EFFECT OF DIGESTATE APPLICATION ON COCKSFOOT ON BIOMASS PRODUCTION AND QUALITY

V. Tilvikiene, Z. Kadziuliene, Z. Dabkevicius
Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Instituto al. 1, LT-58344 Akademija, Lithuania, Tel:+370 37271. vita@lzi.lt

1 INTRODUCTION

Anaerobic digestion is a process that has become a promising technology in biowaste, energy crop and crop residue management throughout the world. During this process organic matter is decomposed by bacteria in the absence of oxygen to produce methane-rich biogas. Anaerobic bacteria break down more than 50 % of organic matter, but anaerobic digestion residuary materials, also called digestates, represent around 90-95% of elements that were fed into the digester (Bermejo, 2010).

Organic nutrients contained in the organic matter are converted and mineralized to more soluble and biologically available forms (Wilkie, 2005; Voca *et. al.*, 2005). Anaerobic digestion converts a major part of organic nitrogen to ammonia, which is then directly available to plants as nitrogen (Wilkie, 2005). Because of the different quality of raw material for biogas production, digestate contains 5.0 – 40 g kg^{-1} of nitrogen, ~0.7 g kg^{-1} of phosphorus and ~0.4 g kg^{-1} of potassium (Wulf et. al., 2002; Kongkaew et. al., 2004; Voca, 2005). The field application with digestate could reduce the need for applying mineral nitrogen fertilizers and it could decrease the ammonia volatilization and nitrate leaching, mitigating environmental impact (Voca *et. al.*, 2005). The digestate application can influence soil fertility and the yield and the quality of the plant (Fuchs, 2008, Marcato, 2008).

When the various organic residues including dead animals are used for anaerobic digestion, seen from the human side it is not very attractive to use digestate for the fertilization of food or feed crops, but on the other hand digestate is very well suited as a fertilizer because it has a reduced content of pathogens and a high nitrogen fertilizer vlaue. One of the ways to utilize digestate properly is to use it as a fertilizer for energy crops. Because of their methane yield per hectare, integration into the farm organization and input for agro ecology, perennial grasses are highly competitive energy crops. Perennial grasses could be used for anaerobic digestion or co-digestion with manure or agricultural residues (Lehtomäki *et al.*, 2008). One of the main factors in selecting energy crops for biogas production is achieving large quantities and good quality biomass feedstock with low input (Amon et al., 2007; Heiermann et al., 2007).

The aim of the current research was to estimate the potential utilization of residues from biomass digestion and ascertain the effect on cocksfoot (*Dacltylis glomerata* L.) biomass yield and quality when applying the digestate to the soil as organic fertilizer.

2 MATERIALS AND METHODS

The study has a dual purpose 1) digestate is a good fertilizer for grass production and 2) the grass fertilized with digestate is a good feed for the biogas plant. The digestate as an organic fertilizer was obtained from the biogas plant. Pig manure and organic residues were the raw materials for the anaerobic digestion. The concentrations of chemical elements are summarized in table 1.

TABLE 1 **The chemical composition of soil and biomass, fermented during biogas production process**

	Elements,% in natural matter							Indicators mg kg^{-1} DM					
	$N\text{-}NO_3$	$N\text{-}NH_4$	N	P	K	SM	C	Cd	Cr	Ni	Pb	Cu	Zn
Digestate	0.001	0.505	0.7	0.09	0.046	3.58	1.01	1,09	15.9	16,6	9,47	715	882
The highest allowable concentrations of heavy metals in the soil (HN 60:2004)								3	100	75	100	100	300

Pure swards of cocksfoot (*Dactylis glomerata* L) were cultivated in central Lithuania (55° 24‘N). Field and laboratory experiments were carried out during 2008 – 2009. The crop was sown in 2008. The soil of the experimental site is characterized as *Apicalcari - Endohypogleyic Cambisol, light loam.*

In the first growing year, the swards were cut twice and in the second year - four times per season (first cut at heading stage). Not fertilized swards, two levels of fertilization with mineral nitrogen fertilizers (N_{180} and N_{360}) and five levels of fertilization with organic fertilizers (N_{90}, N_{180}, N_{270}, N_{360} and N_{450}) were chosen for the research. In the first growing year, 1/3 of annual fertilizer rate was applied at the tillering stage. In the second growing year, 1/3 of annual fertilizers was applied in early spring at the beginning of vegetation, the second fertilization was made after the first cut and the third fertilization after the second cut.

The grasses were cut using a mowing machine. The biomass yield of the grasses was determined by taking 4 samples from an area of 15 m^2 area and weighing them. After that harvested grass material samples of about 0.5 kg were taken to the laboratory and chopped to a ca. 1 cm parctical size then weighed and dried in an oven in 105 ^oC temperature until a constant weight. Dry matter yield was measured.

The samples of digestate for analysis were taken immediately after the process of anaerobic digestion. The contents of the main chemical components and heavy metals were analyzed in the digestate using ISO 11047-1998 and ISO DIS 2002036:2006 methodologies. The concentration of total nitrogen in digestate was measured using ISO 11261 methodology. The total nitrogen and organic carbon in cocksfoot biomass were determined using the Dumas method (DIN/ ISO 13878). The van Soest methodology of fibre fraction was used to analyze the concentration of structural biopolymers in biomass.

Difference was considered significant for a probability below 0.05 ($P < 0.05$).

3 RESULTS AND DISCUSSION

Biomass yield. In our research in 2009 the annual biomass yield of cocksfoot was 11.83 t ha^{-1} when the swards had been applied with mineral fertilizers N_{180} and 12.26 t ha^{-1} when mineral nitrogen level was N_{360}. The annual biomass yield of swards fertilized with organic fertilizers was 11.9 and 12.26 t ha^{-1}, respectively. The first findings of our research are consistent with previous experiments when the sward yield was intended for feed, it was noticed that the annual biomass yield of cocksfoot could be as high as 10 – 12.5 t ha^{-1} depending on the weather conditions and cultivation technologies (Lemežienė *at al.*, 1998, Kanapeckas *at al.*, 1999). There was no significant difference in annual biomass yield between the swards fertilized with 180 t ha^{-1} and N_{360} level of mineral and organic nitrogen fertilizers (Table 1). The results from the first experimental years let us doubt with that previous research has proved the digested fertilizers due to the fact that after the process of digestion, the nutrients are already mineralized and thus can be used by plants effectively, but it does not surpass mineral fertilization in biomass yield formation (Fuchs, 2008; Ortenblad, 2000). The nitrogen fertilization had a significant positive effect on biomass yield in all swards, compared to not fertilized crops, nevertheless, as we see from table 2, we did not get any significant difference in annual biomass yield in the swards fertilized with both N_{270} N_{360} nitrogen levels applied with organic fertilizers. These results suggest that in 2009 the N_{240} nitrogen level was the highest that cocksfoot could assimilate. The highest biomass yield of all in swards fertilized with N_{450} could be reached because of higher concentrations of other nutrients.

TABLE 2 **The DM yield of cocksfoot during the first and the second sward age year**

	DM yield t ha^{-1}								
Fertilizer rate	**2008** **1st cut**	**2nd cut**	**Annual**	**Fertilizer rate**	**2009** **1st cut**	**2nd cut**	**3rd cut**	**4th cut**	**Annual**
0	1.65	1.97 ^{ab}	3.62 ^{ab}	0	2.48^{a}	2.94^{a}	3.10^{bc}	0.07^{a}	8.59^{a}
Fertilized with mineral nitrogen fertilizers									
60	1.65	2.24 ^{cde}	3.89 ^{cde}	180	2.95^{ab}	5.45^{bc}	3.01^{abc}	0.42^{bcd}	11.83^{c}
120		2.14 ^{e}	3.79 ^{e}	360	3.26^{bc}	5.44^{cde}	2.94^{abc}	0.62^{d}	12.26^{cde}
Fertilized with organic fertilizers									
30		2.03 ^{abc}	3.68 ^{abc}	90	3.06^{abc}	4.29^{b}	2.96^{abc}	0.27^{ab}	10.59^{ab}
60		2.25 ^{abc}	3.90 ^{abc}	180	3.29^{bc}	5.03^{cde}	2.65^{a}	0.12^{a}	11.09^{bc}
90	1.65	2.36 ^{bc}	4.01^{bc}	270	4.03^{de}	5.31^{bcde}	3.26^{c}	0.14^{ab}	12.74^{cde}
120		2.49 ^{c}	4.14^{c}	360	3.64^{cde}	5.32^{bcde}	3.11b^{c}	0.19^{ab}	12.26^{cde}
150		2.43 ^{a}	4.08^{a}	450	6.29^{e}	6.44^{e}	2.97^{abc}	0.23^{ab}	15.92^{e}

Values with different letters in columns are significantly different at $P<0.05$

The swards of cocksfoot are characterized as grasses with balanced biomass yield distribution during the growing season. The biomass yield of the first cut usually accounts for 47 % of annual biomass yield (Kanapeckas *at al*., 1999). In our research we found such a trend in the year 2008, but in 2009 the biomass yield of the first cut contained amounted for 25 – 30 %. Because of the dry spring and wet weather conditions after the first cut the biomass yield of the second cut was higher. The swards accumulated significantly lower biomass yield compared to other cuts from August to October when the 4th cut was made. Mineral fertilizers had no significantly higher influence on biomass yield in all cuts compared to the swards fertilized with the same levels of digestate.

Biomass quality. Biomass composition and productivity are equally important for biogas production. Anaerobic bacteria first of all begin to digest water soluble carbohydrates (WSC) and decompose them to biogas without many losses (Wilkie, 2005). The concentration of WSC in cocksfoot biomass was the highest in not fertilized swards (Table 3).

The swards applied with mineral nitrogen fertilizes exhibited a slightly better utilization of nitrogen. Therefore in the first and the second years of our research the content of nitrogen and crude proteins was higher in the biomass of swards, fertilized with mineral fertilizers compared with that in the swards fertilized with organic fertilizers. The results of the concentrations of WSC and crude proteins from our research agree with previous research results when grasses were analyzed as a source for feed (Butkutė and Paplauskienė, 2006).

TABLE 3 **The averaged concentration and variation of chemical elements in cocksfoot biomass during the growing period**

		Control	**Mineral Fertilizers**		**Organic fertilizers**				
		N_0	**N_{180}**	**N_{360}**	**N_{90}**	**N_{180}**	**N_{270}**	**N_{360}**	**N_{450}**
Crude proteins	**Mean**	11.17	15.56	18.51	10.97	12.27	13.55	15.09	14.69
	Range	8.6-17.6	13.3-18.7	16.0-21.4	9.0-12.3	9.6-16.6	9.7-18.6	11.3-17.5	10.1-18.2
	CV%	29	12	10	14	21	23	17	20
WSC	**Mean**	16,50	14,31	11,56	13,87	13,92	12,68	13.94	15.76
	Range	10.2-21.5	6.2-20.1	6.8-14.2	7.2-20.2	6.9-17.3	5.7-16.9	9.1-16.3	9.6-18.4
	CV%	34	40	39	39	30	33	19	22

Fermentation is most stabile at a C:N ratio of ca. 20-30 (Dennis, 2001). In the firs year of our research, the carbon to nitrogen ratio did not exceed the minimum values (Fig. 3).

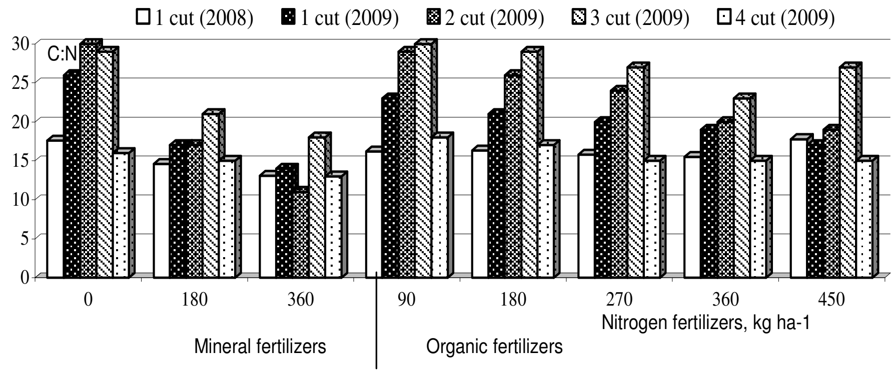

FIGURE 3 **The variation of the carbon to nitrogen ratio in the biomass of cocksfoot**

In the second experimental year, the carbon to nitrogen ratio values were higher and better for biogas production in the biomass, fertilized with organic fertilizers. The lowest concentrations of these elements were in the swards, applied with mineral fertilizers. Previous research suggestedthat carbon to nitrogen ratio varied significantly during plant growth (Amon, 2007; Raclavská, 2007; Lemežienė at al., 2009). The same trend was measured in our research: not only fertilization, but also the timing of the cut significantly influenced the variation of C:N. The carbon to nitrogen ratio was higher for the second and third cut compared to the first cut. The lowest results we obtained for the fourth cut, C:N values did not exceed minimum allowable values.

4 CONCLUSIONS

The research showed that the nitrogen applied in digestate to grassland was as efficient as mineral fertilizer nitrogen. The second year of this study indicated that cocksfoot harvested from plots applied digestate had a carbon to nitrogen ratio that was better suited for biogas production than cocksfoot from plots added mineral fertiliser. Thus, the first two years study indicated that nutrient-rich digestate, utilized as organic fertilizer, exerted a positive effect on biomass yield and chemical composition of cocksfoot.

ACKNOWLEDGEMENTS

The study was supported by the Lithuanian State Science and Studies Foundation.

REFERENCES

Amon T, Amon B, Kryvoruchko V, Machmuller A, Hopfner-Sixt K, Bodiroza V, Hrbek R, Friedel J, Poutsch E, Wagentristl H, Schreiner M, Zollitsch W 2007. Methane production through anaerobic digestion of various energy crops grown in sustainable crop rotations. Bioresource Technology 98, 3204-3212.

Beriejo G, Ellmer F 2010. Use of dry and wet digestates from biogas plants as fertilizer in the agriculture. Green Week Scientific Conference 2010: Challenges of Education and Innovation, January, 13th and 14th, 2010, Berlin.

Butkutė B, Paplauskienė V 2006. Daugiamečių varpinių žolių pašarinės vertės potencialas. Zemdirbyste-Agriculture 93 (3), 172–187

Dennis A, Burke PE 2001. Dairy Waste Anaerobic Digestion Handbook pp. 57

Fuchs JG 2008: Effects of digestate on the environment and on plant production – results of a research project. ECN/ORBIT e.V. Workshop The future for Anaerobic Digestion of Organic Waste in Europe 19.

Heiermann M, Plöchl M, Linke B, Schelle H, Herrmann C 2009, Biogas Crops – Part I: Specifications and Suitability of Field Crops for Anaerobic Digestion. Agricultural Engineering International: the CIGR Ejournal. Manuscript 1087, 11.

Kanapeckas J, Lemežienė N, Tarakanovas P 1999. Plaukėjimo fazėje pjautų daugiamečių varpinių žolių derliaus ir jo vertės palyginimas. Žemės ūkio mokslai 1, 10–16

Lehtomaki A, Huttunen S, Lehtinen T M, Rintala J A 2008. Anaerobic digestion of grass silage in batch leach bed processes for methane production. Bioresource Technology 99, 3267–3278

Lemežienė N, Kanapeckas J, Butkutė B 2009. Biodujų gamybai tinkamo paprastosios šunažolės (*Dactylis glomerata* L) veilės, selekcinės linijos ir ekotopai. Zemdirbyste – Agriculture 96 (3), 36 – 46.

Lemežienė N, Kanapickas J, Tarakanovas P, Nekrošas S 1998. Daugiamečių žolių derlingumas bei kitos ūkiškai naudingos savybės. Žemės ūkio mokslai 1, 42–47

Ortenblad H 2000. The use of digested slurry within agriculture, in: AD-Nett (ed): *AD:* Making energy and solving modern waste problems. Herning municipal utilities, Denmark, pp.53-65

Raclavská H, Juchelková D, Roubíček V 2007. Utilisation of biomass and mixtures for the gas production. International conference on engineering education. Coimbra, Portugal

Voća N, Krička T, Ćosić T, Rupić V, Jukić Ž, Kalambura S 2005. Digested residue as a fertilizer after the mesophilic process of anaerobic digestion. Plant, soil and environment 51, 262-266

Kongkaew K, Kanajareonpong A, Kongkaew T 2004. Using of SLUOGE from Biogas Digestion Pool as bio-fertilizer. The Jodint International Conference on Sustainable Energy and Environment. Thailand, 350 – 352

Wilkie A 2005. Anaerobic digestion: Biology and benefits. Dairy manure management conference: Natural resource, agriculture and engineering service. Ithaca 2005, 63–72

Wulf S, Maeting M, Clemens J 2002. Application technique and slurry co-fermentation effects on ammonia, nitrous oxide, and methane emission after spreading: II. Greenhouse gas emission. Journal of environmental quality 31, 1795-1801.