EVALUATION OF FACTORS INFLUENCING ASH MELTING CHARACTERISTICS IN LINSEEDS AND HEMP

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Abstract. Ash melting temperature in biomass fuels is lower, as compared to the fossil fuels. The study was conducted with an aim to evaluate a variety of factors (agro-meteorological conditions, chemical composition of straw and shives, nitrogen fertilizer rates) influencing the ash melting temperature. The objects of the research are linseed and hemp. The plants used within the research were grown in humi-podzolic gley soil, and afterwards, during the time period 2008-2010, the acquired samples were tested in the Agricultural Science Centre of Latgale (Latvia) and Upyte Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry (Lithuania). The following parameters were studied: 1) chemical composition of straw and shives (ISO 11466; ISO 625, ISO 333, ISO 334); 2) ash melting characteristics in oxidizing atmosphere (ISO 540); 3) yield (ISO 6496); 4) and ash content (ISO 1171 – 81). The ash melting temperature of hemp dry matter was lower than 1000 ºC. The research indicated some ash melting anomalies – sublimation (in 2009). As compared to 2010, the ash content in 2009 was 2.0-3.0 times higher, and the amount of alkali and alkaline elements also was higher.

Keywords: ash melting characteristics, hemp, linseed.

Introduction

Population on the Earth is growing every year; therefore, the energy consumption all over the world and in Latvia as well is increasing. Earth nature is varied, while available resources still are limited. Natural resources used in the energy production probably may run short before finding solutions to substitute them. Society is polluting environment with various emissions and chemicals regardless the fact that air and water are vitally necessary for living organisms. With an aim to reduce pollution, the use of biomass in energy production should be facilitated by substituting commonly utilised fossil fuels – coal and oil products. Biomass may be used differently, e.g., as a biofuel.

In Latvia combustion experiments have been conducted fragmentary and only on several plant species or parts thereof at relatively low temperatures not causing ash sintering. Researchers from the State Stende Cereal Breeding Institute and the LUA Institute of Mechanics in 2007-2008 researched in the ash melting temperature of spring wheat and barley, oats and winter crops (wheat, rye, triticale) and the factors influencing it (experiment year, specie, variety, plant part) [1].

The aim of the research is evaluation of various factors – agro-meteorological conditions, chemical composition of straw and shives, and nitrogen fertilizer rates – influencing the ash melting temperature.

Materials and methods

Annual crops – hemp (*Cannabis sativa* L.) from the *Cannabinaceae* family and linseed (*Linum usitatissimum* L) from the *Linacea* family – were tested in the locations during the time period 2008 – 2010 and under the conditions described in the articles [2-4] as well as hemp (*Cannabis sativa* L.) of different varieties with low THC content were tested in Lithuania. Yield capacities of the tested crops were evaluated under different agro-climatic conditions. The following parameters were tested: 1) chemical content of straw and shives (ISO 11466; ISO 625, ISO 333, ISO 334); 2) ash melting behaviour in oxidizing atmosphere (ISO 540; 3) yield (ISO 6496); 4) ash content (ISO 1171 – 81).

To evaluate the moisture conditions in a particular territory, agro-meteorology suggests using the hydrothermal coefficient of Selianinov (1928) (HTC of Selianinov) [5-7], as it shows the ratio between precipitation during a certain time period (e.g., vegetation period) and evaporation.

The trial data were processed using correlation, regression and variance analyses (ANOVA) and descriptive statistics with the programme Microsoft Excel for Windows 2000 [8]. The means are presented with their LSD test values.

Table 1

Water stress expressed as hydrothermal coefficient (HTC) in 2008-2010

Parameter	In Viļāni			In Upyte		
	2008	2009	2010	2008	2009	2010
HTC in April	0.59	0.00	0.66	2.19	-	-
HTC in May	0.89	0.61	1.75	0.99	0.50	1.46
HTC in June	1.21	2.23	2.77	1.23	1.69	1.43
HTC in July	1.28	2.12	0.90	1.22	1.96	1.58
HTC in August	2.44	0.74	0.74	2.08	1.42	1.12
HTC in September	0.91	1.68	1.71	0.40	1.06	-

- HTC ≤ 0.5 – strong, very strong drought;
- HTC = 0.6 – weak drought;
- HTC ≤ 0.7 – dry conditions;
- HTC ≥ 1.0 – sufficient moistening;
- HTC > 2.0 – too high moisture;

Results and discussion

Evaluation of the nitrogen fertiliser rate influence on the hemp ash melting temperature showed that it is not influencing the hemisphere temperature (*Ht*) and flow temperature (*Ft*), i.e., the temperatures are stable – higher than 1500 ºC. If nitrogen (N) fertiliser rates are increased, the ash melting deformation temperature is reducing in both – hemp shives and hemp straw [3; 4]. Still higher ash melting temperature was observed for hemp stalks, as compared to hemp shives.

The ash melting deformation temperature of hemp stalks (n = 15; $P < 0.05$) indicates positive linear correlation with silicon (Si) (r = 0.74), negative with potassium (K) (r = -0.59), sodium (Na) (r = -0.63), whereas the ash melting deformation temperature of hemp shives shows positive linear correlation with Si (r = 0.56), and negative with K (r = -0.89) and Na (r = -0.61) (Fig. 1). Similar relationships are observed also for the hemp species grown in Lithuania. The study resulted in finding that the ash melting temperature has significant and positive correlation with Na and Ca as well as negative correlation with K. Similar results were obtained in the research carried out by the State Stende Cereal Breeding Institute on spring cereals (2007-2008) [1].

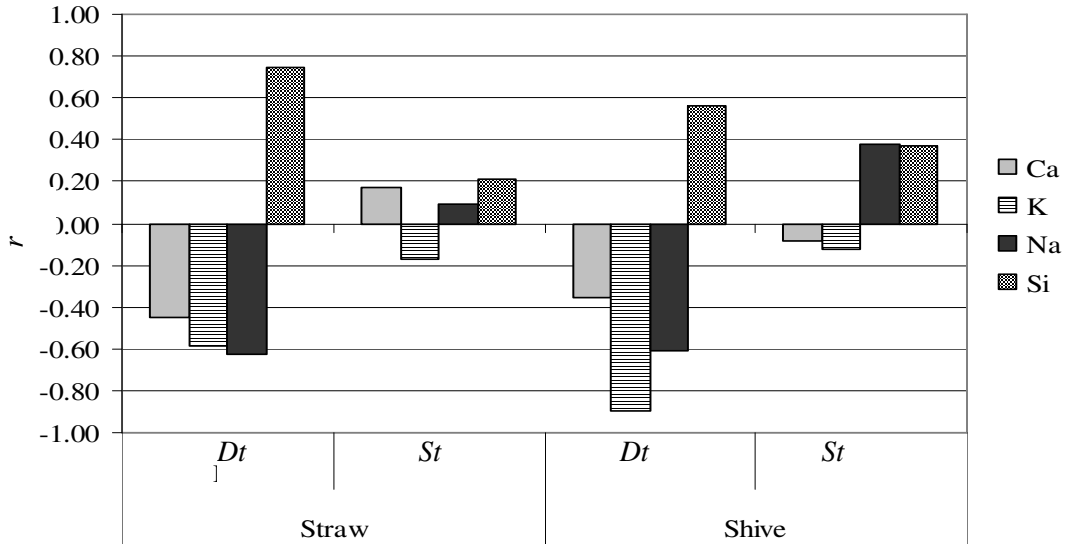

Fig. 1. **Hemp (n = 15) correlations between ash melting temperature and chemical content:** *Dt* – deformation temperature; *St* – sphere temperature

To increase the ash melting deformation temperature it is necessary to reduce the ash content in hemp ($P < 0.05$). The equation $y = -112.59x + 1429$ shows the dependence of the ash melting deformation temperature upon the ash content. Significant ($P < 0.05$; n=20) correlations in linseed

stalks and shives were observed only between *Dt* and *Si* (r = -0.57), *St* and *Na* (r = 0.41), *St* and *Si* (r = -0.47).

Scientific researches [9; 10] show that presence of alkali metals (phosphorus, chlorine, silicon) and potassium is a significant factor influencing the ash melting temperature. The most often reduction of the ash melting temperature is related to the rise in the potassium content [11]. Also German researchers V. Scholz, R. Ellerbrock [12] have indicated that potassium in biomass fuels causes boiler corrosion and diminishes ash melting, and as a result dross is formed.

Researchers from the State Stende Cereal Breeding Institute [13] in their study on winter cereals assumed that the ash melting temperature is influenced by the plant chemical content that under the influence of high temperatures facilitates certain chemical reactions [13]. Meteorological conditions affect the plant growth and nutrition during the particular experiment year. The weather conditions in Latvia and Lithuania in 2008-2010 differed (Table 1). July 2010 was hot and sunny, air temperature in several days reached 32-33 ºC, while average air temperature in July comprised 21.7 ºC (4.8 ºC higher than norm). Precipitation reached 25.1 mm – 31% of the average annual indicator. Soil was very dry. Due to the hot weather, plants were wilting. June and July 2009 may be characterised as too wet months. This fact may explain the differences in the chemical content of plants that is varying among the years and also versatile crop quality, and that, in turn, influences the ash melting temperature.

Meteorological conditions influence not only ash melting, but also the yield of hemp and linseed. Average harvested yield (dry matter DM) of hemp straw (variety "Pūriņi") was the highest in 2009 – 9.53 t·ha^{-1}, and the lowest in 2008 – 7.03 t·ha^{-1}, while average yield of hemp straw (variety "Bialobrzeskie") dry matter was the highest in 2010 – 14.29 t·ha^{-1}, and the lowest in 2009 – 13.63 t·ha^{-1}. The harvested yield of linseed straw DM was the highest in 2009 – 2.6 t·ha^{-1}, whereas the lowest in 2010 – 1.49 t·ha^{-1}. The amount of the harvested shives constituted approximately 20-30 % of the average yield in the corresponding experiment year.

In Lithuania, the highest hemp yield was recorded in 2009: for the variety "Bialobrzeskie" it was 18.1 t·ha^{-1}, while average yield of all varieties tested comprised even 19.8 t·ha^{-1} of dry matter. The lowest hemp yield in Lithuania was fixed in 2010. The average yield of all varieties tested was close to 10.5 t·ha^{-1}, while the yield of the hemp variety "Bialobrzeskie" was 11.6 t·ha^{-1} of dry matter.

Deviations from the desirable ash melting temperature were observed (2008 - 2010). In 2009, the deformation temperature of linseed chaff indicated sublimation (when using nitrogen fertiliser rate 0 kg·N·ha^{-1}), while linseed shives showed sublimation in 2010 (when using 0-100 kg N·ha^{-1}) (Figure 2). The hemisphere temperature (*Ft*) was not fixed, because the drip structure disappeared and the liquid vented phase was not formed.

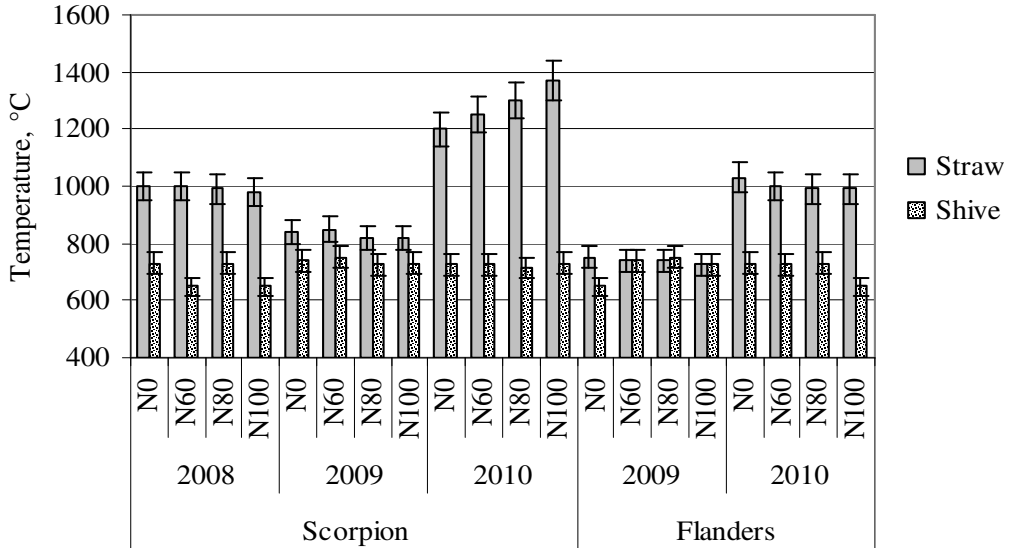

Fig. 2. **Ash melting deformation temperature of linseed in Latvia depending on experiment year, variety and N fertiliser norm**

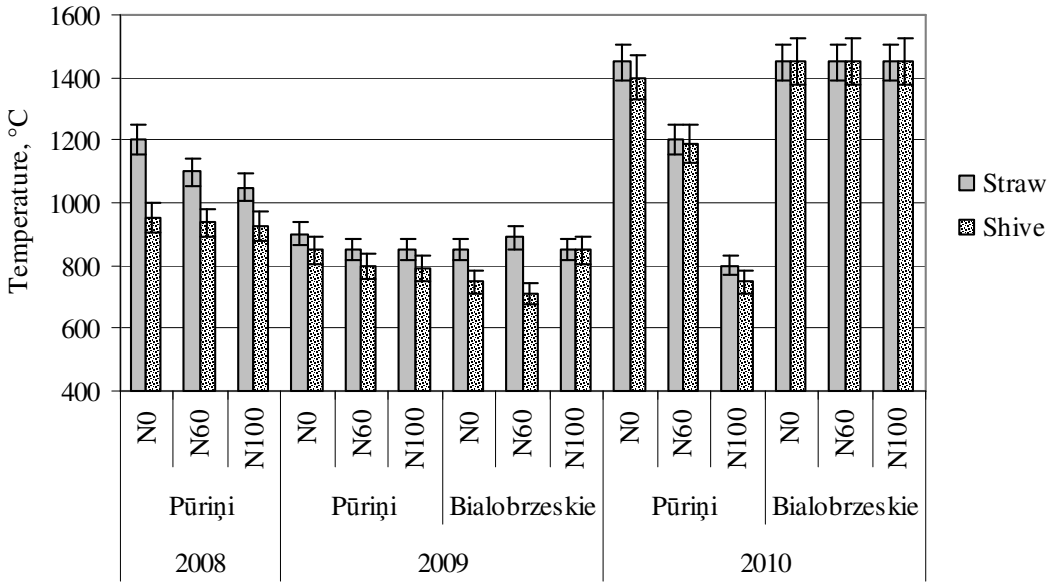

Fig. 3. **Ash melting deformation temperature of hemp in Latvia depending on experiment year, variety and N fertiliser norm**

In 2009, more than a half of the hemp samples indicated sublimation (710-850 ºC) in deformation temperature (Fig. 3). This year the crop samples indicated higher content of alkali and alkaline earth metals, and the ash content was even two times higher than that in 2010.

In 2010, when the plants were harvested in the middle of August, strong *Dt* sublimation (starting from 710 ºC) was observed in both samples harvested in Latvia and Lithuania. It may be explained by the fact that hemp in August is still growing rather rapidly until the blooming phase. Researcher M. Talevska [14], when studying *Potamogeton Perfoliatus* L., found out that the potassium, sodium and calcium content is changing during various vegetation months – it is higher at the development peak (in this case – in August) and afterwards the amount of nutrients is reducing.

Among the hemp samples harvested in September, only "Pūriņi" indicated sublimation – the sample retains its form, while the volumes are slightly changing. The hemp samples are maintaining their form also if *Ht* is raised to 1500 ºC, while in the Ft phase further sublimation was not observed.

Conclusions

1. The ash melting temperature depends on the agro-meteorological conditions during the experiment year that notably influence the chemical content of crops.
2. A higher content of alkali and alkaline metals in plants facilitates sublimation during ash melting.
3. The ash melting deformation temperature is influenced by the N fertiliser rates applied.

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