300	0.150
R14 500 g Ie + 20 g ZS + 1 ml MEL1	1.3	0.302	42.61	0.554	0.129
R15 500 g Ie + 20 g ZS + 1 ml MEL1	1.5	0.349	32.47	0.487	0.113
R16 Ie 500 g	0.1	-	-	0.005	-
R1 Ie 500 g	0.1	-	-	0.005	-

Note: Biogas and methane values for bioreactors 2-15 with fresh source biomass are provided with already subtracted average biogas and methane values obtained from the reactors 1 and 16.

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

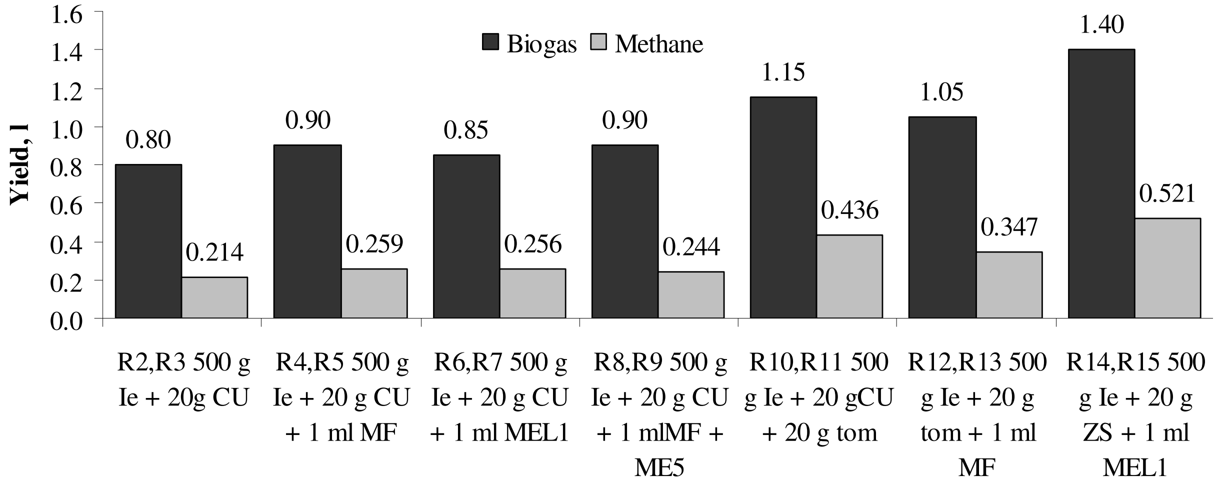

Fig. 1. **Biogas and methane yield in liters, if added MF, ME5 and MEL1**

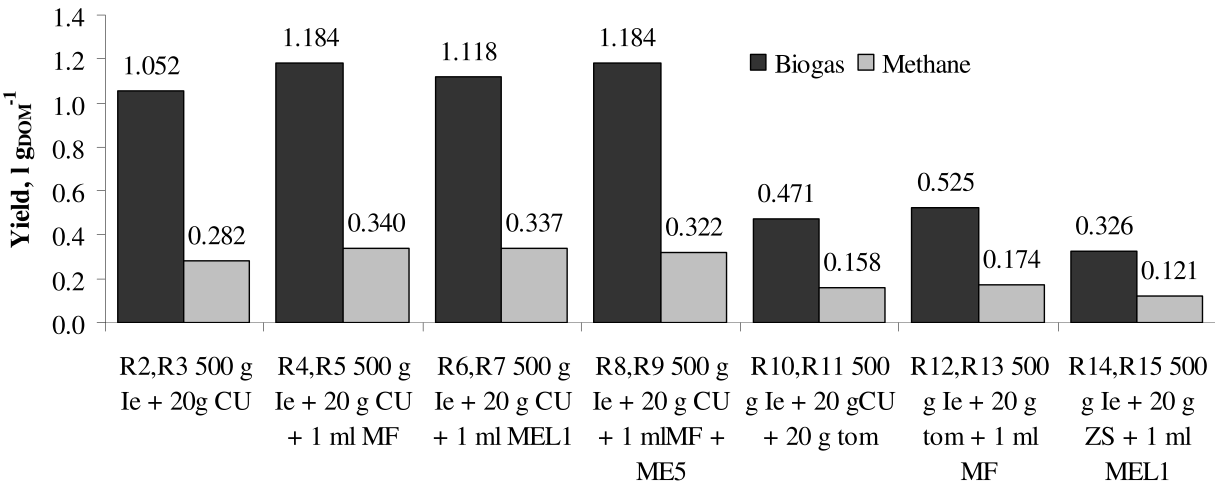

Fig. 2. **Biogas and methane yield in l g_{DOM}^{-1}, if added MF, ME5 and MEL1**

Conclusions

1. Specific quantities of methane from cucumbers l g_{DOM}^{-1} were significantly better than the tomatoes foliage. This could be explained by the fact that tomato topping contains saponin and a lot more fiber. Inside tomatoes digestate was still a lot in incompletely decomposed leftovers.
2. The selected dose of additives increased the gas yield in all cases.
3. An average methane yield increased to 20.57 %, if 1 ml Metaferm was added to cucumber waste.
4. An average methane yield increased to 19.5 %, if 1 ml Metaferm and MEL1 were added to cucumber waste.
5. An average methane yield increased to 14.18 %, if 1ml Metaferm and trace element mixture ME5 were added to cucumber waste.
6. An average methane yield increased to 9.81 %, if 1ml Metaferm was added to tomatoe leftovers.

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