ASH MELTING BEHAVIOUR OXIDIZING ATMOSPHERE IN ENERGY CROPS

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Abstract. The way ashes stick together is dependant on the ash melting temperature. The ash melting temperature which is above 1500 ºC, does not show the ash melting or formation of pieces. On the other hand, a lower(<1300 ºC) melting temperature means, that to burn these materials it is important to observe correct burning procedures, to ensure the grating mechanism is not damaged. The summary of the mean research results for the last three years show an overall insight into the melting conditions for ashes in an oxidizing atmosphere for three energy crops (reed canary grass, hemp and linseed). Therefore, in this paper mainly common trends are emphasized. The lowest ash melting temperature was established for linseed. The nitrogen fertilizer norm was small affected for the deformation temperature for the local hemp. The ash melting temperature in reed canary grass, hemp and linseed is dependant on the carbon and lignin content in the crops. That means that the meteorological conditions in the specific growth period influence the crop nutrition and also the biomass fuel energy properties.

Keywords: *Cannabis sativa* L., *Linum usitatissimum* L., *Phalaris arundinacea*, ash melting behaviour.

Introduction

The way ashes stick together is dependant on the ash melting temperature. The ash melting temperature above 1500 ºC, does not show the ash melting or formation of pieces. On the other hand, a lower melting temperature (<1300 ºC) means, that to burn these materials, it is important to observe the correct burning procedures, to ensure the grating mechanism is not damaged.

The ash melting temperature, determined by all four of the standardized values, changes over a very wide scale, even within the boundaries of one biomass group, nonetheless the basic deformation temperature exceeds 1200 ℃, which allows the biomass fuel to be used in household and industrial boilers. Mainly the incineration experiments were achieved with a relatively low temperature, when the ashes had not stuck together yet. The lowering of the melting temperature is most commonly associated with an increase in the potassium oxide content [1]. Biomass ashes have a comparatively low ash melting temperature – deformation temperature (Dt) mainly within the range of 750 to 1000 ºC [2 – 3]. The aim of the research is to evaluate the ash melting behavior for energy crops (reed canary grass, hemp and linseed) in an oxidizing atmosphere.

Materials and methods

Annual crops – linseed (*Linum usitatissimum* L.) from *Linacea* family and hemp (*Cannabis sativa* L.) from *Cannabaceae* family and perennial crop – reed canary grass (*Phalaris arundinacea* L.) from family *Poaceae* were tested in Latvia and under the conditions described in Table 1. The trial was carried out in the Agricultural Science Centre of Latgale in 2008 – 2010.

Table 1

Trial methods in 2008 - 2010

Energy crop sort - variety	**Reed canary grass – “Marathon”**	**Hemp – local hemp “Pūriņi”**	**Linseed – “Scorpion”**
Soil type	Sod-podzolic loamy soil	Humi-podzolic gley soil	
Soil composition	$pH_{KCl} = 5.8$	$pH_{KCl} = 7.0 – 7.3$	
	OM = 5.2 %	OM = 3.8 – 6.5%	
	$P_2O_5 = 20$ mg·kg^{-1}	$P_2O_5 = 83 – 145$ mg·kg^{-1}	
	$K_2O = 90$ mg·kg^{-1}	$K_2O = 65 – 118$ mg·kg^{-1}	
Pre-crops	Bare fallow	Spring rape in 2008 and 2009, winter wheat in 2010	
N:P:K Fertilizers	N:P:K 5:10:25, 400 kg ha^{-1}	6:26:30, 300 kg ha^{-1} in 2008 6:26:30, 300 kg·ha^{-1} in 2009 18:9:9, 350 kg·ha^{-1} in 2010	6:26:30, 300 kg ha^{-1} in 2008 6:26:30, 300 kg·ha^{-1} in 2009 18:9:9, 350 kg·ha^{-1} in 2010

Table 1 (continued)

Energy crop sort - variety	Reed canary grass – "Marathon"	Hemp – local hemp "Pūriņi"	Linseed – "Scorpion"
Sowing time	12th August in 2008	9th May in 2008 4th May in 2009 13th May in 2010	9th May in 2008 4th May in 2009 6th May in 2010
Seeding rate	25 kg·ha-1	70 kg·ha-1	70 kg·ha-1
N fertilizer rate	N0, N30, N60, N90 kg·ha-1	N0, N60, N100 kg·ha-1	N0, N60, N80, N100 kg·ha-1
N fertilizer time	20th April 2009 21st April 2010	11th June in 2008 10th June 2009 1st June 2010	19th June in 2008 15th June 2009 1st June 2010
Harvesting/ picking time	12th October in 2009 6th April in 2010 6th October in 2010	23rd September in 2008 21st September in 2009 7th September in 2010	29th August in 2008 28th August in 2009 10th August in 2010
Trial plots	16 m2	20 m2	7.5 m2
Replication	3	4, but 3 in 2010	4

The following parameters were tested: 1) carbon content, according to the standard ISO 625; 2) sulphur content, according to the standard ISO 334; 3) gross calorific value ($Q_{gr.d}$) with V (volume) = constant for dried fuel at 105 ºC, according to the standard LVS CEN/TS 14918; 4) ash melting behaviour oxidizing atmosphere, according to the standard ISO 540; 5) lignin content in the samples was determined using the method of Classon [4]. The differences between the sample repetitions are no more than 5 %.

The MS Excel programme was used for data statistical processing. The statistical evaluation of the data was carried out by using the methods of correlation and regression, and dispersion analysis, as well as descriptive statistics [5 – 6].

Results and discussion

The growth periods during 2008 – 2010 were distinctive in Latvia. The amount of rainfall in May 2008 was 39.6 %, in June 54.4 % and in 2009 accordingly 32.3 % and 61.1%, from the mean long – term level (52 mm). The mean temperature for July 2008 was 0.5 ºC lower, and for 2009 0.1 ºC lower than the long – term mean temperature of 16.9 ºC. The rainfall amount respectively 82.7 % and 74.7 % from the long term mean of 81 mm. In the first ten days of May the rainfall exceeded the norm and achieved 18.7 mm or 125 % of the long term mean indicator. 2010 July was a hot and sunny period. For a few days the air temperature was between 32 – 33 ºC. The mean temperature for the 24 hour period in July was 21.7 ºC, over 4.8 ºC greater than the norm. The rainfall amount was 25.1 mm, which was 31 % of the long – term mean. The hot and dry climate influenced negatively the growth and development of linseed. The soil had a noticeable moisture deficiency. Due to the great heat, plant withering was noticed as well.

Evaluating the influence of the growth year, it can be seen, that the deformation temperature start (Dt) for linseed was the lowest in 2009 (832 ºC) and the highest in 2010 (1280 ºC); for local hemp the lowest in 2009 (866 ºC) and the highest in 2010 (1150 ºC) ; for reed canary grass the lowest on the 6th October 2010 (990 ºC) and the highest on the 6th April 2010 (1300 ºC) (Fig. 1, Fig. 2, Fig. 3). For each energy crop there are noticeable differences between the varieties, for instance, for summer wheat straw the (Dt) is in the range of 885 – 1003 ºC according to the variety [3].

Evaluating the energy crop – reed canary grass, hemp and linseed – melting temperature; it can be seen that the lowest deformation start temperature is for linseed, achieving the maximum temperature in the flow stage. The ash melting temperature is dependant on the chemical composition of the ash and small elemental changes can show substantial temperature changes [3].

Great influences on the effectiveness of the fertilizer use are the specific annual growth conditions, including the amount of rainfall and temperature, and drier years show greater effectiveness [6]. Also our research results have shown, that the greatest Dt for reed canary grass was using N 60 kg·ha^{-1}, for linseed – N100 kg·ha^{-1}, and for local hemp – N0 kg·ha^{-1}. That means, that the nitrogen application rate must be such, that the crop is economically viable. With higher fertilizer rates the nitrogen fertilizer utilization coefficient is reduced, therefore, there is a risk that the unutilized nitrogen compounds can pollute the environment by reaching reservoirs by the action of rainfall [8].

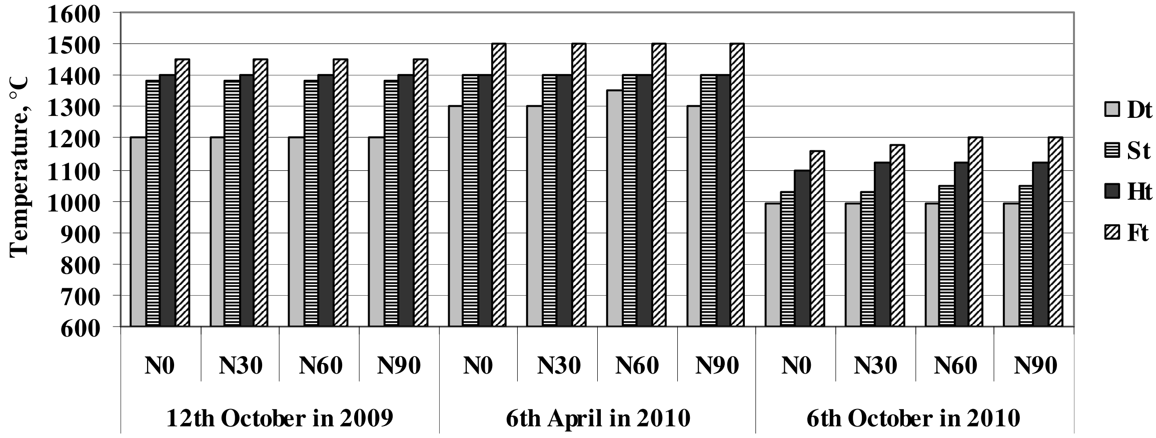

Fig. 1. **Ash melting behaviour oxidizing atmosphere depending on the reed canary grass variety "Marathon" harvesting time, and N fertilizer rates:** Dt – deformation temperature, St – sphere temperature, Ht – hemisphere temperature, Ft – flow temperature

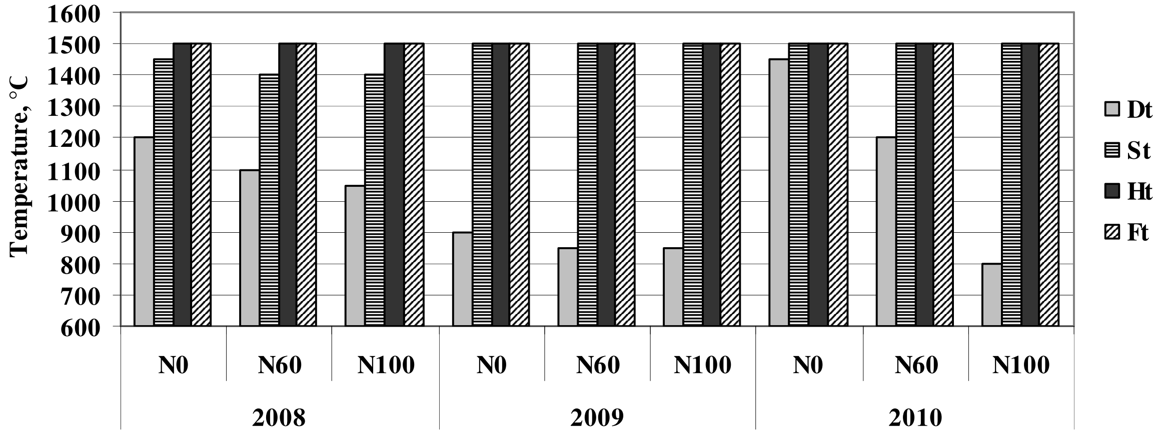

Fig. 2. **Ash melting behaviour oxidizing atmosphere depending on the local hemp "Pūriņi" growing year, and N fertilizer rates:** Dt – deformation temperature, St – sphere temperature, Ht – hemisphere temperature, Ft – flow temperature

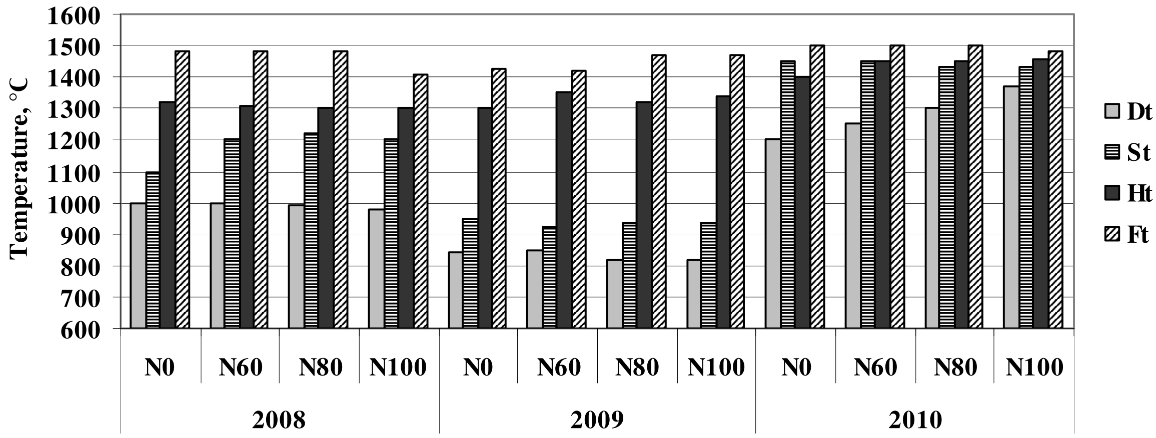

Fig. 3. **Ash melting behaviour oxidizing atmosphere depending on the linseed variety "Scorpion" growing year, and N fertilizer rates:** Dt – deformation temperature, St – sphere temperature, Ht – hemisphere temperature, Ft – flow temperature

The ash flow temperature (Ft) for each variety was different – for reed canary grass 1160 – 1500 ºC, for local hemp – 1500 ºC, for linseed 1410 – 1500 ºC, which was greater than for cereal straw (1075 – 1223 ºC) [3]. The growth year and the nitrogen fertilizer norms influenced the Ft less than the Dt.

For biomass fuel the content indicators of ash, sulphur, carbon and lignin are important. Our research has established the correlation and deformation coefficients between the Dt (x) and ash, S, C, lignin content and the gross calorific value (y) (Table 2).

Table 2

Correlation coefficients and characteristics of linear regression between ash deformation temperature and ash, S, C, lignin content and calorific value from different energy crops

Parameters	Reed canary grass – "Marathon"	Hemp – local hemp "Pūriņi"	Linseed – "Scorpion"
Correlation	Deformation temperature, ºC		
Carbon content	-0.78*	-0.67*	0.39
Sulphur content	0.54*	0.19	-0.59*
Ash content	0.12	-0.44	-0.12
Lignin content	0.50*	0.19	0.75*
Gross calorific value	-0.32	0.03	0.95*
Characteristics of linear regression	Deformation temperature, ºC (y)		
Carbon content (x)	$y = -0.0121x + 51.903$	$y = -0.006x + 43.433$	$y = 0.006x + 36.345$
Sulphur content (x)	$y = 0.0002x-0.042$	$y = 3 \cdot 10^{-5}x + 0.121$	$y = -0.0001x + 0.241$
Ash content (x)	$y = 0.0036x + 2.506$	$y = -0.003x + 6.128$	$y = -0.0003x + 1.816$
Lignin content (x)	$y = 0.0068x + 13.618$	$y = 0.0035x + 30.369$	$y = 0.003x + 21.483$
Gross calorific value (x)	$y = -0.001x + 18.532$	$y = 2 \cdot 10^{-5}x + 18.594$	$y = 0.0019x + 1.816$
Samples	$n = 12$	$n = 9$	$n = 12$

* Correlation is significant at the 0.05 level.

Our research has established, that there is a fundamental negative linear correction between C and Dt for reed canary grass and local hemp, and a positive linear connection between the lignin content and Dt. That shows that the ash melting temperature is influenced by the plant chemical composition, that the effect of a high temperature produces definite chemical reactions [3]. The meteorological conditions also influence the plant growth and conditions for the absorption of nutrients in a specific growth year.

Conclusions

1. The highest ash melting temperature was observed for the local hemp "Pūriņi"", followed by the reed canary grass variety "Marathon" and the linseed variety "Scorpion". The ash melting temperature Dt is influenced by the growth year, but the Ft effectively is not influenced.
2. The increase of the nitrogen fertilizer norms for reed canary grass, local hemp and linseed does not increase the ash melting temperature significantly for these energy crops.
3. The ash melting temperature is influenced by the carbon and lignin content in the plants.

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