METHANE PRODUCTION FROM BRIQUETTES OF BIRCH SAWDUST

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Abstract. Renewable energy sources have the potential to reduce emissions of GHG when compared to the combustion of fossil fuels and thereby to mitigate climate change. Bioenergy systems can contribute to climate change mitigation if they replace traditional fossil fuel use (IPCC, 2012). Latvia is also striving to achieve neutral emissions by 2030. Therefore, the use of renewable energy is supported. Wood waste maybe an important resource for biogas production. The biodegradability is however limited because of the recalcitrant nature of the biofibers (lignocellulosic biomass) it contains. More and more biogas plants used the pellets or briquettes from various residues as a raw material. Their advantage is not only cheaper transport over longer distances, but also they absorb moisture well and do not form a floating layer. Hydraulic retention time working with such raw materials as birch sawdust and briquettes is relatively long and requires large volumes of bioreactors. Variety of additives can be used to improve the anaerobic digestion process. This article shows the results, where the enzymes alpha amylase, xylanase and biocatalyst Metaferm are used for the digestion process of birch briquette improvement. Birch briquettes were digested in 0.75 l bioreactors at temperature 38 ºC in a batch mode process. Two biorectors were for control purposes and contained inoculums only. Other 14 biorectors contained biomass substrates without or with added enzymes or biocatalyst. Average specific biogas or methane yield from anaerobic fermentation of birch briquettes was 0.427 $L \cdot g^{-1}_{DOM}$ or 0.178 $L \cdot g^{-1}_{DOM}$ respectively. Addition of enzymes and biocatalyst (1ml) in bioreactors with birch briquettes increases the average methane yield.

Keywords: anaerobic digestion, methane, enzymes, sawdust, birch briquettes.

Introduction

Climate change is one of the great challenges of the 21st century. The most severe impacts may still be avoidable if substantial efforts are made to transform current energy systems. Renewable energy sources have the potential to reduce emissions of GHG when compared to the combustion of fossil fuels and thereby to mitigate climate change. Bioenergy systems can contribute to climate change mitigation if they replace traditional fossil fuel use (IPCC, 2012). Latvia is also striving to achieve neutral emissions by 2030. Therefore, the use of renewable energy is supported.

Renewable biomass (wood waste, straw, grain waste, etc.) controlled burning (in burners or furnaces) produces a small amount of GHG compared to fossil fuels. However, biomass burning causes emissions of solid particulates and poisonous gases (dioxides, nitrous oxides, and others). Emission of particles increases for biomass having high content of ashes [1]. In Latvia, forest products are widely used for heat production by direct incineration. As it causes air pollution, especially in cities, other technologies are being considered. One of them is anaerobic digestion of biomass or biogas (methane) production.

The results of our previous study [2] (Dubrovskis et al. 2009) on sawdust from different trees showed relatively low methane yields. That is why we use various enzymes for improving of the methane yield.

There have been studies on the improvement of biogas production from lignocellulolytic materials, one of the largest and renewable sources of energy on the earth, after pre-treatment with cellulases and cellulase-producing microorganisms [3]. Enzymes that break down biomass are already present in anaerobic digesters as they are produced by the microorganisms of anaerobic digestion. To enhance this breakdown, a mixture of enzymes can be added, and may include cellulose, hemicellulose, pectin and starch degrading enzymes.

The addition of enzymes into substrates for anaerobic digestion has been evaluated in many different studies [4-6]. There is some evidence to suggest that enzymes added directly to the biogas reactors have no significant effect [7] and are degraded quickly after addition. Several batch anaerobic digestion studies have indicated that the addition of enzymes to the first stage of a two-stage anaerobic digestion process leads to slightly higher substrate solubilisation (leading to higher biogas yield), such as with addition of cellulase on grass [8], or with cellulosic enzyme cocktail on wheat straw [9]. Enzyme Alpha amylase is a protein enzyme EC 3.2.1.1 that hydrolyses polysaccharides, such as starch and glycogen, yielding glucose and maltose. It is the major form of amylase found in humans and other mammals. It is also present in seeds containing starch as a food reserve and is secreted by many fungi. Enzyme Xylanase (EC 3.2.1.8) is of a class of enzymes that degrade the linear polysaccharide xylan into xylose, thus breaking down hemicellulose, one of the major components of plant cell walls.

An experimental study [10] was conducted that promoted the efficiency of anaerobic digestion by hydrolyzing pig manure in advance with amylase before loading it into the digester. The results showed that the removal percentage of TS and VS, the biogas production potentials and rates have been improved through the amylase pre-treatment. Especially through a- amylase and γ-amylase pretreatment together, the removal percentage of TS and VS, as compared with the control group, was increased by 10.84% and 11.11% respectively, the biogas production potential increased by 13.10%, and the specific biogas production rate increased by 9.30% [10].

There is little information about birch used for methane production. Mirahmadi [11] has performed alkaline pretreatment using 7% wet weight NaOH on milled spruce (softwood) and birch (hardwood) samples at different temperatures between -15 and 100 °C. Anaerobic batch digestion assay was then performed at thermophilic conditions (55°C) for 30 days. Treatment of birch at 100 °C led to a methane yield of 0.469 $m^3 \cdot kg$ VS, compared to 0.25 $m^3 \cdot kg$ VS for the untreated birch samples. On the other hand, the best results for spruce were obtained when the samples were treated with NaOH at 5°C resulting in 74% improvement in the methane production. Furthermore, it was concluded that the use of alkaline treatment was more successful for hardwood than for softwood. There was, however, almost no destruction of lignin observed [11].

Biogas yields from birch sawdust and birch briquettes have not been studied so far in Latvia. The aim of this study is the evaluation of the biogas and methane production potential from birch briquettes and improvement, if added enzymes alpha amylase, xylanase and biocatalyst Metaferm.

Materials and methods

The widely applied methods were used for the AD process investigation [12-15] in 16 experimental bioreactors with the volume of 0.75 litres. Two bioreactors for control were filled with 500.0 ± 0.2 g inoculums and the rest bioreactors were filled with mixtures of inoculums (500 g), added biomass (20 ± 0.005 g) and enzyme, according to the experimental plan, see Table 1.

Bioreactors R2- R5 were filled with inoculum 500g and 20g birch briquettes, bioreactors R6-R9 were filled with 500g inoculum, 20 g birch briquettes and 1 ml enzyme alpha amylase. Bioreactors R10-12 were filled with 500g inoculum, 20g birch briquettes and 1ml enzyme xylanase, bioreactors R13-15 were filled with 500g inoculum, 20g birch briquettes and 1 ml biocatalyst Metaferm.

Dry organic matter (DOM) content was determined by weighting of the initial biomass samples, dried in the thermostat at 105 °C and placed for ashing in the oven (“Nabertherm” type) at 550 °C. All components were carefully mixed together and filled in bioreactors. All bioreactors were placed into a heated thermostat at the same time before starting of anaerobic digestion. Gas released from each bioreactor was collected in a storage bag positioned outside of the container. Gas volumes were measured using a flow meter (Ritter drum-type gas meter). The composition of gases, including oxygen, carbon dioxide, methane, and hydrogen sulphide was measured by help of a gas analyser (model GA 2000). The substrate pH value was measured before and after finishing off the AD process, using a pH meter (model PP-50) with accessories. The scales (Kern, model KFB 16KO2) was used for weighting of the total weight of substrates before and after the AD process.

Fermented cattle manure (from 120 l bioreactor working in continuous mode with very low organic loading rate) was used as the inoculum. The batch mode AD process was ongoing at the temperature 38 ± 0.5 °C. Biogas released was collected in gas bags for further measurements of the gas volume and elemental composition. Biogas and methane volumes and gases composition were measured during the AD process at regular time intervals. The AD process was provided until biogas emission ceases. The obtained experimental data were processed using appropriate statistical methods.

Results and discussion

Results of investigation of sample substrates, including inoculums, and birch briquettes with and without enzymes, before starting the AD process are shown in Table 1.

Table 1

Results of analyses of raw material samples before anaerobic digestion

Bio-reactors	Raw material	pH	TS, %	TS, g	ASH, %	DOM, %	DOM, g	Weight, g
R1; R16	IN 500g	7.63	4.01	20.05	29.36	70.64	14.163	500
R2-R15	20gBB		93.15	18.63	0.47	99.53	18.542	20
R2-R5	20gBB + 500gIN	7.63	7.44	38.68	15.45	84.55	32.705	520
R6- R9	20gBB + 500gIN + 1ml AA	7.62	7.43	38.70	15.44	84.56	32.724	521
R10-R12	20gBB + 500gIN + 1ml XA	7.61	7.43	38.71	15.44	84.56	32.724	521
R13-R15	20gBB + 500gIN + 1ml MF	7.65	7.43	38.72	15.48	84.52	32.725	521

Note: IN – inoculum;; BB – birch briquettes; AA – alpha amylase; XA – xylanase; MF – biocatalyst Metaferm; ASH – ashes; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R16 – bioreactors

Birch briquettes have a high dry matter and organic dry matter content. They rapidly absorbs moisture from the bioreactor, dissolve, but do not swim. The bacteria from inoculum can easily access the organic matter. Biogas and methane yields from bioreactors R2-R15 with added biomass are shown in Table 2 and Fig. 1 with already subtracted average values of biogas and methane obtained from the control reactors R1 and R16 filled with pure inoculum.

The production of biogas and methane from birch briquettes with and without enzyme mixtures and from the control reactors is presented in Table 2.

Table 2

Production of biogas and methane

Bioreactor/Raw material	Biogas, L	Biogas, $L \cdot g^{-1}_{DOM}$	Methane, aver.%	Methane, L	Methane, $L \cdot g^{-1}_{DOM}$
R1 500IN	0.2	0.014	7.8	0.016	0.001
R16 500IN	0.2	0.014	0.5	0.001	0.0
Average R1, R16	**0.2**	**0.014**	**4.5**	**0.009**	**0.001**
R2 500 g IN + 20g BB	8.9	0.480	42.83	3.812	0.206
R3 500 g IN + 20g BB	7.6	0.410	45.96	3.493	0.188
R4 500 g IN + 20g BB	7.3	0.394	41.66	3.041	0.164
R5 500 g IN + 20g BB	7.9	0.425	36.42	2.877	0.155
Average R2- R5 500 g IN + 20g BB ± st. dev.	**7.925 ±0.7**	**0.427 ±0.037**	**41.72 ±3.97**	**3.306 ±0.426**	**0.178 ±0.023**
R6 500 g IN + 10g BB + 1ml AA	8.8	0.475	50.12	4.411	0.238
R7 500 g IN + 10g BB + 1ml AA	10.3	0.556	49.45	5.093	0.274
R8 500 g IN + 10g BB + 1ml AA	10.2	0.550	50.27	5.128	0.277
R9 500 g IN + 10g BB + 1ml AA	11.2	0.604	47.39	5.308	0.286
Average:R6-R9 500 g IN + 20g BB + 1 ml AA ± st. dev.	**10.125 ±1**	**0.546 ±0.053**	**49.23 ±1.33**	**4.985 ±0.394**	**0.268 ±0.021**

Table 2 (continued)

R10500 g IN + 20 g BB + 1ml XA	9.5	0.512	46.68	4.416	0.238
R11 500 g IN + 20 g BB + 1ml XA	10.2	0.550	48.19	4.915	0.265
R12 500 g IN + 20 g BB + 1ml XA	10.3	0.556	48.04	4.948	0.267
Average R10-R12 500g IN + 20 g BB + 1ml XA ± st. dev.	**10.0 ±0.4**	**0.539 ±0.024**	**47.60 ±0.83**	**4.760 ±0.298**	**0.257 ±0.0162**
R13 500 g IN + 20 g BB + 1ml MF	9.7	0.523	44.30	4.297	0.232
R14 500 g IN + 20 g BB + 1ml MF	10.0	0.539	43.98	4.398	0.237
R15 500 g IN + 20 g BB + 1ml MF	9.1	0.491	46.72	4.251	0.229
Average R12-R15 500 IN + 20 g BB + 1ml MF ± st. dev.	**9.6 ±0.5**	**0.518 ±0.024**	**44.95 ±1.50**	**4.315 ±0.075**	**0.233 ±0.004**

Note: L·g_{DOM} – litres per 1 g dry organic matter added (added fresh biomass into inoculums)

The results show that birch briquettes are a usable raw material for methane production. Addition of enzymes alpha amylase and xylanase increased the methane yields significantly.

There was much less methane from birch briquettes with added Metaferm. Also, the addition of the enzyme alpha-amylase increased the yield of methane by 50.6%. The specific biogas and methane yields from every bioreactor filled with birch briquettes with and without enzymes are shown in Fig. 1.

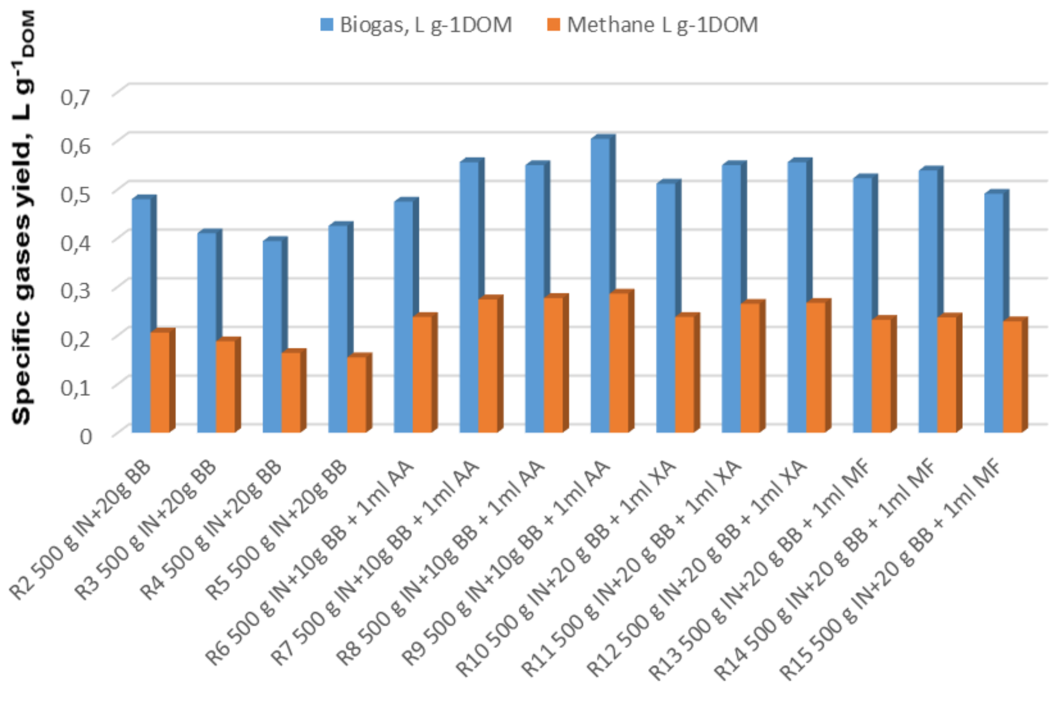

Fig. 1. **Specific biogas and methane yields**

Average methane contents in biogas from birch briquettes with and without enzymes are shown in Fig. 2.

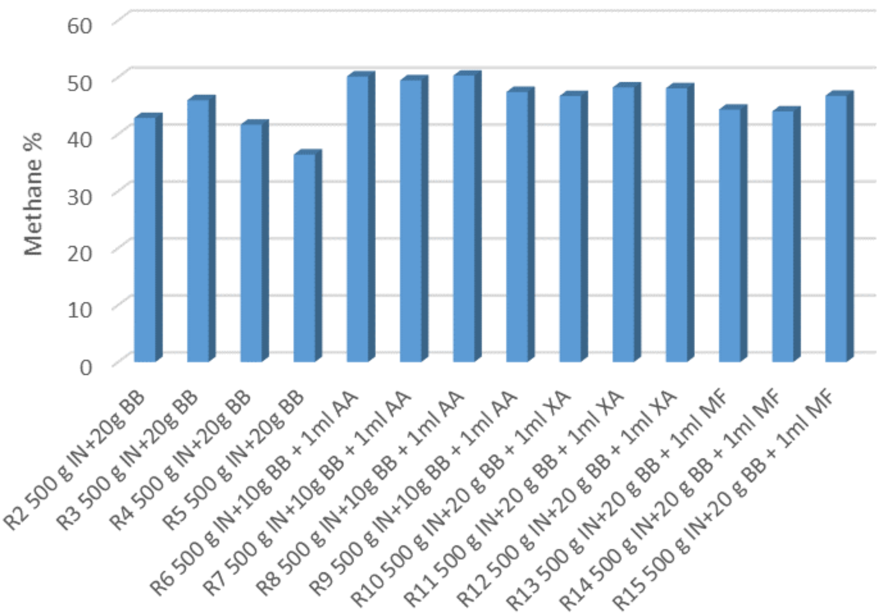

Fig. 2. **Average methane contents in biogas from birch briquettes with and without enzymes**

The methane content, if compared with traditionally used as raw material biomass for anaerobic digestion, is low. This is explained by the fact the biodegradability of sawdust is going on slowly. Adding enzymes improves biodegradability and the methane content.

Conclusions

1. The yield of methane from birch briquettes is 0.178 L·g_{DOM}, which is an average result. It is quite similar to that obtained from sawdust.
2. Addition of enzyme alpha amylase to birch briquettes resulted in a 50.56% increase in the methane yield. This proves the usefulness of this enzyme.
3. Addition of enzyme xylanase to birch briquettes resulted in a 44.38% increase in the methane yield. This proves the usefulness of this enzyme.
4. Addition of biocatalyst Metaferm to birch briquettes resulted in a 30.9% increase in the methane yield. This proves the usefulness of this biocatalyst.
5. Also birch briquettes, especially if enzyme alpha amylase is added, can be used as raw material for methane production. For decision which additive is better economical calculations are needed.

Author contributions

Conceptualization, V.D.; methodology, and V.D.; software, D.D.; validation, D.D. and V.D; formal analysis, V.D and D.D..; investigation, V.D.; data curation, V.D. an D.D.; writing – original draft preparation, V.D.; writing – review and editing, D.D. and V.D.; visualization., V.D.; project administration, D.D.; funding acquisition, D.D. All authors have read and agreed to the published version of the manuscript.

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