BIOGAS PRODUCTION FROM REED CANARY GRASS AND SILAGE OF MIXED OATS AND BARLEY

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Abstract. There is a need to find acceptable crops for energy production for the climatic and soil conditions of Latvia. Average annual dry matter yields from fodder red canary grass, oats and barley mixed or maize vary 7-11.2 t ha^{-1}, 5-8 t ha^{-1} or 12-16 t ha^{-1} under the climatic conditions of Latvia. Reed canary grass (*Phalaris arundinacea* L), oats-barley silage and maize silage were investigated for biogas production in anaerobic digestion process in 6 digesters of volume 5l operated in batch mode at the temperature of 38°C. Average biogas yields from reed canary grass, oats-barley silage or maize silage was 263 l kg_{VSd}^{-1}, 527 l kg_{VSd}^{-1} or 553 l kg_{VSd}^{-1} respectively. Average methane content was 48 %, 56 % or 53 % in biogas from reed canary grass, oats-barley silage or maize silage respectively.

Key words: Anaerobic digestion, reed canary grass, oats-barley silage, maize silage.

Introduction

Biogas production from energy crops is one of the most energy-efficient and environmentally friendly ways of production of biogas in Latvia. Production of methane rich biogas through anaerobic digestion of organic materials can provide cleaner energy due to lower emissions into environment of biogas burning, compared to direct burning or incineration or biomass. Various plants can be raised as the source for biogas production in Latvia [1, 2].

For successful biogas production it is very important to find the best energy crop for local climatic and soil conditions of Latvia. A promising one is silage of mixed oats and barley due to good competiveness of mixed cereals with weeds, low expenses (compared to maize) for seeds and acceptable dry matter yield 5-8 t ha^{-1}. There are many wet soils in Latvia suitable for growing of reed canary grass (*Phalaris arundinacea* L). This plant can provide yield up to 7-11.2 t ha^{-1} dry matter during a 10-12 years period without reseeding. Reed canary grass can be harvested in the first cut in the middle of June and in the second cut, that can be performed after 40 days or within the subsequent period including early spring in the next year. Maize is a relatively new plant introduced for forage production and has the total area around 5000 ha in the year 2007 in Latvia. Maize has green biomass yield depending on the variety, 30-40 t ha^{-1} [1] or dry matter yield in the range of 12-16 t ha^{-1} under the climatic conditions of Latvia. Barley and oats mixed can be harvested in the end of July or in August, and maize can be harvested during September or in the first part of October. Biomass can be used both for biogas production immediately after harvesting or can be ensilaged for biogas production in periods, when biomass harvesting is not favourable.

The need for round year biogas production can be achieved by growing these three crops simultaneously, as well as the right choice of time for harvesting, as the reed canary grass, oats and barley mixture or maize have different harvesting periods. It is feasible to erect biogas production facilities alongside with livestock farm for codigestion of field biomass together with animal manure. Animal manure can also serve as the cheap inoculum source for successful anaerobic treatment process. Biogas digester can not only produce heat, cold and power, but also serve as the conditioning point of waste produced by various agricultural and food industry sources (Fig. 1). Operation of digester in rural area ensures an environmentally sound way for the cycling of plant nutrients in nature. Carbon dioxide obtained in biogas treatment in the cogeneration/trigeneration process or from composting of digesters residues can be used in greenhouses as a valuable plant nutrient. Special methods are offered for the dehumidification, desulphurisation and processing of biogas to natural gas quality and carbon dioxide in this case reaches even food quality [3].

The aim of the study is investigation and evaluation of parameters of biogas released from the above mentioned energetic crops in the anaerobic digestion process.

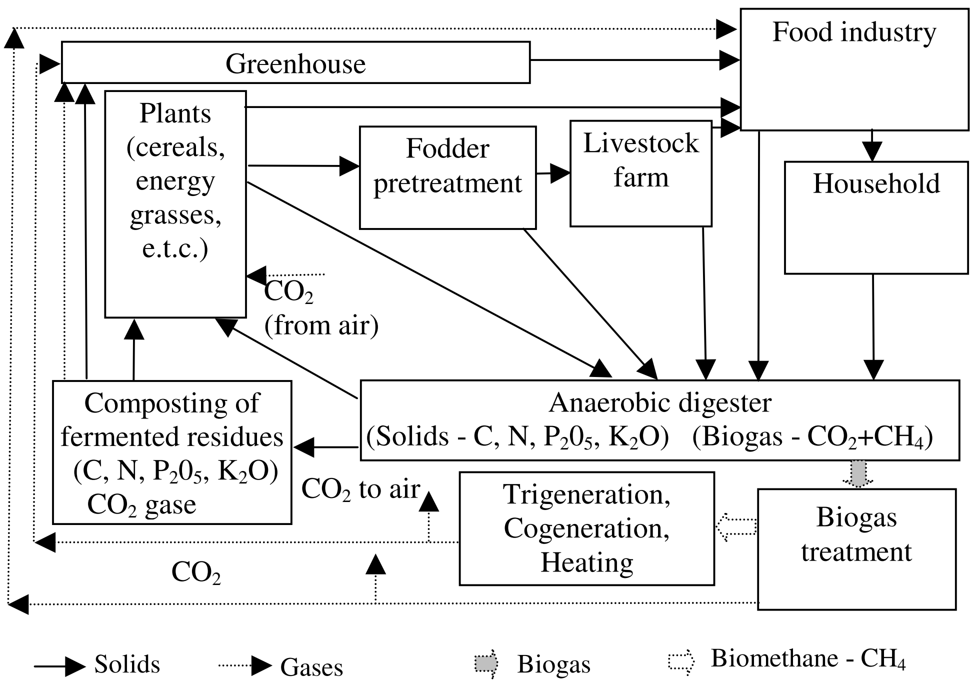

Fig. 1. **Scheme of raw materials supply to anaerobic digester and plant nutrients cycling in rural area**

Materials and methods

Barley and oats mixed was harvested in July, and maize was harvested in September as green biomass. Usual agricultural technologies were applied for making of oats-barley silage and maize silage. Red canary grass was harvested in the middle of June and used in experiments as fresh green biomass. Each representative sample of oats-barley silage or reed canary grass was composed by sampling from different parts of the whole harvested biomass. The plant biomass was chopped and mixed with water before filling in digesters. The biogas yield was investigated using original laboratory equipment B4 consisting of 6 digesters operated in batchwise mode. Each digester was of volume of 5l and equipped with heating devices for automated regulation of temperature of 38±1.0 ˚C inside the digesters. Digesters were equipped with pH, temperature and gas volume sensors and a system for automated registering of data in computer. Red canary grass mixtures with water and inoculum (fermented cow manure) were used for anaerobic fermentation in digesters D1 – D2. The substrates used for anaerobic fermentation in digesters D3 – D4 were oats-barley silage with inoculum at different proportions (Table 1.). Biomass was chopped and mixed with water before.

Maize silage was mixed with inoculum (fermented cow manure) and filled in digesters D5 and D6. Substrates were analysed for organic matter, volatile solids and moisture content before filling in and after extracting out of digesters. Ambient temperature, temperatures inside of the digesters, pH values of substrates and biogas volumes were registered in computer continuously and also fixed manually in a notebook every day. Digestion process was continued for an excessively long time to ensure that all extractable biogas is harvested. Accuracy of measurement was ±0.2 g for substrate weight, ±0.02 for pH value, ±0.0025l for gas volume and ±0.1˚C for temperature measurements.

The accuracy of moisture balance MOC-120H for moisture and dry matter measurements was ±0.001 g, and the accuracy of industrial equipment GA2000 for measurements of methane content in biogas was ±0.01 %. Volatile solids were measured keeping of samples in a laboratory furnace (type L3/11/B170) at the constant temperature of 550±5 ˚C during the period of 0.5 hours.

Results and discussion

Parameters on substrates composition at the beginning and results of anaerobic fermentation process within all digesters are shown in Table. Organic solids in substrates varie from 6 % to 8.3 %, that corresponds to the traditional wet anaerobic fermentation process.

Table 1

Parameters of substrates and results of anaerobic fermentation in all digesters

Parameter	Unit	D1	D2	D3	D 4	D5	D6
Substrate composition	%	25 in, 75 rcg+w	25 in, 75 rcg+w	20in 80 obs+w	20 in 80 obs+w	10 in 90 ms+w	10 in 90 ms+w
Total substrate weight	kg	3.985	3.992	4.230	4.225	4.120	4.142
Total solids	%	9.8	10.0	7.3	7.3	7.1	7.2
Organic solids	%	8.3	8.3	6.1	6.1	6.0	6.1
Biogas yield	$l\ kg_{VSd}^{-1}$	260.2	266.1	520.4	534.3	542.3	564.3
Average methane content	%	47	48	55	56	54	53
Methane yield	$l\ kg_{VSd}^{-1}$	123.3	128.3	288.3	299.2	293.4	296.8
Conversion rate	%	49.3	49.6	65.2	65.6	66.3	66.4

Abreviations: in – inoculum (fermented cow's manure); rcg – reed canary grass; obs – oats-barley silage; ms – maize silage; w – water; VSd – volatile solids destroyed.

Average biogas and methane volumes released from each plant in the anaerobic digestion process are showed in Fig. 2.

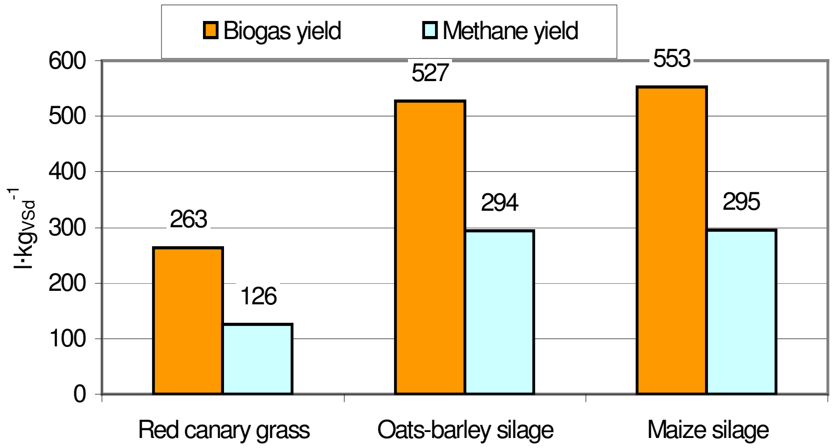

Fig. 2. **Average biogas and methane yields obtained from different agricultural biomass**

Lowest average yields of biogas 185 $l\ kg_{VSd}^{-1}$ and methane 83 $l\ kg_{VSd}^{-1}$ were obtained from reed canary grass (D1-D2), that can be explained by specific features of the cell membranes of reed canary grass containing more lignine and cellulose and less easely degradable carbohydrates compared to whole-crop cereals or maize. Methane output from the reed canary grass was only 43 % of methane yield obtained from oats-barley or maize silage. The average content of methane was within the range 48-56 % in biogas from all investigated biomass (Fig. 3), therefore biogas is usable both for heat production and power generation after treatment, aimed to increase the methane content in biogas. Conversion rate shows, that almost half of reed canary grass and around two thirds of oats-barley silage or maize silage organic matter was destroed in the anaerobic digestion process. Residue after the anaerobic digestion process (digestate) retains almost all plant nutrients (nitrogen, phosphorus, potassium, e.t.c) apart from the carbon, oxygen and hydrogen, escaped in biogas.

Thereof, residues should be incorporated in field for soil enriching and lowering of the needs for commercial fertilisers input. Average prices, used for calculation of plant nutrients value in commercial fertilisers within EU in 2007, were EUR 0.43, 0.54 and 0.36 EUR for 1kg of nitrogen (N), phosphoric pentoxide (P2O5) and potassic dioxide (K_20) respectively. Usage of digestate for soil fertilisation not only saves financial resources for farmers, but also reduces the energy necessary for excavation (production), transportation and distribution of commercial fertilisers. Maximal distance for transportation of digestate depending on organic fertilizer moisture is limited to 5-20 km.

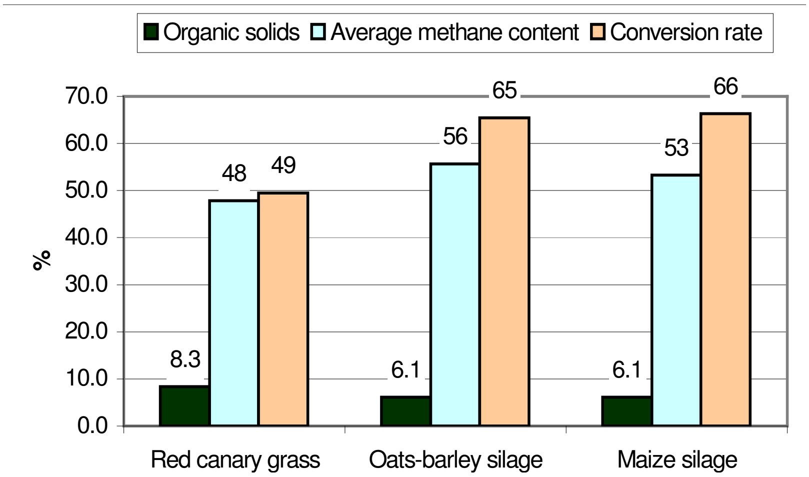

Fig. 3. **Content of methane in biogas, percentage and conversion rate of organic solids**

Lowering of actual costs for raw materials is an important measure for the improvement of economical viability of biogas production. Le Gall and Pflimlin (1997) noted that, taking account of ensiling losses, harvesting costs and the low energy value of silage from whole-crop cereals in France, the price of a kilogram of silage dry matter was equivalent to the price of a kilogram of cereal grain, which had 40 percent higher energy value [4]. It is obviously that lowered quality standards and cheaper ensilage technologies compared to prescribed for fodder silage should be elaborated especially for biogas production. Hay production technologies can be introduced instead of biomass ensilage for oats and barley as well as for energy grasses to minimise the costs of raw materials. For example, oats and barley mixed can be harvested in July or August and dried to the moisture of 18-20 % using natural or artificial heat energy, e.g. heat energy from power generation engine cooling system can be used. Further investigations should be provided to find out simplified ensilage technologies and evaluate the usability of hay for the production of biogas.

Conclusions

1. The average annual yields from fodder red canary grass, oats and barley mixed or maize vary 7-11.2 t ha^{-1}, 5-8 t ha^{-1} or 12-16 t ha^{-1} dry mass under the climatic conditions of Latvia.
2. The average biogas yields from reed canary grass, oats-barley silage or maize silage was 263 l kg_{VSd}^{-1}, 527 l kg_{VSd}^{-1} or 553 l kg_{VSd}^{-1} respectively, if inoculum of fermented cow's manure was used.
3. The average methane content was 48 %, 56 % or 53 % in biogas from reed canary grass, oats-barley silage or maize silage respectively.
4. The conversion rate of red canary grass was lower compared to oats-barley silage or maize silage, as reed canary grass has got a higher content of lignin and cellulose.

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