BIOGAS PRODUCTION FROM FRESH AND OLD SAWDUST LITTER WITH CHICKEN MANURE

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Abstract. 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. Biofuels and biogas are playing a key role in the decarbonisation of the transport sector and will contribute in the future to a fuel switch in combination with electrification, for example in hybrid cars. In sectors which are difficult to decarbonize, such as heavy-duty vehicles, ships and airplanes, biofuels often represent the only technically and economically viable solution. The European Biogas Association estimates that by 2030 overall annual potential for biogas will be at least 50 billion m^3. In Latvia, there is a lot of timber processing and there is a lot of sawdust. They are also used as bedding in poultry farms. Bird droppings could improve their utility for biogas production. This article shows the results about anaerobic digestion of fresh and old sawdust and sawdust litter with chicken manure and slaughterhouse waste. Fresh and old sawdust and sawdust litter with chicken manure and slaughterhouse waste were digested in 6 l digesters at temperature 38 ºC in batch mode process. Average specific biogas or methane yield from anaerobic fermentation of fresh sawdust was 0.407 $L \cdot g^{-1}_{DOM}$ or 0.175 $L \cdot g^{-1}_{DOM}$ respectively. Average specific biogas or methane yield from anaerobic fermentation of old sawdust was 0.369 $L \cdot g^{-1}_{DOM}$ or 0.153 $L \cdot g^{-1}_{DOM}$ respectively. Average specific biogas or methane yield from anaerobic fermentation of sawdust litter with chicken manure and slaughterhouse waste was 0.554 $L \cdot g^{-1}_{DOM}$ or 0.335 $L \cdot g^{-1}_{DOM}$ respectively.

Keywords: anaerobic digestion, biogas, methane, sawdust, chicken manure.

Introduction

Biofuels and biogas are playing a key role in decarbonisation of the transport sector and will contribute in the future to a fuel switch in combination with electrification, for example in hybrid cars. In sectors which are difficult to decarbonize, such as heavy-duty vehicles, ships and airplanes, biofuels often represent the only technically and economically viable solution. Bioenergy represents 63.3% of the EU’s renewable energy consumption but its role often goes unnoticed. To date, forest biomass is the main source for bioenergy production [1].

Biogas production has been growing steadily in recent years and has made its contribution to renewable energy generation and reducing negative impacts on the environment, both in the form of GHG emissions and the pollution of soil and water courses [2]. The European Biogas Association estimates that by 2030 overall annual potential for biogas will be at least 50 billion m^3. Thus, by 2030 with the right policies in place, the industry could deliver 2-4% of the EU’s electricity needs and provide a 15-30% share of today’s methane (natural gas) market. The concurrent contribution to the heat demand as a by-product of the electricity provisions by means of combined heat and power units has not been recognized adequately yet.

A key strategy allied with today is to develop an alternative energy source instead of fossil fuels in order to compensate present energy need in addition to reduce environmental concerns owed by pollution and global warming. Energy generation in feasible manner without possessing environmental crash is a difficult task where alternative concepts were requisite to ensure sustainable development with accessible technologies. Further advances triggered renewed attention in biogas production technology while it has great impacts on diminishing major economic issues raised in the world.

Sawdust is composed of fine particles of wood. The most common way to convert this biomass fuel derived from wood to electricity is to combust them. They can also be gasified to produce combustible gasses, used for the anaerobic digestion process, or converted to liquid fuels. A significant environmental benefit of using sawdust and wood shavings for electricity generation is that their energy value is utilized while landfill disposal is avoided, also as long as clean – burning combustion technologies are employed, carbon emissions to the atmosphere can be minimized.

Several pretreatment techniques have been studied intensively prior to both biogas and ethanol production from lignocellulosic substrates with respect to facilitating the biological degradation. Each of the treatment methods has its advantages and drawbacks [3].

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These pretreatment methods can be divided into mechanical, thermal, chemical as well as biological treatments or a combination of these techniques. Co-digestion is yet another method used to enhance biogas production [4]. This method entails planning loading of the digester so that an advantageous blend of different substrates serves as organic load. This ultimately means, e.g. that substrates with low nitrogen content but high carbon content can be mixed with a substrate that contains a high amount of nitrogen but a low amount of carbon in order to obtain a balanced C/N ratio. In this way, the microbiological processes in the digester balance themselves at very little cost to the plant operator.

Materials and methods

In our research we used methods similar to those described in the works [5-8]. Biogas yield was investigated using two laboratory equipments B4 consisting of 8 digesters operated in batch mode (Figure1). Each digester was of 6 l volume and was equipped with heating devices for automated regulation of temperature 38 ± 1 ºC in digesters. Digesters were equipped with sensors for automated registering of pH and gas volume data in the computer.

Fig. 1. **Laboratory equipment B4**

Chicken manure with sawdust litter (Chm) was filled in the digesters R1 and R2 (Table 1) and chicken manure (with sawdust litter) mixture with slaughterhouse waste (Sw) was used in the digesters R3 and R4. Mixtures of fresh sawdust (Fsd) with water were filled in the digesters R5 and R6, and old sawdust (Osd) mixtures with water were filled in the digester R7. Inoculum mixtures with water were used in the digester R8. Inoculum - fermented cow’s manure 2000g was added to all digesters each, to provide methanegenous microbial inoculum for a successful anaerobic fermentation process. According to the plan of the experiments into each digester was added water (see Table1). Substrates were analysed for organic matter, total solids, organic solids and moisture content before filling in and after extracting of the digesters. The accuracy of the measurement was ± 0.02 for pH value, ± 0.0025 l for the volume of gas and ± 0.1 ºC for the temperature. Anaerobic fermentation in the digesters was provided during 3 months period and interrupted, when biogas producing is stopped. The composition of gases, including oxygen, carbon dioxide, methane, and hydrogen sulphide was measured by help of a gas analyser (model GA 2000). Dry matter (TS) and dry organic matter (DOM) were determined by investigation of initial biomass sample weight and dry weight by using scales Shimazu at 105 ºC and by investigation of ashes content by help of a furnace (Nabertherm model) burning the samples at 550 ºC according to a special heating cycle.

Substrate pH value was measured before and after finishing the anaerobic fermentation process, using pH meter (PP-50 model) with accessories. 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 [9]. Experimental data were recorded in the experimental log and also stored in computer.

The fermentation process was provided in batch mode without mixing (apart the initial mixing) or recirculation of the liquid part of substrates in all digesters.

Results and discussion

Results of the analyses of biomass for all digesters 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- R8	IN	7.65	3.42	68.4	24.85	75.15	51.403	2000
R1-R2	Chm	8.12	45.2	678.0	17.22	82.78	561.25	1500
R3-R4	Sw	7.02	0.5	5.0	23.92	76.08	3.804	1000
R5- R6	Fsw	-	35.4	531.0	11.24	88.76	471.32	1500
R7	Osw	-	39.8	597.0	14.65	85.35	509.54	1500
R1, R2	2000In + 1500Chm + 2000W	7.79	13.57	746.4	17.92	82.08	612.653	5500
R3, R4	2000In + 1500Chm + 1000W + 1000Sw	7.8	13.66	751.4	17.96	82.04	616.457	5500
R5, R6	2000In + 1500Fsd + 2000W	7.34	10.89	599.4	12.79	87.21	522.723	5500
R7	2000In + 1500 Osd + 2000W	7.36	12.09	665.4	15.7	84.3	560.943	5500
R8	2000In + 2000W	7.52	1.71	68.4	24.85	75.15	51.403	4000

Note: In – inoculum; Chm –sawdust with chicken manure; Sw – slaughterhouse waste; Fsd – fresh birch sawdust; Osd – old birch sawdust; W- water; ASH – ashes; TS – total solids; DOM – dry organic matter (on raw substrate basis); R1-R8 – bioreactors

Inoculum substrates in the control bioreactor (R8) and others have low dry matter content as almost finished digestate was used for inoculums. As it can be seen from the raw material (Table 1) sawdust as litter with chicken manure biomass has a relatively high dry matter and organic dry matter content. This is explained due to the fact that the sawdust litter with chicken manure taken from the chicken house after 45 days according to the technology for chicken breeding is relatively dry. This raw material, containing a lot of organic dry matter, is well suited for biogas production [12]. The slaughterhouse waste is with very small dry matter. This is explained due to the fact that we took an average sample and for washing much water was used.

Results of the anaerobic fermentation of biomass for all digesters are shown 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 2000In + 1500Chm + 2000W	326.5	0.533	56.25	183.8	0.300
R2 2000In + 1500Chm + 2000W	338.2	0.552	55.86	188.9	0.308
Average R1, R2 ± st. dev.	**332.35 ± 8.3**	**0.543 ± 0.013**	**56.06 ± 0.28**	**186.35 ± 3.61**	**0.304 ± 0.006**
R3 2000In + 1500Chm + 1000Sw + 1000W	337.2	0.547	60.8	205.0	0.332
R4 2000In + 1500Chm + 1000Sw + 1000W	345.2	0.560	60.4	208.4	0.338
Average R3, R4 ± st. dev.	**341.2 ± 5.7**	**0.554 ± 0.009**	**60.6 ± 0.28**	**206.7 ± 2.40**	**0.335 ± 0004**

Table 2 (continued)

Bioreactor/Raw material	Biogas, L	Biogas, L·g-1DOM	Methane, aver.%	Methane, L	Methane, L·g-1DOM
R5 2000In + 1500Fsd + 2000W	218.5	0.418	42.86	93.65	0.179
R6 2000In + 1500Fsd + 2000W	206.5	0.395	43.25	89.31	0.171
Average R5, R6 ± st. dev.	**212.5 ± 8.5**	**0.407 ± 0.016**	**45.06 ± 0.28**	**91.48 ± 3.07**	**0.175 ± 0.006**
R7 2000In + 1500Osd + 2000W	207.0	0.369	41.43	85.76	0.153
R8 2000In + 2000W	2.1	0.041	11.22	0.236	0.005

Note: Biogas and methane values for bioreactors R2-R8 with fresh source biomass are provided with already subtracted average biogas and methane values obtained from the digester R8

For comparison the results of the same studies by other researchers could not be found. The use of chicken manure and sawdust mixtures for biogas production has been studied in Malaysia. They found: the methane content from chicken manure with sawdust reaches its peak on the 30th day of the digestion which is 54.33% [10]. Our average methane content was 56.06 ± 0.28%. However, such a comparison would not be quite correct, as the sawdust and other conditions were different.

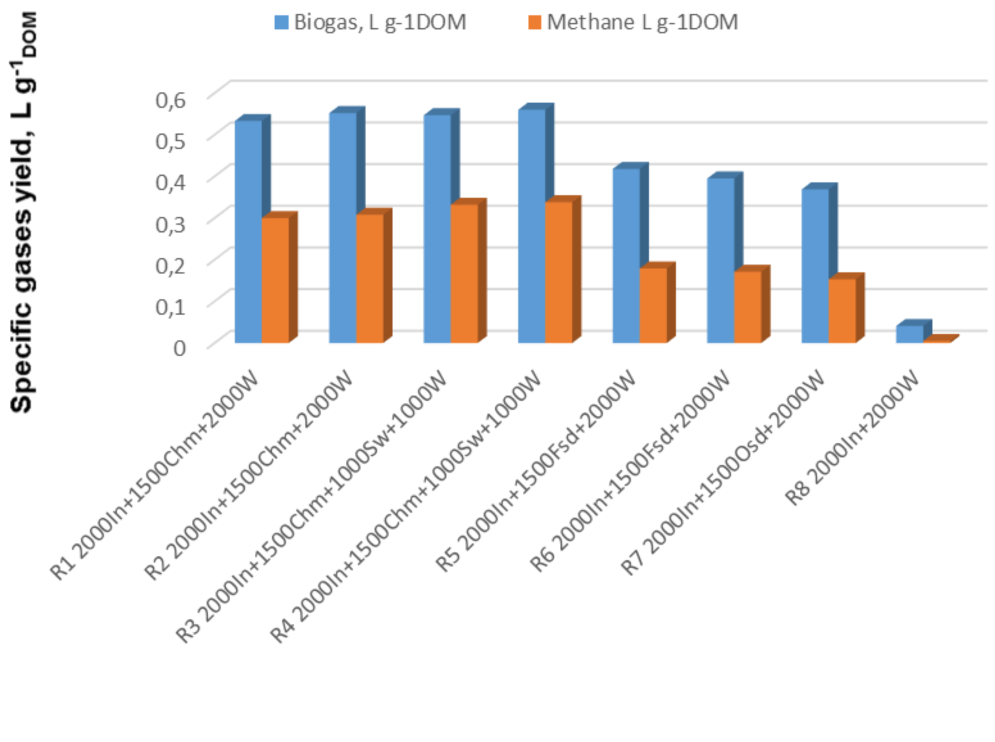

Fig. 2. **Specific biogas and methane yields**

Average methane contents in biogas from sawdust and sawdust litter with chicken manure are shown in Figure 3. The highest methane content is from the digesters with sawdust litter with chicken manure and slaughterhouse waste (60.6%). It can be explained by the fact that chicken manure and slaughterhouse waste contain much good biodegradable matters as fats, proteins for methane forming bacteria.

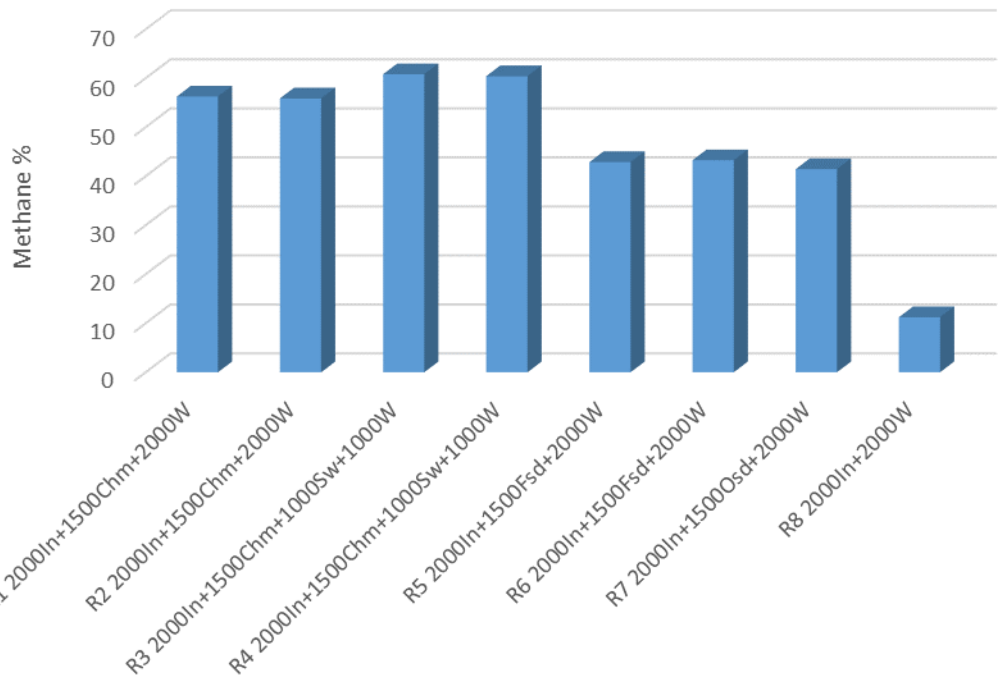

Fig. 3. **Average methane contents in biogas from sawdust and sawdust with chicken manure**

Conclusions

1. The yield of methane from fresh birch sawdust is 0.175 $L \cdot g^{-1}_{DOM}$. This is less than average methane yields from cow manure 0.21 $L \cdot g^{-1}_{DOM}$; from pig manure 0.3 $L \cdot g^{-1}_{DOM}$ and maize silage 0.31 $L \cdot g^{-1}_{DOM}$..
2. The yield of methane from old birch sawdust is 0.153 $L \cdot g^{-1}_{DOM}$. This is low, because some part of organic matter was destroyed.
3. The yield of methane from sawdust litter with chicken manure is 0.304 $L \cdot g^{-1}_{DOM}$. This is 1.7 times better than from fresh sawdust alone.
4. The yield of methane from sawdust litter with chicken manure and slaughterhouse waste is 0.335 $L \cdot g^{-1}_{DOM}$. This is 10.2% better than without.
5. The results show that sawdust litter with chicken manure and slaughterhouse waste are good biomass for methane production in the anaerobic digestion process. This is the preferable technology.

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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