THE ANALYSIS OF CARBON CONTENT IN DIFFERENT ENERGY CROPS

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Abstract. *Local grass and water plant use is an important part in diversification of the energy sources. The various plants are one of the most important types of the local biomass, whose potential in Latvia until now is not being adequately used. The objective of this work was to determine the suitability of the biomass of reed (Phragmites australis (Cav.) Trin. Ex Steud), tall fescue (Festuca arundinacea Schreb.), festulolium (x Festulolium), reed canary grass (Phalaris arundinacea L.) as fuel. The carbon content in the biomass was determined using carbon/sulphur analyzer ELTRA CS–2000. Reeds are one of the widespread water plants in Latvia. The analyzed samples were collected from 11 natural and artificial water bodies. The field trials of tall fescue, festulolium, reed canary grass was carried out during 2011-2012 growth seasons in Research and Study Farm "Peterlauki" (56°53'N, 23°71'E) of the Latvian University of Agriculture. Plants were cultivated in the sod calcareous soils pHKCl 6.7, containing available P 52 mg kg^{-1}, K 128 mg kg^{-1}and organic matter content 21 to 25 g kg^{-1}. According to the results of the three-year study the carbon content in the reeds were 42.41 ± 0.18%. The carbon content is similar to various tall fescue – 47.55 ± 0.09%, festulolium 47.14 ± 0.14%, reed canary grass varieties 'Marathon', 'Bamse', 'Pedja' was 47.24 ± 0.09%. The carbon yield for one hectare was within the range 1.09-3.89 t ha^{-1}. It was dependent on the variety, plant age and nitrogen fertiliser use. Plant carbon content analysis established that biomass of reeds, tall fescue, festulolium, reed canary grass is suitable for energy generation. Carbon content in these plants is similar to that of the firewood.*

Key words: *carbon content,cammon reed, tall fescue, festulolium, reed canary grass.*

INTRODUCTION

Carbon dioxide (CO_2) and in the form of methane (CH_4), and the presence of these gases is a substantial influence on the atmosphere qualities (temperature level) and therefore the climatic conditions on the planet. Therefore the Carbon Oxide emission level increase can be a factor which negatively influences the governing environmental factors. By burning biofuels the same amount of CO_2 is distributed, as the plants take from the atmosphere; and therefore not increasing the global warming effect, reducing the harmful and toxic effects, which include the cancerogenic compounds, and emissions in the air; reducing illnesses connected with the respiratory organs in urban areas [7].

Carbon is the main burning element in fuel, producing a high burning temperature, and forming the main part of the burning mass [3],[16]. Burning carbohydrates, carbon dioxide and water are produced, and solar energy is released. This type of biomass is a natural, sustainable and infinite battery for the storage of solar energy.

The Carbon content in energy plants and fuel is influenced by diverse factors: 1) the fuel form and the location conditions [4],[6], 2) the variables for different plants, the varieties within a plant species and plant sections [2],[4], 3) the sampling period [1].

MATERIALS AND METHODS

In each of the lakes investigated: after inspecting the reed areas, four reed stands were selected, which according to the characteristics visually conformed to the average level in the specific water body. In each stand two sampling plots were investigated. From each sampling plot was taken about 1 kg reed biomass, which was used to establish the reed parameters in laboratory conditions. Even though previous research has shown, that reed stems and leaves have different abilities to accumulate chemical elements deposits [8]. In our research the reed stems were not separated from the leaves. As for harvesting the reed for fuel production, this type of separation is complicated and energy capacious, which increases the cost of reed processing. The reed samples collected from the eight sampling plots in each water body (Lubanas lake, Kvapanu ponds, Idenas ponds, Luknas lake, Cirisa lake, Sivera lake, Rusonas lake, Feimanu lake, Raznas lake, Cirmas lake, Ludzas lake) were combined producing an average sample. The reeds were chopped up, and for the laboratory research 1 kg of the reed fragments was taken as an average sample.

Reed canary grass (RCG) varieties 'Marathon' and 'Bamse' were carried out in sod-podzolic loamy soil (the organic content of the soil – 5.2%, pHKCl – 5.8, P_2O_5 – 20 mg kg^{-1}, and K_2O – 90 mg kg^{-1} of the soil) in the Agricultural Science Centre of Latgale. The area of the plots was 16 m^{-2}, the location of the plots was randomised. The RCG was sown after bare follow. Before sowing a complex fertiliser was applied N:P:K – 5:10:25 – 400 kg ha^{-1}. The RCG varieties 'Marathon' and 'Bamse' were sown in April 2009 and 2010. The samples for the laboratory research were collected in October 2009 and 2010.

The carbon content in the biomass was determined using carbon/sulphur analyzer ELTRA CS–2000 in Chemical laboratory of Rezekne higher education institution. The plant length was determined for five plants on each repeat occasion (for all plant stalks). The reed canarygrass samples were taken on the 12th October 2009, 6th October 2010. The meteorological conditions were different in both trial years. The meteorological conditions for agriculture during 2009 the plant growth period had a significant deficit in rainfall. The temperature was in compliance with the long term yearly long-term average. In the winter of 2009/2010 snow was observed to be greater and the temperature was lower than the long term yearly long-term average. On the 23rd and 24th of April 2010 there was snow and hail. The plant growth period in 2010 was characterized by higher temperatures and a lack of precipitation in April, July, August and September.

Research objects: RCG (*Phalaris arundinacea* L.) and tall fescue (*Festuca arundinacea* Schreb.) that are perennials yielding for 8-10 years, plant length up to 1.5 m, they are modest in terms of requirements for soil and may grow in marginal soils, moreover they are suitable for cultivation in moisture meadows, with strong root system and excels also with durability against draughts cold tolerance.

The field trial was carried out during 2011–2012 in Research and Study Farm "Peterlauki" (56°53'N, 23°71'E) of the Latvia University of Agriculture, in the sod calcareous soils pHKCl 6.7, containing available for plants P 52 mg kg^{-1}, K 128 mg kg^{-1}, organic matter content 21 to 25 g kg^{-1} in the soil. The field test fertiliser norms applied were following (kg ha^{-1}): $N_0P_0K_0$ (control) P_2O_5 – 80, K_20 – 120 (F – background), F+N30, F+N60, F+N90, F+N120 (60+60), F+N150 (75+75), F+N180 (90+90). Seed sowing norm – 1000 germinant seeds per 1 m^{-2}; usage type: mowing two-three times.

Carbon (C) content in various samples was found out in the agricultural scientific laboratory for agronomic analyses of the University of Latvia in compliance with the measured using the analyser 'ELTRA CS–500 Analyzer'.

The trial data were processed using correlation and variance analyses of two and three factors (ANOVA) and descriptive statistics. The means are presented with their LSD test. Representative average samples of the indicators were used in the calculations.

RESULTS AND DISCUSSION

Carbon is one of the important elements in ensuring the efficiency of the photosynthetic process, when from non-organic matter, under the impact of solar light, organic matter is created. Even though photosynthesis is a non-effective process, as the most productive plants can only convert 6% of the solar energy [5]. Carbon is also the main burning element in fuel. Carbon has a high burning temperature, and it makes up the greatest part of the burning mass [3]. As cereal grasses are used for granule production, then it is important to evaluate the carbon content. For the lake reeds the carbon content was 42.41 +/–0.18% (Table 1). For the lake reeds changes in carbon content for each of the three years researched did not exceed a 5% range.

The scientists from the Latvian State Forest Research Institute "Silava" in their research have found that in the reed canary grass dry matter there was 49% carbon [9]. In our research the carbon content was 37.65-39.87% (Table 2), which shows that the carbon content is influenced by several relevant factors. Carbon content in reed canary grass dry matter was found to be on average 38.3 ± 0.5%.

Table 1

Carbon content in lake reeds, %

Year	Average	Min	Max	Standard error
2010	42.71	41.62	44.21	0.24
2011	42.61	41.39	43.76	0.23
2012	41.90	40.50	44.35	0.42
3 year average	42.41	40.50	44.35	0.18

Carbon content is influenced by the plant age: for the year 2009 autumn harvest dry matter the carbon content was in the range 37.45-40.68%, but in the following year – 40.07-41.88%. The greatest carbon content was found in the reed canary grass 'Marathon', Carbon yield from one hectare was in the range 1.09-3.89 t ha^{-1}. It was dependant on the variety, plant age, and the nitrogen fertilizer norm.

Table 2

Carbon content in reed canary grass, %

Variety	Year	Average	Min	Max	Standard error
'Marathon'	2009	38.79	37.45	40.68	0.36
	2010	40.96	40.07	41.88	0.25
	Average	39.87	37.45	41.88	0.31
'Bamse'	2009	36.92	35.55	40.07	0.55
	2010	38.38	36.58	40.68	0.44
	Average	37.65	35.55	40.68	0.38

The agro meteorological conditions for the trial year (F_A), as a factor for the chemical composition influencing proportions is different for the two reed canary grass varieties [15] (but of fundamental importance (Table 3).

The influence of the agro meteorological conditions was observed to be greatest on the carbon content in the reed canary grass variety 'Marathon' (η = 66%). A lower influencing proportion was observed for the nitrogen fertilizer norm (F_B). The factor interaction for the variety 'Bamse'(η = 71%) and for the variety 'Marathon' (η = 12%) shows, that each variety reacts differently to the environmental conditions (Table 3).

Table 3

The factor influencing proportions for reed canary grass carbon content (P<0.001), η, %

Variety	Factors		
	Harvesting time – F_A	Nitrogen fertiliser norm – F_B	Interconnection between F_A un F_B
'Marathon'	66	21	12
'Bamse'	17	13	71

The undesirable elements in plants As, Cd and Pb form a close fundamental negative correlation in connection to carbon (Fig.1 which can adversely affect the plant development and the quality of the hard fuel. The heavy metals are phytotoxic, especially as, they can interact with various elements in a synergic and antagonistic way, which is also dependant on the soil pH [12]. In the reed canary grass trial plots the soil pHKCl was 5.8.

For reed canary grass, the alkali and alkalisoil metals are organically fixed in various carbon structures [10],[11],[14]. Reed canary grass dry matter at the start of the ash melting, the hemisphere point, the ash flow temperature forms a negative linear correlation with carbon content ($r = -0.52$; $r = -0.49$; $r = -0.49$; $P < 0.001$; $n = 36$).

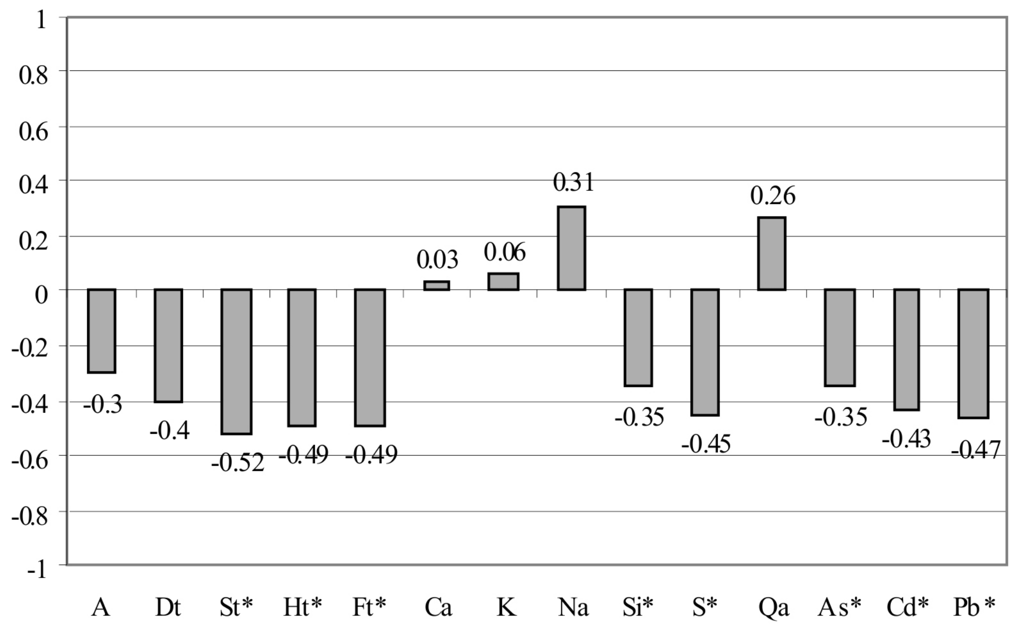

Figure1. **Correlation with carbon content, where Dt – deformation start temperature, St – ash melting start, Ht –hemisphere point, Ft – ash flow temperature, A – ash content, Qa – greatest thermal capacity, * – P<0.001.**

Sowing reed canary grass in different years and different soil conditions, it can be seen that the carbon content is nearly 10% greater (Table 3). For cultivated tall fescue and festulolium the carbon content is similar – 47%. For the varieties 'Marathon' and 'Bamse' the carbon content varies in the range 0.55 and is similar in tall fescue and festulolium.

Table 3

Carbon content in cereal grasses for the year 2012, %

Crops	Variety	Average	Min	Max	Standard error
Reed canary grass	'Marathon'	47.71	47.21	48.11	0.07
	'Bamse'	47.24	46.57	47.90	0.09
	'Pedja'	46.50	45.95	47.57	0.14
Tall fescue		47.55	47.07	48.19	0.09
Festulolium		47.14	46.28	48.05	0.14

The carbon content in biomass varies in the range 42-71% while in the C peat and coal it is 56-87% [13]. In our research the results show, that the conditions for cultivation have a substantial influence on the carbon content.

CONCLUSIONS

The carbon content for energy plants was substantially influenced by the agro meteorological conditions in the trial year.

The carbon content in lake reeds is about 42%, in reed canary grass it is 37-47%, in tall fescue and festulolium 47% for the biomass dry matter.

The phytotoxic elements As, Cd, and Pb form close fundamental negative correlations with carbon, reed canary grass dry matter at the start of the ash melting, the hemisphere point, and the ash flow temperature which forms a negative linear connection with the carbon content.

REFERENCES

1. Alaru M., Olt J., Kukk L., Luna-delRisco M., Lauk R., Noormets M. (2011) Methane yield of different energy crops grown in Estonian conditions. *Agronomy Research*, Biosystem Engineering Special Issue 1, pp. 13-22.
2. Belicka I., Miglāne V., Jansone Z. (2009) Vasarāju graudaugu sugu piemērotība siltumenerģijas ražošanai. In: *Environment. Technology. Resources: Proceedings of the 7th International Scientific and Practical Conference*. June 25-27, 2009. Rezekne, Latvia. Vol. 1, pp. 24-31.
3. *Cars A. Energoresursi (Energy resources). SIA Baltic Communication Partners, 2008. 102 p. (in Latvian).*
4. Čubars E., Noviks G. (2009) Evaluation of reed resources in the Lubanas lake and substantiation of their use in energy production. In: *Environment. Technology. Resources. Proceedings of the 7th International Scientific and Practical Conference* June 25-27, 2009, Vol. 1. Rezekne, 2009. pp. 66-73. (in Latvian).
5. Grāvītis J. (2004) Biorafinēšana–ķīmijas, biotehnoloģijas un inženierzinātņu krustpunktā. Zinātnes Vēstnesis, 2004. Nr. 6 (277) [Internet resource]: www.lza.lv/ZV/zv040600.htm (15.01.2010.) *(in Latvian).*
6. Grzybek A. (1999) Straw heating systems in Poland. In: *Renewable Energy in Agriculture: Proceedings of the International Conference Lithuanian Institute of Agriculture Engineering.* September 16-17, 1999. Raundonvaris, Lithuania. pp. 153-161.
7. Kivliņš A. (2004) Bioetanola attīstības perspektīvas Latvijā, balstoties uz pasaules pieredzi. *Latvijas Universitātes raksti*, 677. sēj., 184.-193. lpp.
8. Lasage E., Rousseau D.P.L., Meers E. Et.all. (2007) Accumulation of metals in the sediment and reed biomass of a combined constructed wetland treating domestic wastewater. In: *Water Air Soil Pollut 183*, pp. 253-264.
9. Lazdiņa D., Lazdiņš A., Bārdulis A. (2008) Daudzgadīga stiebrzāļu energokultūra – miežabrālis (Perennial grasses energy crop – canary reed seed). LVMI „Silava”, 2008. 10 p. (in Latvian).
10. Maciejewska A., Veringa H., Sanders J., Peteves S.D. (2006) *Co-firing of biomass with coal: constraints and role of biomass pre–treatment*. Luxemburg: Office for Official Publications of the European Communities. 100 p.
11. Magasiner N., van Alphen M., Inkson M., Misplon B. (2002) Characterising fuels for biomass – coal fired cogeneration. *International Sugar Journal*, Vol. 104, No. 1242, pp. 251-267.
12. Neuschütz C., Stolz E., Greger M. (2005) Root penetration of sealing layers made of fly ash and sewage sludge. *Journal of Environmental Quality,* Vol. 35, No. 4, pp. 1260-1268.
13. Vassilev S.V., Baxter D., Andersen L.K., Vassileva Ch.G. (2010) An overview of the chemical composition of biomass. *Fuel.* Vol. 89, pp. 913-933.
14. Wright I.G., Leyens C., Pint B.A. (2000) An Analysis of the potential for deposition, erosion, or corrosion in gas turbines fuelled by the products of biomass gasification or combustion, ASME Paper No. 2000-GT-0019. 15 p. *[tiešsaiste] [skatīts 2014. g. 05. apr.]. Pieejams:* http://www.docstoc.com/docs/22717516/AN-ANALYSIS-OF-THE-POTENTIAL-FOR-DEPOSITION-EROSION-OR#
15. Xiong S., Zhang Q–G., Zhang D–Y., Olsson R. (2008) Influence of harvest time on fuel characteristics of five potential energy crops in northern China. *Biosource technology*, Vol. 99, pp. 479-485.
16. Белосельский Б.С., Соляков В.К. Энергетическое топливо (Energy Fuel). Энергия. Москва, 1980. 168 c. (in Russian).