BIOMASS OF TALL FESCUE AS RAW MATERIAL FOR BIOGAS PRODUCTION

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Abstract

Understanding the variation in the biochemical composition of different raw materials is of utmost importance for developing effective biomass energy chains. The composition of biomass depends on grass species, plant maturity, timing and frequency of cut, as well as cultivation inputs. Field and laboratory experiments carried out at the Lithuanian Institute of Agriculture were designed to identify changes in biochemical composition of tall fescue as influenced by the timing of the first cut and different nitrogen input for biomass cultivation. The results of the first experimental year showed differences in tall fescue biomass yield and biochemical composition with different nitrogen input and different time of first cut. Biomass yield was higher with nitrogen input at both first cut times, but biomass composition was more suited when the first cut was taken at heading stage. Tall fescue biomass, with or without nitrogen fertilization, when first cut at heading stage was found to contain less lignin and more water-soluble carbohydrates comparing with first in flowering stage. Carbon and nitrogen ratios were within the near optimal range for anaerobic digestion.

Introduction

The growing greenhouse gas emission and lack of mineral energy sources obligate us to look for alternative ways to produce energy for fuel, heating, electricity. Biogas production is becoming the most popular source for bioenergy in small farms, food factories and waste water treatment. The anaerobic digestion of energy crops and agricultural residues can contribute considerably to national energy balances (Plöchl, Heiermann, 2006; Holm-Nielsen, Olieskewicz-Popiel, Al Seadi, 2007).

The biogas production (anaerobic digestion) is the process of the decomposition of organic matter by a microbial consortium in an oxygen-free environment (Gerin et al., 2008). This process is influenced by many parameters which are related to the process conditions, substrates and the concentrations of nitrogen, carbon, lignin, cellulose, hemi cellulose, sugars, proteins in them (Janušauskas, 2003; Raclavská, Juchelková, Roubíček, 2007). Because of its methane yield per hectare, the ease of mechanization, integration into the farm organization and input for agro ecology perennial grasses are highly competitive energy crops which could be used for biogas production as substrate or co substrate with cow, rabbit, swine, and poultry waste (Lehtomäki et al., 2008; Uzodinma, Ofoefule, 2009). Assessment of the potential biomass supply in Europe showed, that the largest biomass potentials lie in energy crops, which have long lead times (Ericsson, Nilsson, 2006). Methane yields of grassland biomass vary in a wide range, mainly depending on the intensity of grassland use. An intensive management with an early first cut and several cuts per year leads to both high substrate-specific and area-specific methane yields and vice versa (Prochnow et al., 2008).

When estimating CO_2 gas emission and energy efficiency in the process of biogas production it is obvious, that it depends on grass growing technology, the composition of biomass, the distance of transportation to biogas plant, the anaerobic digestion process etc. In spite of the fossil energy consumed for their production and transformation to biogas, maize and grass energy crops allow a net production in fossil energy related CO2 emission. Maize presents a better renewable energy productivity and yield. Grass, while being less productive, offers good energy balances and has several other agricultural and environmental advantages (Gerin at al., 2008). Growing grass in various grass – grain crop rotations significantly increases the content of soil carbon and dry organic matter. Long – term erosion – resisting crop rotations and perennial grasses increase dry organic matter levels 14.7–17.8 % after 20 years of use (Jankauskas et al., 2009). The selection of appropriate plant species as feedstock for biogas production is an important aspect in decision-making. Biogass crops should have characteristics like high yields and low production inputs (Heiermann et al., 2009).

Grassland or grasses in our climate and soil conditions could be grown in arable land as pure swards or in mixtures with legumes and used for energy purposes. It is forecasted that in Lithuania energy crops could be grown on 22 % (740 thousand ha) of the total agricultural land (Šateikis, 2006). Dry matter yield of fodder grass swards can reach 6 – 13 t ha^{-1} in leys and 6 – 7 t ha^{-1} DM in pastures depending on management (Brenciene, 1995; Daugeliene, 2002; Kadziuliene, Kadziulis, 2007; Jasinskas, Zaltauskas, Kryzeviciene, 2008).

The aim of the present study was to estimate the chemical composition of tall fescue biomass grown for biogas production in relation to the timing of the first cut and mineral nitrogen fertilization.

Materials and methods

Field and laboratory experiments were carried out at the Lithuanian Institute of Agriculture in Dotnuva (55˚ 24`N) in 2008. The soil of the experimental site is characterised as *Apicalcari - Endohypogleyic Cambisol, light loam.* The biomass yield and content of chemical components were analysed in tall fescue (*Festuca arundinacea* Schreb.) swards in the second year of use.

Tall fescue swards were grown without fertilizers and with mineral nitrogen applied at a rate of 150 kg ha^{-1} in spring at the beginning of vegetation. The swards were cut twice per season (on the dry weather conditions). The first cut was taken at different growth stages - heading or flowering.

Laboratory experiments were conducted to determine the chemical composition of the biomass. The total nitrogen and organic carbon were determined using the Dumas method (DIN/ ISO 13878). Crude protein was calculated Nx 6,25. Acid detergent fibre (ADF), neutral detergent fibre (NDF), and lignin (ADL) were estimated using the van Soest methodology of fibre fraction, and then the quantities of cellulose, hemicellulose were calculated: cellulose = ADF-ADL, hemicellulose = NDF-ADF, (Faithfull, 2002).

Results and discussions

The energy potential of swards is greatly dependent on the productivity of grasses (Navickas et al., 2003), therefore it is very important to assess the DM yield of the swards. The data of tall fescue DM yield are presented in Table 1. Nitrogen fertilization had a great effect on biomass yield which was more than twice higher than that of not fertilized sward. Such tendency persisted for both cuts. The annual biomass yield depended not only on fertilization but also on the plant growing stage at first cut. Tall fescue biomass yield was lower when the first cut was taken at heading stage compared to that taken at flowering stage. Unfortunately, the total annual DM yield was not very high due to dry growing season. In earlier experiments, when the sward yield was intended for feed, it was noticed that the yield could be as high as 12.1 – 13.6 t ha^{-1} (Brenciene, 1995). Such differences in results encouraged us to extend the experiments to more significant data.

Biomass composition and productivity are equally important for biogas production. The bacteria responsible for the anaerobic process require carbon and nitrogen, as do all living organisms, but they consume carbon roughly 20 – 30 times faster than nitrogen, therefore the carbon and nitrogen ratio in the biomass for anaerobic digestion is optimum 20 – 30 (Dennis, Burke, 2001). A higher ratio leaves carbon still available after the nitrogen has been consumed, starving some of the bacteria of this element. Too much nitrogen causes this to be left over at the end of digestion which stops when the carbon has been consumed (Wilkie, 2005).

Table 1 – Tall fescue biomass yield

Treatment	Dry matter yield, t ha^{-1}	Annual dry matter yield, t ha^{-1}
Not fertilized		
1 cut at heading stage	0,7	1,9
2 cut	1,2	
1 cut at flowering stage	1,6	2,2
2 cut	0,6	
Fertilized with N_{150}		
1 cut at heading stage	1,8	3,9
2 cut	2,1	
1 cut at flowering stage	4,7	6,2
2 cut	1,5	

In our research the most suitable carbon to nitrogen ratio for biogas production was in fertilized and not fertilized tall fescue biomass cut at heading stage. The influence of grass vegetation period on carbon to nitrogen ratio was higher than that of nitrogen fertilization. The biomass of not fertilized sward at flowering stage contained less nitrogen and more

carbon compared to fertilized sward. A significant difference was found between these treatments (Table 2).
In the second cut, taken late in the autumn, the carbon to nitrogen ratio was higher than optimal for biogas production and there was not found any significant difference on fertilization or the grass stage in the first cut period.

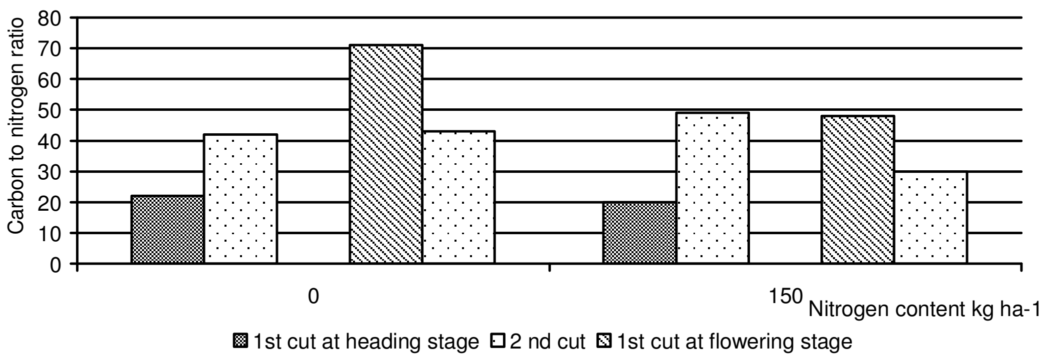

Figure 1 – The variation of carbon to nitrogen ratio in tall fescue biomass at heading and flowering stages

After digestion of sugars and other easy digestible elements, bacteria begin to digest structural biopolymers cellulose, hemicellulose and lignin. The hydrolysis of cellulose materials can be major rate determining biogas production process. The limiting element for anaerobic digestion is lignin. The content of lignin in biomass mostly depends on the vegetation period of grasses; when it is higher than 15% DM, the anaerobic digestion is sharply inhibited (Raclavská et al., 2007).
The biomass of tall fescue at heading stage had very little content of lignin, the concentration was 3.4 % in dry matter and it was not influenced by fertilization. The highest concentration of lignin was in biomass, harvested at flowering stage; it amounted to 6.2 % in dry matter in biomass of not fertilized
sward and 4.9 % in the biomass of sward fertilized with nitrogen (Figure – 2).
There were no significant differences in the concentration of hemicellulose and cellulose in the biomass of fertilized and not fertilized tall fescue, cut at heading and flowering stages.

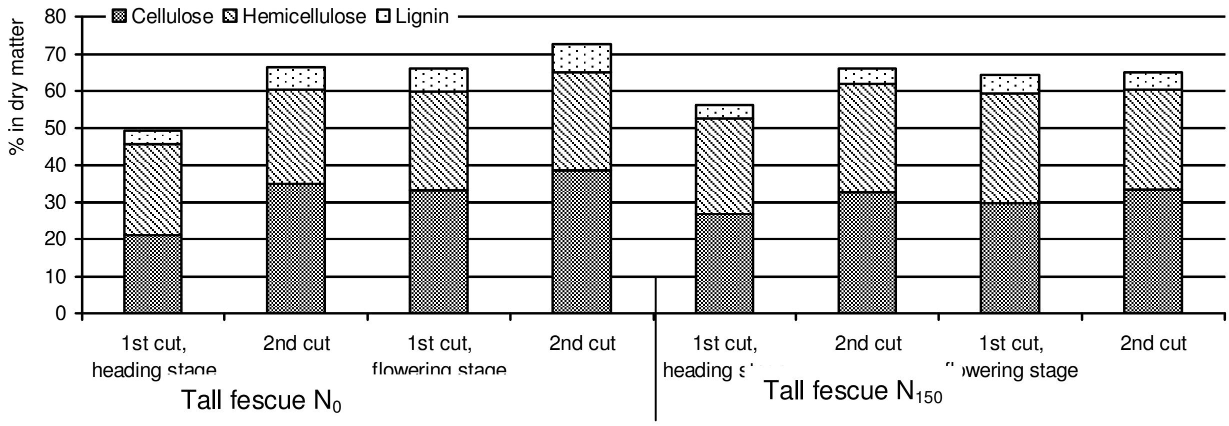

Figure 2 - The variation of the ratio of structural biopolymers in the fibre of the biomass of tall fescue at heading and flowering stages

Table 3 – The variation of elements in tall fescue biomass at heading and flowering sages

Cutting time	Indicators g kg^{-1} DM						
	P	K	S	Ca	Mg	Crude protein	WSC
Tall fescue N_0							
1st cut, at heading	2.62	23.2	1.99	4.31	0.81	123.0	237
2nd cut	3.89	14.3	2.30	8.63	1.52	64.4	145
1st cut, at flowering	1.86	13.6	1.68	2.55	0.64	38.5	171
2nd cut	2.46	12.4	1.56	6.70	1.37	63.8	108
Tall fescue N_{150}							
1st cut, at heading	2.70	21.6	2.14	4.31	1.07	141.0	159
2nd cut	2.84	14.8	1.63	6.68	1.14	56.3	110
1st cut, at flowering	1.67	18.6	1.73	3.34	0.68	58.1	160
2nd cut	3.76	15.0	2.72	11.0	1.73	92.5	148

The most suitable grass species for biogas production are those which are rich in biodegradable carbohydrates such as sugars, proteins (Raclavská et al., 2007). In our research the biomass of tall fescue contained more than three times higher yield of crude proteins at heading stage compared to biomass, cut at flowering stage (Table 3). Harvesting time and nitrogen fertilization exert a marked influence on many biomass components and variability of their concentrations (Butkutė, Paplauskienė, 2006). There were found little differences in the concentration of macro elements in the biomass of fertilized and not fertilized with nitrogen swards cut at heading stage. At flowering stage, the concentration of macro elements in the biomass of fertilized grass, except phosphorus, was higher compared to the biomass, cut at heading stage. It is likely that fertilization with nitrogen influenced not only biomass yield, but also the high concentration of many macro elements.

A trend was found suggesting that there is higher phosphorus and calcium and lower potassium concentration in the biomass of grass in the second cut and it did not depend on the stage of the first cut (Table 3).

Conclusions

The annual biomass yield was higher in fertilized sward compared to not fertilized, and the highest biomass yield was produced when the first cut had been taken at flowering stage. The biomass of tall fescue at the heading stage is better suited for biogas production, since it contains less lignin and more water-soluble carbohydrates in dry matter and a more adequate carbon-to-nitrogen ratio. Further research on tall fescue management for biogas production is needed.

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