GALEGA BIOMASS FOR BIOGAS PRODUCTION

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Abstract. There is need to find an acceptable energy crops for energy production for climatic and soil conditions in Latvian. The 35 mixed swards of fodder galega (*Galega orientalis Lam.*) were developed on Stagnic Luvisol and Gleyic Podzol soils. Swards were cut two to four times during the growing season. Green biomass yield of pure galega swards varies between 40 - 70 t ha^{-1}, obtained without application of pesticides or chemical fertilizers. Yield of dry matter (DM) for galega varies between 10.27- 14.23 t ha^{-1} DM, obtained by harvesting in early flower stage. Biogas from galega and cow manure (control) was investigated in laboratory scale digesters of volume 5 l. Methane yield in digesters was 384.2 l/kg$_{VSd}$; 309.2 l/kg$_{VSd}$; 244 l/kg$_{VSd}$ obtained from different mixtures of galega and cow manure, and was 218.6 l/kg$_{VSd}$ from cow manure. Estimated cumulative volume of biogas released from galega haylage, having volatile solids content 19.4 % or 11.1 %, was 116 l·kg$^{-1}{}_{VS}$ or 244 l·kg$^{-1}{}_{VS}$ respectively, or was 2 times higher in digester with lower content of volatile solids after 64-day fermentation period.

Key words: energy crops, galega, anaerobic digestion, biogas, methane.

Introduction

Interest increases on obtaining of energy from biomass during last years in Latvia [1, 4]. Government of Latvia approved energy sector priorities in year 2006. The general goals foreseen the following:

- Self-supply of electricity will be 100 % at year 2016, therefore more than 700 MWh of new power will be necessary to put in action.
- Consuming of local energy resources will increase from 65 PJ up to 82 PJ at year 2016.
- Electricity production from alternative energy recourses (AER) will increase up to 49.3 % at year 2010.

Biogas production from energy crops is one of the most energy-efficient and environmental way for producing of biofuel in Latvia. Potential for biogas production is shown in Table 1.

Table 1

Potential resources for biogas production

Resource	Dry biomass, t/year	Biogas, milj.m^3/year	Energy, MWh/year
Cow manure	107300	32.2	193300
Pig manure	44400	20.0	118830
Poultry manure	43160	21.6	129480
Food waste	57500	23.0	138000
Waste water treatment	23000	7.0	42000
Landfills	400000	23.0	138000
Crop remainder, grass	80000 (800000*)	20.0 (200.0*)	120000 (1200000*)
Silage	20000	8.0	64000
Slaughterhouse wastes	3500	2.1	12600

*in case, if the grass will be raised for energy purposes.

Galega (*Galega orientalis Lam.*) is introduced in Latvia due to its persistency and high yielding ability. Longlived legume survives in pure stands for 25 and more years and provides annual DM yields from 9.56 to 11.0 t ha^{-1} [1, 2]. Successful treatment of galega seeds with nodule bacteria results in fixation of atmospheric nitrogen from 200 to 453 kg ha^{-1}, thus can to decrease the need for commercial nitrogen fertilizers. Production of methane rich biogas through anaerobic digestion of organic materials can to provide clean form of energy, due to low emissions into environment from burning of biogas. Biogas can be used for heat and power generation or as a vehicle fuel, thus reducing the need for fossil fuels and slowing down the climate change. The traditional anaerobic digestion technologies are designed for wastes having high water content, e.g. sewage sludge or manure. Energy crops typically have high total solids content and its digestion requires long hydraulic retention time and large volume of digesters. There is no experience for biogas production from energy crops in Latvia. Perennial herbaceous grasses can easily be stored as haylage, thus providing round year biogas production. For successful biogas production it is very important to find the best energy crop for local climatic and soil conditions in Latvia. Galega is one of the most suitable alternatives for these purposes.

Aim of this study was estimation of productivity of fodder galega/grass swards and investigation of biogas output from fodder galega and galega haylage in anaerobic treatment process.

Materials and methods

Cultivation and research of fodder galega was started at Latvia University of Agriculture in 1978. Field experiments were conducted during a 20 years period (1986-2006), aiming to estimate continuous green forage production from fodder galega-grass swards in the stage of intensive growth.

The 35 mixed (13 binary and 22 multi – species) swards were developed on stagnic – luvisol soils. Pure swards, binary- and multi-species seed mixtures were composed of fodder galega cv. 'Gale' and 13 grass species. Stands were sown in early May in 1980, 1986, 1990 and 1997. The total seeding rate was 1000 germinating seeds on 1 m^2. The ratio of fodder galega:grass seeds was 50:50 in 13 binary mixtures (1986). In all experiment series (1990 and 1997) the mixture contained 40 % fodder galega and 60 % grass seeds: 7 binary mixtures 40:60, 14 three – component mixtures 40:30:30, 5 four – component mixture 40:20:20:20, 1 five – component mixtures 40:15:15:15:15 and 2 six - component mixtures 40:12:12:12:12:12.

The botanical composition of the sward was determined at each cut for all treatments. The chemical composition of plants was determined only for the first cut by following methods: dry matter (DM) – drying; crude protein (CP) – modified Kjeldahl; crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF) and nett energy of lactation (NEL) – Van Soest (1980); *in vitro* digestibility of the organic matter (IVOMD) – De Boever et al. (1994).

Fig. 1. **Part of laboratory equipment B4 for biogas yield investigation**

The biogas yield was investigated on laboratory scale equipment. Original laboratory equipment B4 (Fig. 1) consists 6 digesters working in batchwise mode. Each digester is of volume of 5 l and equipped with heating devices for automated regulation of temperature inside of the digesters at 37±1.0 °C or 54±1.0 °C. Digesters are equipped with sensors for automated registering of pH and gas volume data in computer. The substrates used for anaerobic fermentation in digesters F1 – F4 were galega mixtures with cow manure at different proportions (Table 1).

Galega was chopped and mixed with water previously. The substrates used for anaerobic fermentation in digesters F5 and F6 were galega haylage mixtures with inoculum (fermented cow manure). Additional water was added in digester F6 to increase moisture (Table 1). Substrates were analysed using approved methods for organic matter, volatile solids and moisture content before filling in digesters. Accuracy of measuring instruments for pH value was ±0.02, for gas volume was ±0.0025 l and for mass measurements was ±0.001 g. Results were fixed in computer and also by hand in notebook daily.

Results and discussion

Over 25 production years of pure galega without reseeding the following average yields of DM and CP were obtained at early flowering: 8.97 t ha^{-1} DM and 1.94 t ha^{-1} CP on stagnic luvisol in a two-cutting management. Fodder galega significantly surpasses other forage legumes in respect to productive longevity, and fluctuations in DM yield were insignificant between years of use. Inclusion of a grass species in a mixture resulted in yield increase by 28 to 36 % already in the first production year.

Table 2

Substrate and biogas parameters

Parameter	Unit	Digester 1	Digester 2	Digester 3	Digester 4	Digester 5	Digester 6
Substrate composition	%	100 cm	25 cm 75 g+w	50 cm 50 g+w	75 cm 25 g+w	55 in 45 gh	32 in 68 gh+w
Total substrate weight	kg	4.120	3.294	3.593	3.624	1.142	2.144
Total solids	%	14.70	5.83	9.41	12.60	20.90	11.90
Organic solids	%	12.8	3.4	7.2	10.5	19.4	11.1
Biogas yield	l/kg_{VSd}	411.0	627.8	535.0	436.0	-	-
Average methane content	%	53.2	61.2	57.8	56.1	40.1	49.0
Methane yield	l/kg_{VSd}	218.6	384.2	309.2	244.2	-	-
Conversion rate	%	62.5	68.3	64.6	63.8	-	-

Note: cm – cow manure, gh – galega haylage, in – inoculum (fermented cow manure), g+w – galega plus water, gh+w – galega haylage plus water, VSd – volatile solids degraded.

Split application of the 90 kg N fertiliser affected negatively the proportion of galega in a sward, resulting in the decrease of DM yields by 1.04 t ha^{-1} at two cutting management, compared to unfertilized plots. Frequently cutting (four times) had a declining effect on the productivity of galega-grass mixtures. The total yield of DM decreases by 3.34 t ha^{-1} or by 35.2 % in all experimental plots at a four-cutting management. Average yields from pure galega stands were 9.50 t ha^{-1} DM or 6.16 t ha^{-1} DM at two-cutting or four-cutting management in 9 production years respectively.

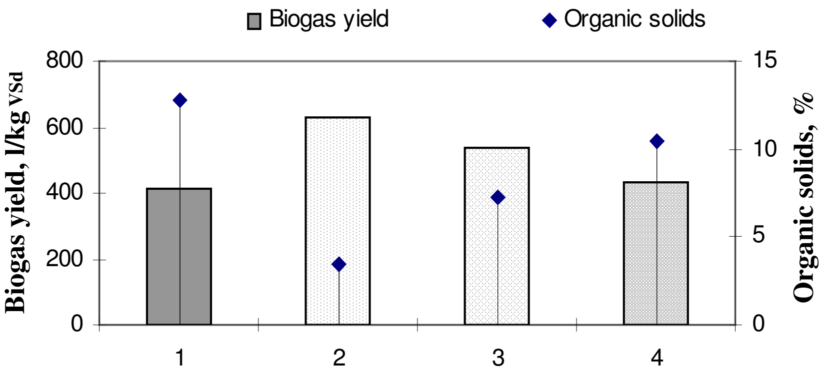

Fig. 2. **Methane yield from mixtures of cow manure with galega mash; 1- manure 100%, 2 manure 25% + galega 75%; 3 - manure 50% + galega 50%; manure 75% + galega 25%**

It is obviously, that methane yield is higher for substrate having low concentration of organic solids.

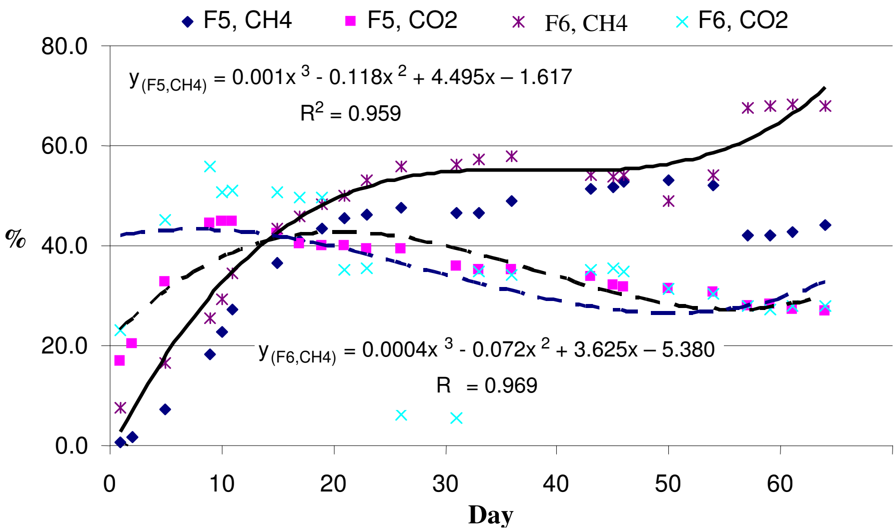

Fig. 3. **Percentage of carbon dioxide and methane in gases released in digesters F5, F6, filled with galega haylage**

Average methane content in biogas was 41 % or 49 %, released from digester F5 or F6 respectively, during 64-day anaerobic fermentation period. Carbon dioxide concentration in biogas released from galega haylage lowers from 45-55 % at the beginning of fermentation period to 23-25 % at the end of anaerobic treatment process.

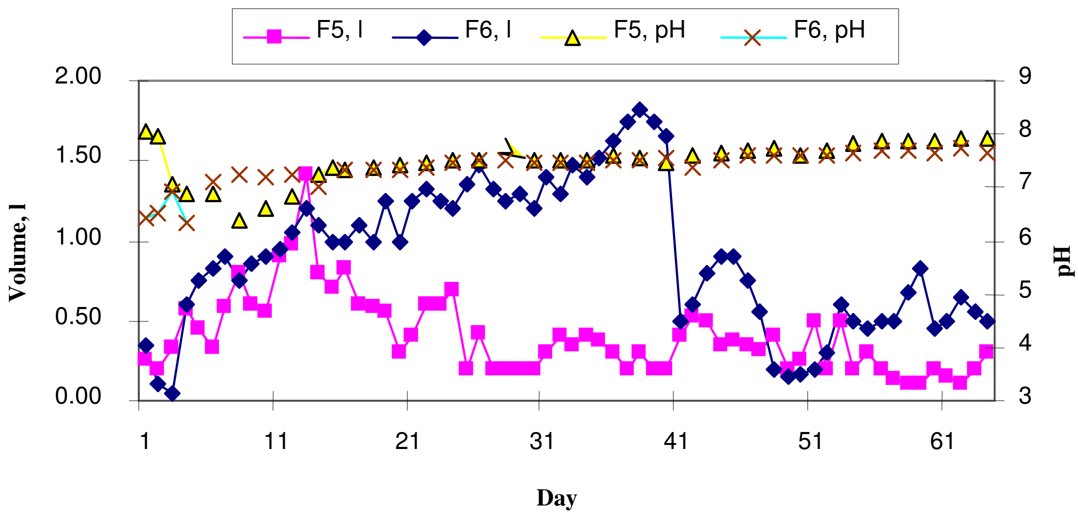

Fig. 4. **Volume of daily gas emissions and pH values in digesters F5, F6, filled in with galega haylage**

Maximum daily volume of biogas from galega haylage was 1.42 $l \cdot day^{-1}$ at 13th day, or was 1.82 $l \cdot day^{-1}$ at 38th day in digesters F5 or F6 respectively. Minimal ph value was 6.35 at 4th day or 6.38 at 8th day in digesters F5 or F6 respectively.

Anaerobic fermentation of galega haylage is ongoing more intensively in substrate with less total solids content (Fig. 5). Estimated specific volume of biogas was 116 $l \cdot kg^{-1}$ VS for digester F5 and 244 $l \cdot kg^{-1}$ VS for digester F6, or by 52 % higher in digester F6 after 64-day fermentation period. Cumulative volume of gases released from galega haylage during fermentation period approximates well help by 2nd order equation.

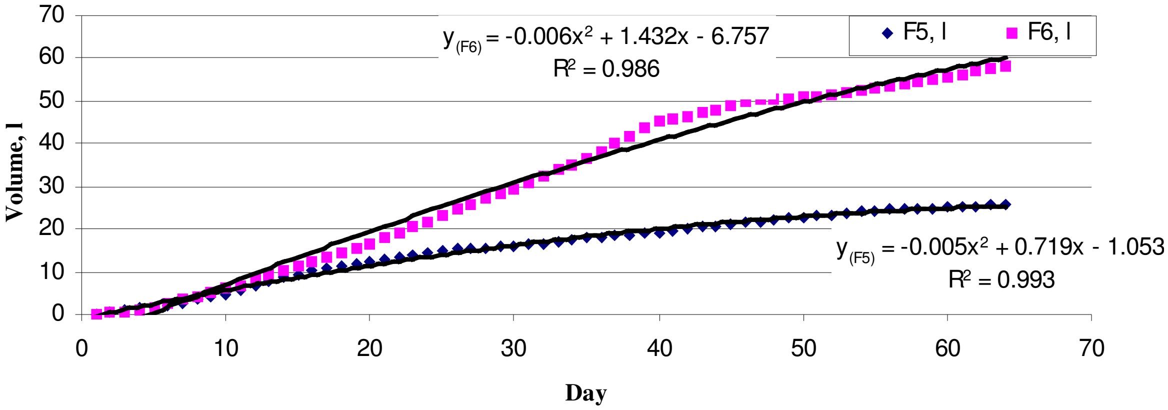

Fig. 5. **Cumulative volume of gases produced from digesters F5 and F6 filled with galega haylage**

Conclusions

1. Yield of dry matter (DM) for galega varies between 10.27-14.23 t ha^{-1} DM, harvested in early flower stage.
2. Fodder galega in pure stands or in mixtures with grasses is productive and persists for long periods, and three species mixtures proved to be most productive.
3. Galega can to produce high (up to 384.2 l/kg_{VSd}) biogas yield obtained despite to organic overloading in two digesters and working without mixing of substrate.
4. Biogas can be successfully obtained from chopped galega haylage with inoculum of fermented cow manure.
5. Estimated cumulative volume of biogas released from galega haylage, having volatile solids content 19.4 % or 11.1 %, was 116 $l \cdot kg^{-1}_{VS}$ or 244 $l \cdot kg^{-1}_{VS}$ respectively, or was 2 times higher in digester with lower content of volatile solids after 64-day fermentation period.
6. Cumulative volume of gases, released from galega haylage in fermentation period, approximates help by 2nd order equations.

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