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Suitability of oat bran for methane production

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Abstract. There is need to investigate the suitability of various cheaper biomasses for energy production. It is necessary to explore ways to improve the anaerobic fermentation process with the help of various catalysts. Biocatalyst Metaferm produced in Latvia previous studies with other biomass gave an increase in production. The purpose of study is evaluation of suitability of granular and crushed oat bran waste biomass for the production of methane and influence of catalyst Metaferm on anaerobic digestion (AD) process. The biomass anaerobic digestion process was investigated in 0.75 L digesters, operated in batch mode at temperature 38 ± 1.0 °C. The average biogas yield per unit of dry organic matter added (DOM) from digestion of granular oat bran was 0.400 L g^{-1}_{DOM} and methane yield was 0.193 L g^{-1}_{DOM}. Average biogas yield from digestion of crushed oat bran was 0.439 L L g^{-1}_{DOM} and specific methane yield was 0.193 L L g^{-1}_{DOM}. Adding of 1 mL Metaferm in substrates with not crushed or crushed oat bran increases specific methane yield by 0.227 L g^{-1}_{DOM} or 0.236 L g^{-1}_{DOM} respectively. Investigated oat bran can be used for methane production, but methane production was less than from traditional biomass, e.g. maize silage.

Key words: anaerobic digestion, oat bran, biogas, methane, additive Metaferm.

INTRODUCTION

59 biogas plants are working today in Latvia. Recent government decisions decreased the support for producers of biogas, due to new tax imposed. There is need to investigate the suitability of various cheaper biomasses for energy production (Rivza et al., 2012).

The aim of the study is to find out the potential of biogas production from oat brans as raw material and to investigate the effect of catalyst Metaferm for improving of anaerobic digestion process.

The process of anaerobic digestion of waste resulting in production of biogas and organic fertilizer is one of the most perspective and environmentally friendly way for the waste utilization. Over the last decade considerable efforts have been made in development of biogas production technologies in many countries in the EU (Kaparaju et al., 2002; Gomez, 2007). The most important purpose of biogas plant is utilisation of organic wastes, e.g. manure, household organic waste, wastewater sludge, and the second purpose is to meet the growing energy demands in the situation, when prices on fuel and energy are increasing. In recent years the biogas production is expanding significantly also in Latvia.

Oat bran is produced by rolling and/or milling of oats and its separating by sieving or other suitable means to obtain the oat flour. By-product oat bran fraction is not more than 50% of the original biomaterial. Oat bran fraction has the total betaglucan content in dry matter (DM) at least 5.5% and the total dietary fiber content of at least 16.0%. At least one-third of the total dietary fiber is soluble fiber. Biogas production from oat bran has potential for energy generation, however, each substrate characteristic should be carefully evaluated to enable the optimization of the anaerobic digestion (AD) process. Biochemical methane potential assays were performed to evaluate the energy potential of the substrates (Misi et al., 2001). Oat husk is lignocellulosic biomass and it is a by-product of mills. Research results on usage of oat husk for biogas and methane production is reported (Kusch et al., 2011). Oat husk was used in innovative continuous two phase, two stage prototype biogas plant at Yettereneby Farm in Jarna, Sweden (2003) for production of biogas in solid phase slow process. The biogas production by this method is slow but it is a steady process (Kaparju et al., 2002).

Our few studies showed that the damaged oat products can be successfully utilised in the production of biogas. The average methane yield from crushed oats was 303 L kg_{DOM}^{-1} and the average methane content was 63.1% (Dubrovskis et al., 2012). The raw materials can be also food production by-products, residues and damaged products that are not more usable for food consumption.

MATERIALS AND METHODS

The biogas production potential was measured using laboratory equipment consisting of 16 bioreactors. Fermentation temperature was maintained 38 ± 1 °C inside containers during batch mode process. Mixture consists of 500 g inoculum (fermented cow manure) and added biomass sample (10 g non-crushed oat bran or 10 g crushed oat bran, into 0.75 L bioreactors for anaerobic fermentation. Dry matter, ashes and organic dry matter content was determined for every sample before filling into bioreactor for anaerobic treatment. Measuring accuracies were following: ± 0.2 g for inoculums and substrate weight (scales model Kern FKB 16KO2), ± 0.001 g for biomass samples for dry matter, organic matter and ashes weight analyses, ± 0.02 pH (accessory PP-50), ± 0.05 L for gases volume, and ± 0.1 °C for temperature inside the bioreactors. Biogas composition, e.g. methane, carbon dioxide, oxygen and hydrogen sulphide was investigated with the gas analyser GA 2000. Gases volume measurements were provided 3–7 times, depending on gases volume, during AD process. Dry matter was determined by specialized unit Shimazy at temperature 105 °C, and ashing was performed in oven Nabertherm at temperature 550 °C using the standard heating cycle lasting approx. 0.70 hours in total. Standard error was calculated by standardized data processing tools for each group of digesters. For calculations of results were used widely approved methods (Angelidaki et al., 2009; Kaltschmitt 2010).

RESULTS AND DISCUSSION

Anaerobic fermentation of out bran for biogas and methane production was provided using 14 bioreactors for inoculum (IN) and out bran mixture and 2 bioreactors for control with inoculum only. Biogas and methane data from all bioreactors were used to calculate the average biogas and methane volume for each group of similar bioreactors filled in with the same sample replications.

The results of substrate components and raw substrates analyses for every group with similar samples replications before anaerobic fermentation are summarized below in Table 1.

Table 1. The results of the analyses of raw materials

Reactor	Raw material	pH	TS, %	TS, g	Ash, %	DOM, %	DOM, g	Weight, g
R1, R16	IN 500	7.4	2.88	14.40	23.45	76.55	11.023	500
R2-R4	IN500+ON10	7.2	4.58	22.34	13.58	86.42	20.170	510
R2-R8	ON10	4.2	89.4	8.94	7.34	92.66	8.284	10
R5-R8	IN500+ON10+1MF		4.57	22.34	13.58	86.42	20.170	511
R9-15	OC10		90.17	9.017	5.84	94.16	8.490	10
R9-11	IN500+OC10		4.59	23.417	16.67	83.33	19.513	510
R12-15	IN500+OC10+1MF		4.58	23.417	16.67	83.33	19.513	511

Abbreviations: R1–R16 – bioreactors numbers;TS – total solids; Ash – ashes; DOM – dry organic matter; IN – inoculum; AN – not crushed oat bran; AS – crushed oat bran; 1MF – 1 mL additive Metaferm.

Biogas and methane yield and average methane concentration in biogas from not crushed and crushed oat bran and for substrates with additive Metaferm is shown in Table 2.

Table 2. Biogas and methane released from oat bran in anaerobic fermentation process

Reactor	Raw material	Biogas, L	Biogas, L g^{-1}_{DOM}	Methane aver. %	Methane, L	Methane, L g^{-1}_{DOM}
R1	IN500	0.4		1.25	0.005	
R16	IN500	0.4		0.75	0.003	
Average, R1, R16		0.4			0.004	
R2	IN500+ON10	3.5	0.423	38.11	1.334	0.161
R3	IN500+ON10	3.5	0.423	48.10	1.684	0.203
R4	IN500+ON10	3.9	0.471	45.92	1.791	0.216
Average, R2-R4		3.633	0.439 ± 0.024	44.12	1.603	0.193 ± 0.027
R5	IN500+ON10+1MF	3.9	0.471	50.46	1.968	0.238
R6	IN500+ON10+1MF	3.9	0.471	46.95	1.831	0.221
R7	IN500+ON10+1MF	3.4	0.410	51.53	1.752	0.211
R8	IN500+ON10+1MF	3.7	0.447	53.16	1.967	0.237
Average, R5-R8		3.725	0.449 ± 0.031	50.47	1.880	0.227 ± 0.014
R9	IN500+OC10	3.5	0.412	47.37	1.658	0.195
R10	IN500+OC10	3.2	0.377	49.00	1.568	0.185
R11	IN500+OC10	3.5	0.412	48.00	1.680	0.198
Average, R9-R11		3.4	0.400 ± 0.018	48.08	1.635	0.193 ± 0.007
R12	IN500+OC10+1MF	5.0	0.588	53.20	2.660	0.313
R13	IN500+OC10+1MF	3.8	0.448	49.71	1.889	0.222
R14	IN500+OC10+1MF	3.9	0.459	53.54	2.088	0.246
R15	IN500+OC10+1MF	3.2	0.377	43.34	1.387	0.163
Average, R12-R15		3.975	0.468 ± 0.105	50.47	2.006	0.236 ± 0.075

Abbreviations: L g^{-1}_{DOM} – litres per 1 gram dry organic matter of the original raw material.

Average volume of biogas (0.4 L) or methane (0.04 L) released in control bioreactors R1, R16 is already subtracted from biogas volume from every bioreactor filled with inoculum and out bran biomass (Table 2).

The obtained methane yield is very similar for not crushed or crushed oat bran. Typically, grinding of the raw material prior to AD process greatly increases the methane yield due to the greater surface area available for microorganisms. Lower results in this case may be explained by evidence of thicker surface layer created by smaller particles not submerged in substrate thus having less mixing possibilities.

Compared with other biomass methane yield it is not high, due to emerging thick surface layer, slowing down digestion process.

Specific biogas and methane production from oat bran with and without additive Metaferm is shown in Fig. 1.

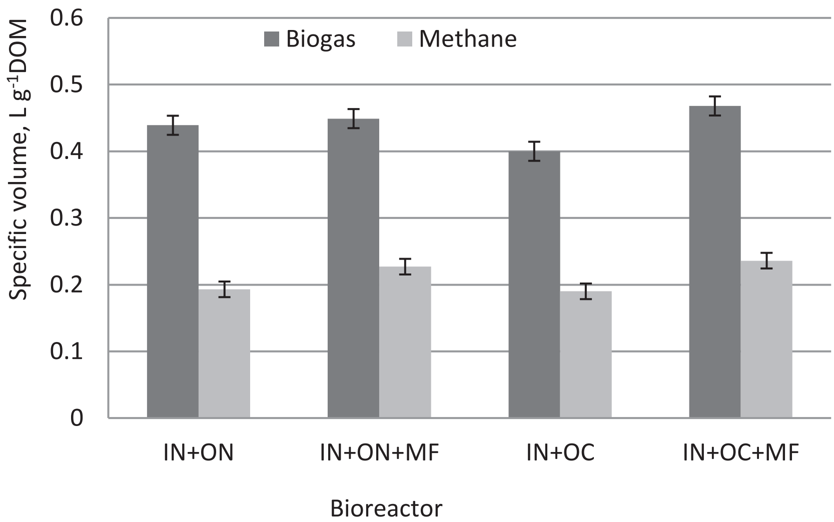

Figure 1. Specific biogas and methane production from oat bran.

Investigated specific methane yield from not crushed and crushed oat bran was approximately equal. Addition of 1 mL Metaferm into not crushed or crushed oat bran mixtures increase specific methane yield significantly by 22.28% or 17.62% respectively. This can be explained by the fact that Metaferm promotes methane formation and have positive effect on bacteria activity.

The relatively low average methane content of gas is explained by the fact that the raw material contains a lot of lignin, cellulose and hemicellulose, which is difficulty to be degraded by bacteria. The relatively low methane yield from added dry organic matter could also be explained by the relatively high initial air volume in bioreactors above the substrate at a start of investigations.

The average methane content (Fig. 2) increases if the oat bran was crushed or additive Metaferm was added in substrates, therefore, chopping of oat bran is recommended before usage for biogas production.

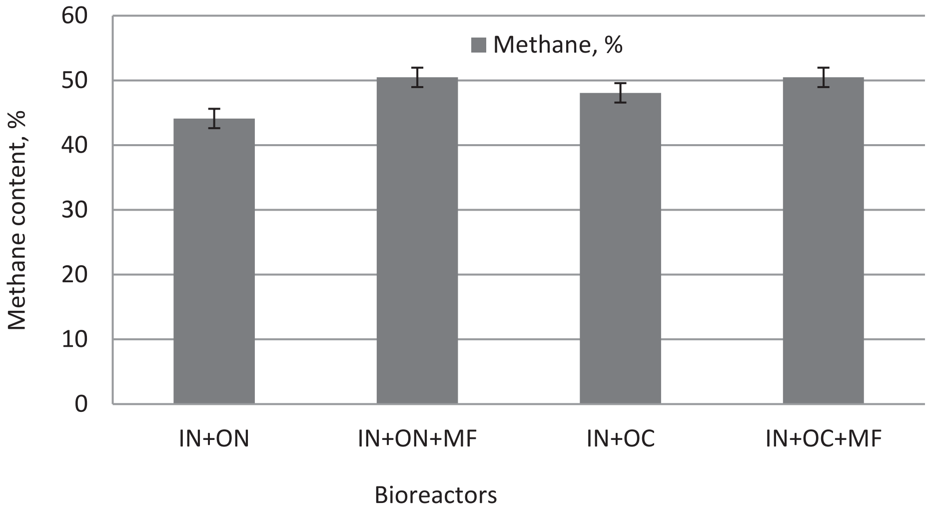

Figure 2. Methane content in biogas from oat bran without and with additive Metaferm.

Usage of additive Metaferm increases both methane production and methane content in biogas, thus it can be recommended for improvement of methane yield and quality of biogas obtainable from the oat bran biomass.

CONCLUSIONS

The average methane production from not crushed and crushed oat bran was the same (0.193 L g^{-1}_{DOM}), however the average methane content in biogas from crushed oat bran was 48% that was by 4% higher compared to methane in biogas from not crushed oat bran.

The average methane yield from not crushed oat bran with added 1 mL Metaferm was 0.238 L g^{-1}_{DOM}, or by 22.28% higher compared to oat bran without additive Metaferm.

The average methane yield from crushed oat bran with additive 1 mL Metaferm was 0.236 L g^{-1}_{DOM}, or by 17.62% higher compared to oat bran without additive Metaferm. It is proposed that additive MF3 may contain the some components facilitating the activity of bacteria.

The average methane content in biogas from not crushed oat bran or from crushed oat bran with added Metaferm is by 6.4% or by 2.4 higher compared to methane content from same substrates without additive Metaferm respectively.

The research results shows that both not crushed or crushed oat bran are acceptable as the raw material for the production of methane.

It is recommended, that oat bran is wetted and stirred before its usage in a biogas plant to reduce the upper biomass layer. Also regular stirring and mixing of upper layer is recommended during anaerobic fermentation process.

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