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CHEMICAL EVALUATION OF HAY FROM SELECTED TYPES OF GRASS WITH RESPECT TO ITS USABILITY FOR POWER ENGINEERING INDUSTRY

CHEMICZNA OCENA SIANA WYBRANYCH TRAW W KONTEKŚCIE ICH PRZYDATNOŚCI W ENERGETYCE

Abstract: The aim of the study was to evaluate the contents of alkaline elements in soil and hay obtained from grass with respect to the possibility of their use as a fuel in furnaces of power engineering industry. Two significantly different types of grass were used in the investigation: *Miscanthus sacchariflorus* and *Calamagrostis epigejos*. The experiment was started on typical for the northern part of the Lublin region podsolic soils that belong to quality class IVb, in the objects of Łęczyńska Energetyka in KWK Bogdanka. The plants were cultivated in conditions similar to these used during their production cultivation, but without the traditional mineral fertilization, which was replaced with post-sewage waters from the local, industrial, mechanical-biological sewage plant. The study revealed that both types of grass had useful properties for burning biomass, because they contained limited amounts of alkaline elements, however, there was a significant discrepancy in absorption of alkaline elements by both grasses.

Keywords: grass, hay, biomass, *Miscanthus sacchariflorus, Calamagrostis epigejos*, alkaline elements, post-sewage waters

Many authors have been claiming that grasses can be used practically as energy plants [1–7]. This fact is due to at least two reasons. Grasses are perennial plants and have constant growth during the vegetation period, results in high demand for water and nutrients. In favorable environmental conditions they provide high yield of biomass which can be harvested a few times during one vegetation period. The biomass of these plants subjected to rainfall for a long period of time improves its energy properties.

The other reason is economic in nature – with the decrease of the number of farm animals there is an excess of food that is not used by a herd and can be used for purposes other than consumption.

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The shape of the landscape where meadows and pastures are situated allows for their irrigation with flooding, and fertilization in the lowest places. Liquid sewage and pre-filtered post-sewage waters can be used for fertilization. This process is similar to filtering sewage in root sewage plants. Such kind of fertilization can be used practically because grass-like plants have coronal roots and by tightly covering soil surface create a natural barrier that protects the liquids from moving deeper into soil profile. During grass fertilization the contents and mutual co-relations between alkaline cations are taken into consideration as a criterion for creating proper growing conditions for grasses [8–10].

When assessing biomass that is used for energy purposes much attention is paid to the presence of at least a few elements, including alkaline elements. In many cases amounts and mutual corelations of these elements can be, at least partially, regulated by human.

In spite of a positive properties of biomass as a fuel and from the point of view of protection of environment, its combustion is not widespread because of some technical problems. The contents of silica and potassium significantly decrease the value of biomass as a fuel. High contents of alkaline elements causes slag to clot, which makes it difficult for the organic mass to move along the grates of the furnace [11, 12]. It is also believed, that potassium and alkaline elements influence the melting point of ash, which is an important energy property of a fuel [13, 14].

The aim of the study it was evaluation of the contents of alkaline elements in soil and hay obtained from grass with respect to their usability as a fuel in furnaces of professional power industry. Such study may provide reasons for using the investigated plants not only as a fuel, but also for bioremediation of soil environment, especially where there is an excess of biogenes.

Material and methods

Two significantly different types of grass were used in the study – *Miscanthus sacchariflorus* and *Calamagrostis epigejos*. The experiment was started with typical for the northern part of the Lublin region podsolic soils that belong to quality class IVb, in the objects of Łęczyńska Energetyka in KWK Bogdanka. The plants have been growing on plots which surface was 36 m^2. The presented results cover only the year 2007 – the third year of the experiment. The plants were cultivated in conditions similar to these used during their production cultivation, but without the traditional mineral fertilization, which was replaced with post-sewage waters from the local, industrial, mechanical-biological sewage plant with the following composition:

pH	8.77
Ca total	$< 1.79\ g \cdot dm^{-3}$
Mg total	$< 0.02\ g \cdot dm^{-3}$
K solved in water	$< 0.83\ g \cdot dm^{-3}$
Na total	$< 0.17\ g \cdot dm^{-3}$

The plots were irrigated 13–15 times during the vegetation period (May–October) with one dose of 15 $dm^3 \cdot m^{-2}$.

After the vegetation period had finished in November, the plants were harvested and the amount of the yield was evaluated for both fresh plants and air-dried plants. The samples of soil and plants were dried and ground in the laboratory. After mineralization total contents of alkaline elements Ca, Mg, K and Na were determined in dry plant mass and in soil. Magnesium was determined with atomic absorption spectrophotometric method (F-AAS) on AAS-3 Carl Zeiss-Jena apparatus, and Ca, K, and Na were determined with atomic spectrophotometric method.

Results and discussion

Repetitive, seasonal irrigation with post-sewage waters that were rich in biogenes caused significant changes in the chemism of the analysed soil.

The changes were observed not only in the case of high contents of alkaline elements in the soil, but also corelations between them (Table 1). It is characteristic that potassium turned out to be the most basic element in both absolute quantities and relative quantities. Potassium constituted 40 % of the total contents of the analysed elements. The significant contents of magnesium in the soil were also characteristic – there was more magnesium than calcium. The mass of magnesium was over 1.40 $g \cdot kg^{-1}$, and constituted 35 % of the total contents of the alkaline elements. Considerably small amounts of calcium were observed – only 23 % of the total mass of this group of elements. There was also little sodium in the soil. The mass of sodium was below 0.1 $g \cdot kg^{-1}$, which was 2 % of the mass of all alkaline elements.

Table 1

Mean contents and structure of alkaline elements in soil

Plant	Alkaline elements								Sum	
	Ca		Mg		K		Na			
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	0.89	22	1.37	34	1.72	42	0.102	2	4.082	100
Calamagrostis epigejos	0.99	24	1.50	36	1.55	38	0.097	2	4.137	100
Mean value	0.94	23	1.44	35	1.63	40	0.099	2		

Table 2 reveals that potassium dominated in the biomass of the investigated grasses, and constituted on average 50 % of the whole mass of the analysed elements. However, it should be noted that there was a significant discrepancy in uptaking of potassium between *Miscanthus sacchariflorus* and *Calamagrostis epigejos*. *Calamagrostis epigejos* uptake over 5 $g \cdot kg^{-1}$ of potassium, which was 75 %, and *Miscanthus sacchariflorus* uptake only 24 % of the total mass of potassium. Similar discrepancies were observed in uptaking of calcium. *Miscanthus sacchariflorus* uptake over 60 %, whereas *Calamagrostis epigejos* exactly 1/10 of this mass. Despite high contents of magnesium in the soil, both grasses uptake small amounts of this element. On average, the plant biomass contained only over 10 % of the mass of magnesium. There was very little sodium observed in the plant material – its mass constituted only 1 % of the total mass of alkaline elements.

Table 2

Mean contents and structure of alkaline elements in plant biomass

Plant	Alkaline elements								Sum	
	Ca		Mg		K		Na			
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	5.66	62	1.16	13	2.22	24	0.041	1	9.081	100
Calamagrostis epigejos	0.49	7	1.21	17	5.43	75	0.046	1	7.176	100
Mean value	3.08	34	1.18	15	3.83	50	0.043	1		

The data presented in Table 3 reveals that the contents of calcium in the biomass were higher than in the soil. A clear discrepancy can be observed between uptaking of calcium by both grasses. *Miscanthus sacchariflorus* has 7 times higher mass of this element than in the soil. The calculations that were performer reveal that the plant material of *Miscanthus sacchariflorus* contained nearly 90 % of the total amount of calcium. A small amount of this element (10 %) was found in the soil in the form of a reserve. *Calamagrostis epigejos* showed a totally different demand for calcium. There was a smaller amount of this element found in the plant (33 % of the mass) than in the soil. Reduced uptaking of calcium from the soil by *Calamagrostis epigejos* left a considerable amount in the soil in the form of a reserve.

Table 3

Mean contents and proportional contents of calcium in soil and plant

Plant	Content of Ca					
	Soil		Plant		Sum	
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	0.89	14	5.56	86	6.45	100
Calamagrostis epigejos	0.99	67	0.49	33	1.48	100
Mean value	0.94	40	3.03	60		

Table 4 reveals that both *Miscanthus sacchariflorus* and *Calamagrostis epigejos* uptook magnesium, that abounded in the soil, in a similar, limited manner. Similar amounts of this element were found in the biomass of both grasses in absolute quantities as well as in relative quantities.

Table 4

Mean contents and proportional contents of magnesium in soil and plant

Plant	Content of Mg					
	Soil		Plant		Sum	
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	1.37	54	1.16	46	2.53	100
Calamagrostis epigejos	1.50	55	1.21	45	2.71	100
Mean value	1.44	55	1.19	45		

The results in Table 5 confirm the fact that potassium was uptaken from the soil by both grasses in highest, but varying, amounts. The greatest amounts of potassium were found in *Calamagrostis epigejos*. There was 78 % of potassium found in its biomass. Slightly smaller amounts of this element were uptaken by *Miscanthus sacchariflorus* (56 %). Nevertheless, this amount was significant – over 2 $g \cdot kg^{-1}$ of potassium.

Table 5

Mean contents and proportional contents of potassium in soil and plant

Plant	Content of K					
	Soil		Plant		Sum	
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	1.72	44	2.22	56	3.94	100
Calamagrostis epigejos	1.55	22	5.43	78	6.98	100
Mean value	1.63	33	3.83	67		

The results in Table 6 unanimously reveal that both grasses uptaken little amounts of sodium that was present in the soil. Considerable amounts of this element (60–70 %) remained in the soil in the form of a reserve. Both grasses uptaken similar amounts of sodium, 0.043 $g \cdot kg^{-1}$ on average, which constituted 31 % of the total contents of sodium.

Table 6

Mean contents and proportional contents of sodium in soil and plant

Plant	Content of Na					
	Soil		Plant		Sum	
	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%	$g \cdot kg^{-1}$	%
Miscanthus sacchariflorus	0.102	71	0.041	29	0.143	100
Calamagrostis epigejos	0.097	68	0.046	32	0.143	100
Mean value	0.099	69	0.043	31		

Discussion

Chemical properties of podsolic soil that was used in the experiment were different from the properties of such soils found in natural environment. This was caused by the use of fertilization only with post-sewage waters from biological-mechanical sewage plant over consecutive vegetation periods. This sewage was specific because on of its main sources was miners' bath.

The conditions created in the experiment were good enough for the grasses to thrive properly, and the yield of the plant biomass did not differ from this found in literature, which was noted in the previous work of the authors [15].

The results of the analysis of the soil with regard to the contents of alkaline elements show proper supply of soils. A different amount of elements can be observed in the soil and plant, as well as their mutual corelation in both cases. It is also characteristic that both in the soil and the plant potassium dominated among the alkaline elements. The amounts of potassium were the highest of all the alkaline elements – 40 % of the mass of the alkaline elements in the soil, and 50 %, on average, in the biomass of both grasses. However, there was a significant discrepancy in the ability to store potassium by both grasses. In the case of *Calamagrostis epigejos* the contents of potassium were 75 % of the total contents of the analyzed element, and in *Miscanthus sacchariflorus* it was only 24 %. Low contents of potassium in *Miscanthus sacchariflorus* are confirmed by results obtained by other authors [15–17].

It was also characteristic for both grasses to uptake calcium and magnesium from the soil. In the soil the amount of magnesium (35 % of total amount of the alkaline elements) was greater than of calcium (slightly over 20 %), but in the biomass of both grasses these proportions were reversed. Calcium in plants constituted 34 % of the total mass of the alkaline elements, and magnesium 15 %. Considerable differences in uptaking of calcium were also observed. *Miscanthus sacchariflorus* retained as much as 86 % of this element (5.56 $g \cdot kg^{-1}$) and *Calamagrostis epigejos* only 33 % (0.49 $g \cdot kg^{-1}$). Similar amounts of calcium in *Miscanthus sacchariflorus* (5.56 $g \cdot kg^{-1}$) can be found in the experiments [1].

Uptake of sodium from the soil by the grasses was marginal. In the biomass only 31 % of the total contents of sodium were observed and the rest remained in the soil in the form of a reserve. Little amounts of sodium in energy plants are confirmed by the works of Kalembasa et al [17, 18].

The sum of alkaline element uptake in the biomass of *Miscanthus sacchariflorus* was 9 $g \cdot kg^{-1}$, and *Calamagrostis epigejos* absorbed 7 $g \cdot kg^{-1}$ of alkaline elements. Uptake abilities of the investigated grasses are not great when compared with other energy plants. Other works of the author [19] revealed that amounts of alkaline elements obtained with the same methods were: 18 $g \cdot kg^{-1}$ in the case of *Helianthus tuberosus*, and 12 $g \cdot kg^{-1}$ in the case of salix.

It should be noted, that there was a significant discrepancy in alkaline element uptake by both grasses. *Miscanthus sacchariflorus* has high capabilities to calcium uptake. This proves an observation that optimum soils for cultivation of this plant are V, and VI quality class soils, with reaction close to alkaline and contents of calcium in undersoil

[20]. The results that were obtained also prove an opinion that *Calamagrostis epigejos*, being a pioneer plant, often occurs on very acidic soils and does not require calcium for its growth, but mainly silica. The study reveals that under favorable growth conditions this plant uptake large quantities of potassium.

Conclusions

1. Both grasses show properties that are useful for combustion of biomass because they contain limited amounts of alkaline elements.
2. It was observed, that *Miscanthus sacchariflorus* and *Calamagrostis epigejos* have different qualitative and quantitative abilities to uptake alkaline elements from the soil with optimum contents of these elements. It was estimated, that *Miscanthus sacchariflorus* uptook 20 % more of the total mass of these elements than and *Calamagrostis epigejos*.
3. The basic element uptook by both grasses was potassium (on average 50 % in the composition of biomass) and calcium (34 %). The grasses uptook considerably less magnesium (15 %) and trace amounts of sodium (1 %).
4. There was a significant discrepancy in uptaking of alkaline elements by both grasses. *Miscanthus sacchariflorus* uptook 62 % of calcium and 24 % of potassium, and *Calamagrostis epigejos* retained 7 % of calcium and 75 % of potassium.

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CHEMICZNA OCENA SIANA WYBRANYCH TRAW W KONTEKŚCIE ICH PRZYDATNOŚCI W ENERGETYCE

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Abstrakt: Celem przeprowadzonych badań była ocena zawartości pierwiastków zasadowych w glebie i sianie traw w kontekście możliwości ich wykorzystania jako paliwa w piecach energetyki zawodowej. W badaniach wykorzystano 2 gatunki zdecydowanie różniących się traw: *Miscanthus sacchariflorus* oraz *Calamagrostis epigejos*. Doświadczenie założono na typowych dla północnej części Lubelszczyzny glebach bielicowych zaliczanych do IVb klasy bonitacyjnej w obiektach należących do Łęczyńskiej Energetyki w KWK Bogdanka. Rośliny uprawiane były w warunkach zbliżonych do produkcyjnych, ale bez tradycyjnego nawożenia mineralnego, które było zastąpione wodami pościelowymi z miejscowej oczyszczalni przemysłowej typu mechaniczno-biologicznego. Przeprowadzone badania wykazały, że obie trawy charakteryzują właściwości przydatne do spalania biomasy, bowiem zawierają ograniczone ilości pierwiastków zasadowych, przy czym wystąpiło wyraźne zróżnicowanie pobierania poszczególnych pierwiastków alkalicznych przez obie trawy.

Słowa kluczowe: trawa, siano, biomasa, miskant cukrowy, trzcinnik piaskowy, pierwiastki alkaliczne, woda pościekowa