BIOGAS PRODUCTION FROM DRY BIOMASS

Vladimirs Kotelenecs
Institute of Agricultural Energetics, Latvia University of Agriculture,
wazavova@inbox.lv; 29798516

Vilis Dubrovskis
Institute of Agricultural Energetics, Latvia University of Agriculture,
vilisd@inbox.lv

Abstract. Anaerobic treatment of relatively dry biomass (W=30-55 %) has an advantage, compared to the traditionally used wet biomass, due to lowered expenses of the transportation of raw or finished materials. By the help of laboratory scale 5l digesters biogas production was investigated from different biomass in anaerobic fermentation in the batch process. Inoculum from cow manure finished fermentation process was added in each digester to facilitate the anaerobic fermentation process. The lowest average yield of biogas 185 l kg_{vsd}^{-1} was obtained from fresh sawdust. The methane yield (percentage of methane) obtained from different biomass was the following: fresh sawdust 83 l kg_{vsd}^{-1} (45 %); old sawdust 91 l kg_{vsd}^{-1} (46 %); broiler manure with sawdust litter 98 l kg_{vsd}^{-1} (49 %); broiler manure with slaughterhouse waste 185 l kg_{vsd}^{-1} (52 %); and grain mill wastes 132 l kg_{vsd}^{-1} (5 0 %).

Key words: biogas, anaerobic fermentation, broiler manure, grain mill waste, methane.

Introduction

Agricultural production technologies require heat and power energy for heating of homes, drying of harvest, heating of greenhouses, powering of electric equipment, etc. Heat energy obtained in the burning process of fossil fuels and biomass cause the greenhouse gas (GHG) emissions. Unused biomass residues can produce gases that contain up to 50 % methane (CH_4) during its natural degradation or 5-10 % CH_4 during its open burning. In a global scale, biomass was burned within an area of 8 million ha yearly, and carbon dioxide (CO_2) or methane emissions are estimated to account for 40 % and 10 % of global emissions respectively [1]. Another investigation shows that in tropical deciduous forest fires CH_4 emission ratios were 1.29 % and 1.59 % of all emissions at two sites investigated [2]. Controlled combustion in a power plant converts virtually all of the carbon in the biomass to CO_2. As CH_4 is a stronger greenhouse gas than CO_2, shifting CH_4 emissions to CO_2 by converting biomass residues to energy significantly reduces the greenhouse warming potential of the recycled carbon. Renewable biomass (wood wastes, straw, grain wastes, 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 [3]. The most environmentally friendly technology is biogas (mixture of CH_4 and CO_2) production from biomass in the anaerobic fermentation process, as it is usable for a relatively "clean" heat and power energy production, as the biogas contains no ashes. Methane produces more heat (891kJ mol^{-1}) per mass unit (16.0 g mol^{-1}) than other complex hydrocarbons. In this context, methane is usually known as a natural gas, and has an energy content of 39MJ m^{-3}. The anaerobic digestion process has an environmental advantage compared to burning of wastes, for example, digestion of poultry manure is preferred, due to the increased risk of emissions of nitric oxides and other harmful substances if burned. Previous investigations revealed possibilities of methane production from sawdust or peat in the anaerobic digestion process [4]. Further investigations should be aimed at biogas production from relatively dry biomass (W=30-55 %) in order to minimize the expenses for both raw material and anaerobic treatment residue transportation. Purpose of this study is to investigate the parameters of biogas released during the anaerobic fermentation of relatively dry forest and agricultural wastes.

Materials and methods

Biogas yield was investigated using laboratory equipment B4 consisting of 8 digesters operated in batch mode. Each digester was of 5l volume and was equipped with heating devices for automated regulation of temperature 38±1 ˚C in digesters. Digesters were equipped with sensors for automated registering of pH and gas volume data in the computer.

Fig.1.

Laboratory digesters for investigation of biogas from biomass

Chicken manure with sawdust litter was filled in the digester D1 (Table 1) and chicken manure (with sawdust litter) mixture with slaughterhouse waste was used in the digester D2. Mixtures of fresh sawdust with water were filled in digesters D3 and D4, and old sawdust mixtures with water were filled in digesters D5 and D6. Grain mill waste mixtures with water were used in digesters D7 and D8. Fermented cow's manure was added to all digesters in the ratio of 24 % to 35 %, to provide methanegenous microbial inoculums for a successful anaerobic fermentation process (Table).

Substrates were analyzed for organic matter, total solids, organic solids and moisture content before filling in and after extracting out of the digesters. The accuracy of the measurement was ±0.02 for pH value, ±0.0025l for the volume of gas and ±0.1 ˚C for the temperature. Anaerobic fermentation in the digesters was provided during 3-6 months period and interrupted, when biogas producing is stopped.

Results and discussion

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 of the anaerobic fermentation of biomass for all digesters are shown in Table 1.

The average parameters of different wastes fermentation are shown in Fig. 2 and Fig. 3. The lowest average yields of biogas 185 l kg_{vsd}^{-1} and methane 83 l kg_{vsd}^{-1} were obtained from fresh sawdust (D3, D4), that can be explained by inhibiting effect of lignin and other harmful substances from sawdust in the anaerobic fermentation process (Fig. 2). A small increase of biogas output was registered for old sawdust (7 %) and for chicken manure (by 9 %), compared to fresh sawdust, due to the inhibiting influence of sawdust. Methane yields from old sawdust, chicken manure, chicken manure with slaughterhouse waste or grain mill waste were higher by 10 %, 19 %, 124 % or 60 % compared to methane yield from fresh sawdust respectively (Fig. 3).

The highest yields of biogas 354.2 l kg_{vsd}^{-1} and methane 184.5 l kg_{vsd}^{-1} were registered in relation to chicken manure with slaughterhouse waste mixture (D2), that can be explained by supplemental easy degradable slaughterhouse waste and a lower amount of sawdust, incorporated in chicken manure as litter (see Fig. 2).

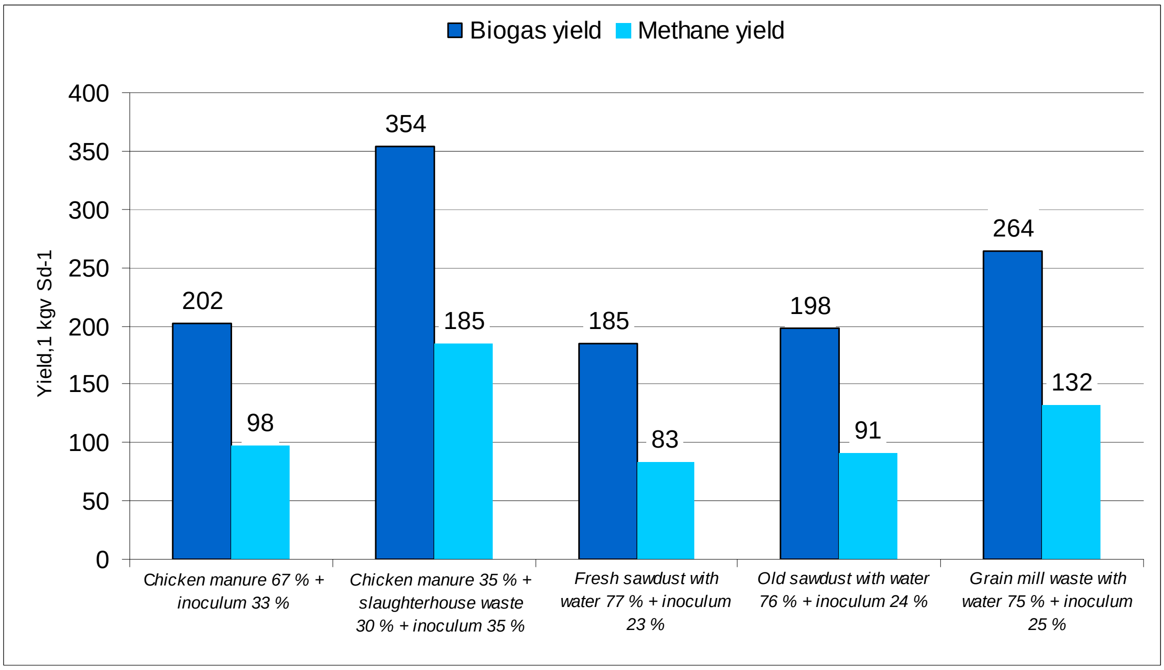
Table 1

Parameter	Unit	D1	D2	D3	D4	D5	D6	D7	D8
Substrate composition	%	67 chm 33 in	30 sw 35 chm 35 in	77 fsw 23 in	77 fsw 23 in	76 osw 24 in	76 osw 24 in	75 gmw 25 in	75 gmw 25in
Total substrate weight	kg	2.230	2.900	3.495	3.573	3.286	3.406	2.842	2.850
Total solids	%	52.4	43.7	37.2	37.8	38.8	38.9	56.4	56.5
Organic solids	%	45.1	33.7	33.1	33.6	32.5	33.1	51.7	51.7
Biogas yield	1 kg_{vsd}^{-1}	202.0	354.2	180.3	188.7	190.2	206.3	261.2	267.3
Aver. methane content	%	49	52	44	45	46	45	50	50
Methane yield	1 kg_{vsd}^{-1}	98.2	184.5	79.7	85.3	87.7	94.5	129.55	133.9
Conversion rate	%	42.1	46.2	37.1	38.2	41.2	44.1	43.3	43.4

Parameters of substrates and biogas in the anaerobic fermentation process

Abbreviations: in – inoculums; sw – slaughterhouse waste; chm – chickens manure with litter; fsw – fresh sawdust with water; osw – old sawdust with water; gmw – grain mill waste with water; VSd – volatile solids destroyed.

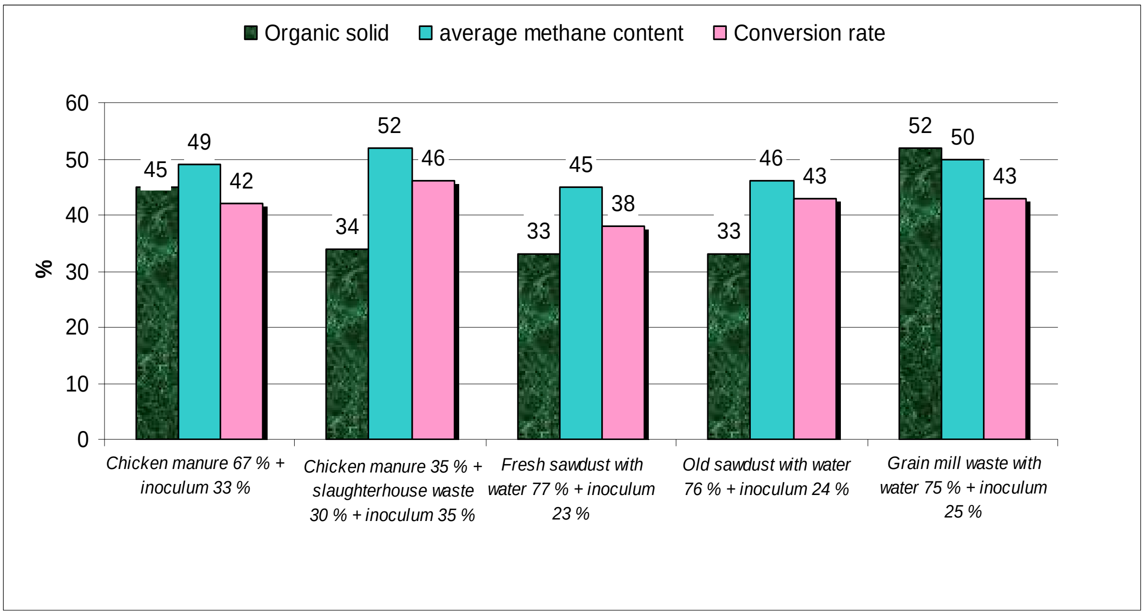
Fig.2.



Average biogas and methane yields obtained from different agricultural wastes

Average biogas and methane yields obtained from different agricultural wastes High average yields of biogas 264 l kg_{vsd}^{-1} and methane 132 l kg_{vsd}^{-1} were obtained from grain mill waste despite the highest organic load (51.7 %) of substrates filled in these two digesters (D7 and D8). Such evidence confirms that grain mill waste is more suitable for biogas production compared to sawdust. The concentration of methane was within the range of 44.2-52.1 % in biogas from all of the investigated wastes (Fig. 3), that is satisfactory in relation to biogas usage for production of heat and power after preliminary treatment aimed to increase methane in the final gaseous fuel. The anaerobic fermentation of relatively dry (W = 33-52 %) biomass is a feasible method for biogas extraction from slowly degradable biomass, such as sawdust or grain mill waste. An additional recirculation of leached liquids can improve the anaerobic fermentation process of relatively dry biomass.

Fig.3.



Content of methane, organic solids and conversion rate from investigated waste

Conclusions

1. Anaerobic fermentation of relatively dry (W = 33-52 %) biomass is a feasible, but too slow method for biogas extraction from slowly degradable biomass, for example, from sawdust or grain mill wastes.
2. The lowest average yields of biogas 185 l kg_{vsd}^{-1} and methane 83 l kg_{vsd}^{-1} were obtained from fresh sawdust.
3. The highest yields of biogas 354.2 l kg_{vsd}^{-1} and methane 184.5 l kg_{vsd}^{-1} were registered from the mixture of chicken manure (with sawdust litter) with slaughterhouse waste.
4. Methane yields from old sawdust, chicken manure, chicken manure with slaughterhouse waste or grain mill waste were higher by 10 %, 19 %, 124 % or 60 % compared to methane yield from fresh sawdust respectively.
5. The investigated methane content in biogas was in the range of 44-52 % from all wastes, that is satisfactory for biogas usage for the production of heat and power.

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