EVALUATE OF HEMP (*CANNABIS SATIVA* L.) QUALITY PARAMETERS FOR BIOENERGY PRODUCTION

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Abstract. In the research paper the calorific value and chemical composition of hemp will be analysed, also the melting temperature of ashes. The aim of the study was to evaluate hemp (*Cannabis sativa* L.) as a bioenergy resource. The hemp variety 'Bialobrzeskie' was sown in humi-podzolic gley soil in 2009 and 2010. Complex fertilizer was added before sowing N – fertilizer rates – N0 kg·ha^{-1} control, N60, and N100 kg·ha^{-1}. The net calorific value of hemp was 15.03-16.14 MJ·kg^{-1}, but the gross calorific value was 17.76-18.98 MJ·kg^{-1}, and the ash deformation temperature was 710-1450 ºC. The oil content in hemp seeds had great variations. The growing of hemp is beneficial to the environment, and hemp is also a good resource as a biofuel.

Keywords: *Cannabis sativa* L., ash, calorific value, oil content, chemical elements.

Introduction

During the Kyoto Conference in December 1997 Latvia agreed to reduce emissions. One of the options considered in the indication strategy was the substitution of coal heating systems for biomass heating systems.

Biomass fuel, the same as fossil fuel, has four important properties: the thermal capacity, the chemical properties, the physical properties and the combustion properties [1]. In comparison with coal, biomass has a greater proportion of alkaline metal elements (K, Ca, Mg, and Na), which are organically connected in various carbon structures [1-3].

Power plants set demanding requirements as regards the biomass properties; which include the total ash content, the melting behaviour, and the chemical composition. Commonly biomass contains less ash than coal; but a greater amount of alkaline metals in the ashes are usually responsible for fouling heat transfer surfaces [3].

The aim of this study was to evaluate hemp's (*Cannabis sativa* L.) as a bioenergy resource.

Materials and methods

Annual crops – hemp (*Cannabis sativa* L.) from the *Cannabinaceae* family were tested in the following locations and under the conditions described in Table 1.

Five consecutive hemp plants were cut 10 cm above the soil and then dried until the moisture content was 8-10 %. This was done to determine the shive content. The sample was weighed (accuracy ±0.0001 g), then scutched with the tool *ЛМ-3*, broken and shaken until the shives were withdrawn. Weighed again and the result was calculated by the formulas [4]. 5 % may be dust, etc. These substances were eliminated from the shive content.

The following parameters were tested:

- The moisture content, according to the standard ISO 589-81 LVS CEN/TS 14774-2.
- The ash content for dry material, according to the standard ISO 1171-81.
- The gross calorific value with V (volume) as a constant temperature for dried fuel at 105 ºC, according to the standard LVS CEN/TS 14918.
- The net calorific value with V as a constant, according to the standard LVS CEN/TS 14918.
- The ash melting behaviour oxidizing atmosphere, according to the standard ISO 540.
- The potassium (K), calcium (Ca), sodium (Na) and silicon (Si) concentrations in mineralized samples with concentrated nitric acid were determined with the inductively coupled plasma optical emission spectrometer *Perkin Elmer Optima 2100 DV*.
- The oil content in the seed samples was determined by the corn analyser *Infratec* 1241^{tm}, which has a specially adapted system; built - in for the analysis of flax and hemp.

Table 1

Trial methods

Trials year		In 2009	In 2010
Coordinates	X, m	683199.460	683214.254
	Y, m	6273258.971	6273355.805
Soil type	-	Humi-podzolic gley soil	
Soil composition	pH_{KCl}	7.3	7.0
	OM, %	3.8 (Turin's method)	6.5 (Turin's method)
	P_2O_5, mg·kg^{-1}	83 (DL method)	145 (DL method)
	K_2O, mg·kg^{-1}	65 (DL method)	118 (DL method)
Pre-crops	-	Summer rape	Bare follow
Complex fertilizers	N:P:K, kg·ha^{-1}	6:26:30, 300	18:9:9, 350
Sowing time	-	4th May	13rd May
Sowing rate	kg·ha^{-1}	70	60-70
Hemp varieties	-	'Bialobrzeskie' (Poland)	
N fertilizer rate	kg·ha^{-1}	N0, N60, N100	
Harvesting time	-	21st September	14th September
Trial plots	m^2	20	
Replication	-	4	3
Agro-chemicals		None	

The meteorological conditions during the hemp growing period are shown in Figure 1.

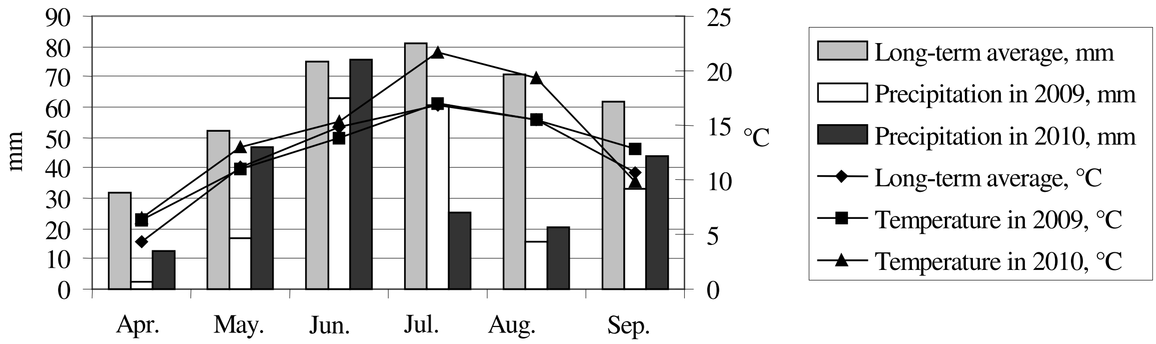

Fig. 1. **Average air temperature and total air precipitation from Viļāni (Latgale) for 2009-2010**

The MS Excel programme was used for data statistical processing. The ANOVA method was used, inclusive of correlation and regression analysis. The test of statistically significant differences ($LSD_{0.05}$) with the Fisher criterion (F-test) and the influence of the factors density were used for the analyses of mean differences [5; 6].

Results and discussion

Hemp is one of the few plants, which has a wide range of utilization for the whole of the plant: the fibre – in textile manufacturing, the shive – for animal bedding, the seeds – for food products, the leaves – as a fertilizer. Also the whole plant can be used as a biofuel.

From one tonne of hemp seed it is possible to extract 370 - 420 liters of hemp oil and about 600 kg of hemp cake [7]. By increasing the nitrogen N fertilizer norm, the oil content in hemp seeds is slightly increased (Table 1). The greatest standard error was noted, for both growth years, in the N fertilizer rate N60.

For the hemp variety 'Bialobrzeskie' total shive in 2009 was from 7 to 9 t·ha^{-1} [8], which is a good result and is dependant on the amount of N supplementary fertilizer applied.

The biomass ashes have comparatively low fusion temperature, the deformation temperature (*Dt*) is usually in the range from 750 to 1000 ºC. Coal ashes in comparison have a *Dt* level which exceeds 1000 ºC, as the ash chemical and mineral content is significantly different [9].

Table 2

Oil content in hemp seed 'Bialobrzeskie', %

Year	N fertilizer rate, kg·ha^{-1}	Oil content in seed DM			
		Average	min	max	Standard error
2009	N0	34.4	32.1	37.1	1.55
	N60	34.8	30.2	44.5	4.10
	N100	35.5	32.3	42.2	2.85
2010	N0	30.8	26.0	36.4	2.88
	N60	32.5	27.7	37.5	3.46
	N100	32.8	29.3	37.9	2.45

For hemp the ash fusion temperature varies according to the year: in 2010 it was higher than for coal, but in 2009 lower (Table 2). For the hemp variety 'Bialobrzeskie' samples for 2009 the *Dt* level was observed within the range 710-890 ºC (during sublimation), as during the growth period there was a precipitation deficit, but the temperature was consisted with the long-term average (Fig. 1). Other researchers [1; 3] have shown that the presence of alkali metals, phosphorus, chlorine, silicon and calcium is a determining factor for the ash fusion temperature. Also in our research the hemp in 2009 had a greater amount of alkali metals and Ca as compared to 2010 (Fig. 2).

Table 3

Ash fusion temperatures – in an oxidising atmosphere

Samples	Year	Plant organ	N fertilizer rate, kg·ha^{-1}	Temperature, ºC			
				Deformation	Sphere	Hemisphere	Flow
Coal [1]	-	-	-	1400	1400	1400	1400
Bagasse[1]	-	-	-	1380	1400	1400	1400
Hemp 'Bialobrzeskie'	2010	Straw, Shive	N0, N60, N100	1450	>1500	>1500	>1500
	2009	Straw	N0	850	>1500	>1500	>1500
			N60	890	>1500	>1500	>1500
			N100	850	>1500	>1500	>1500
		Shive	N0	750	>1500	>1500	>1500
			N60	710	>1500	>1500	>1500
			N100	850	>1500	>1500	>1500

Biomass with a definite K, Ca, Mg and Na amount encourages sticky slag coatings to form on the heating boilers. Biomass has a larger amount of alkaline metals than wood, which can be explained by the use of pesticides and fertilizers for cultivated crops [2]. Our research shows the influence of the cultivation year and the N fertilizer use on the chemical composition of hemp (Fig. 2). By increasing the amount of N fertilizer, there is a reduction of Na in the plants. The amount of potassium in hemp during the 2010 growth period was unchanging, but the amount of Si was twice as large as in 2009.

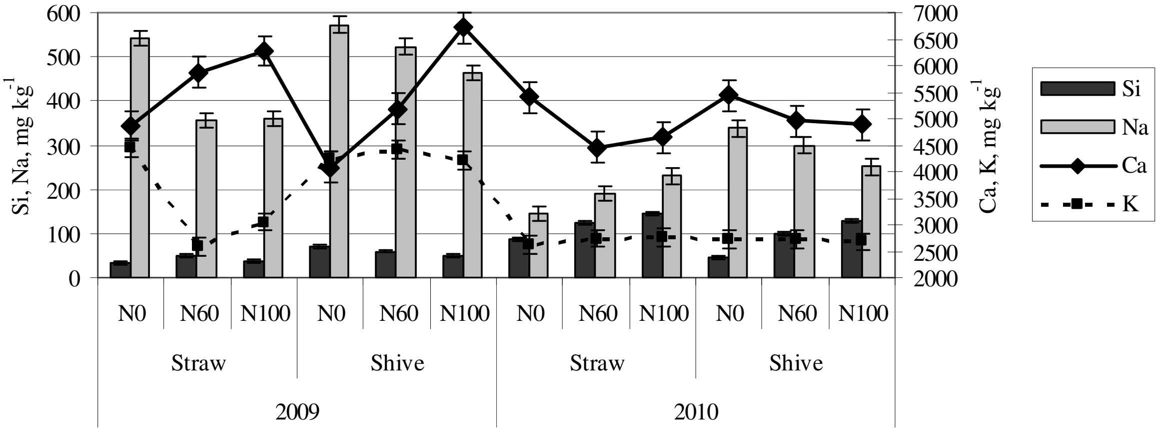

Fig. 2. **Chemicals elements - Si, Na, Ca and K in hemp variety 'Bialobrzeskie'**

Usually biomass contains less ash than coal and their composition is based on the chemical composition required for plant growth, whereas coal ashes have a mineralogical composition [3]. Hemp ash is a very valuable fertilizer. It contains 24 % CaO, 4.85 % P_2O_5 and 6.3 % K_2O [10].

A fundamentally close (p<0.001) linear negative correlation has been observed between the net calorific value $Q_{net}(x)$ and ash content (y) (r=-0.893; n=12). The connection is reflected by the regression equation y=-0.9172x+16.534; R^2=0.797 (Fig. 3). In the same way a fundamental mean linear negative correlation (p<0.05) between the gross calorific value $Q_{gr.d}(x)$ and ash content (y) (r=-0.5799; n=12) (Fig. 4).

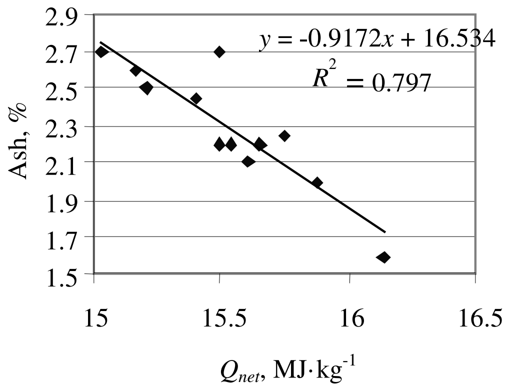

Fig. 3. **Interaction (p<0.05) between average ash content and average net calorific value of hemp variety 'Bialobrzeskie'**

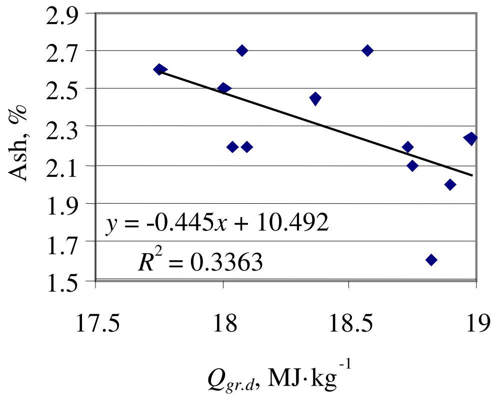

Fig. 4. **Interaction (p>0.05) between average ash content and average gross calorific value of hemp variety 'Bialobrzeskie'**

Hemp stems are used as a fuel, the minimal thermal capacity is 15.739 MJ·kg^{-1}, which is slightly less than the coal from Donetsk (20.09 MJ·kg^{-1}) and fundamentally greater than the thermal capacity of wood (11.30 MJ·kg^{-1}) and cut peat (8.498 MJ·kg^{-1}) [10]. Our research has established the thermal capacity of hemp as; Q_{net}= 15.03-16.14 MJ·kg^{-1}, and $Q_{gr.d}$=17.76-18.98 MJ·kg^{-1}. Hemp with its energy qualities, - the high thermal capacity and relatively large dry matter yield (DM yield) is a good source material for the production of energy; especially, if it is utilised mixed with other energy source materials [11].

Conclusions

1. The oil content in hemp seeds is from 30% to 35%, dependant on the agrometeorological conditions in the growth year.
2. The hemp variety 'Bialobrzeskie' samples from the 2009 crop had the ash deformation temperature from 710-890 ºC (during sublimation), but for the 2010 samples it was 1450 ºC. That is because the 2009 growth period had a precipitation deficit, and within the hemp samples a larger amount of alkaline metals and Ca was noted in comparison with 2010.
3. The growth year and the nitrogen fertilizer norm influenced the chemical composition of hemp. Increasing the N fertilizer norm decreased the amount of sodium in hemp. The amount of potassium for the 2010 growth year was unchangeable, but the amount of silicon was greater than in 2009.
4. The hemp thermal capacity was Q_{net} =15.03-16.14 MJ·kg^{-1}, and $Q_{gr.d}$ =17.76-18.98 MJ·kg^{-1}. The highest and lowest thermal capacity had a fundamental linear negative correlation with the ash content.

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