HEMP QUALITY PARAMETERS FOR BIOENERGY-IMPACT OF NITROGEN FERTILIZATION

Liena Poisa[1], Skaidrite Bumane[2], Edgars Cubars[3], Lidija Antipova[4]
[1]Latvian University of Agriculture, [2]Latvian Plant Protection Research Centre;
[3]Rezekne Technologies Academy, Latvia; [4]Mykolayiv State Agrarian University, Ukraine
lienapoisa@inbox.lv, skaidrite.bumane@laapc.lv, edgars.cubars@inbox.lv, antipova2001@email.ru

Abstract. The aim of the research – to evaluate the nitrogen fertilizer rate impact on the energetic parameters of hemp. The nitrogen fertilizer rate effect on the hemp ash content depends on the hemp variety: for the local variety "Pūriņi", with the increase of the nitrogen fertilizer rate, the ash content decreases, while for the variety "Bialobrzskie" – it is the opposite – increasing the nitrogen fertilizer rate, the ash content increases. Change of the nitrogen fertilizer rate from N_0 to N_{100} increased the resulting thermal capacity from one hectare. In this research it was observed that a higher thermal capacity has a positive ($p < 0.001$) connection with the harvest yield amount. For the sown hemp the nitrogen rate variation increased the thermal energy amount from one hectare for shives by 73 % ("Pūriņi") and 31 % ("Bialobrzskie"), for the stalks by 66 % ("Pūriņi") and 36 % ("Bialobrzskie"). The highest determined thermal capacity for hemp was 171.71 ± 18.31 $GJ \cdot ha^{-1}$.

Keywords: energetic parameters, nitrogen fertilizer rates, hemp, ash content.

Introduction

For biomass fuel, the same as for fossil fuel, there are four important characteristics – the thermal capacity; the chemical characteristics; the physical characteristics; the combustion characteristics [1].

Biomass fuel differs from coal as it causes problems in the functioning of a furnace, which manifests itself as follows - for biomass pyrolysis starts earlier than for coal; the amount of evaporable matter is greater for biomass than for coal; evaporable matter in biomass is about 70 %, in comparison it is 30-40 % for coal; the particular thermal capacity ($kJ\ kg^{-1}$) for the evaporable matter in biomass is lower than for coal; in the biomass structure there is more oxygen than for coal, and it is more porous and reactive; biomass ashes are more alkaline, which can increase the pollution problems and biomass can contain a high chloride content [2].

The fertilizer utilisation effectiveness depends on the specific growth factors for the year, including precipitation amounts and temperature; the drier years are the most effective [3]. The nutrient accessibility and the quality of the acquired yield depend on the fertilizer resource, which essentially affects the ash content [4; 5]. The main (most important) nitrogen fertilizer effectiveness parameter is the gross production increase.

The objective of this research – to evaluate the nitrogen fertilizer rate impact on the energetic parameters of hemp.

Materials and methods

Hemp productivity and quality evaluation research was carried out in the period from 2008 to 2010. The trials took place in the research plant plots of SIA "Agricultural Science Centre of Latgale", Latvia.

Sown hemp trials were on the soil type – sod gleysoil (organic matter content 35-38 $g \cdot kg^{-1}$, pH KCI 7.0-7.3, available plant phosphorus content – 83 – 145 $mg \cdot kg^{-1}$ P_2O_5, potassium content – 65-b 118 $mg \cdot kg^{-1}$ K_2O – Egner – Riehm method). Hemp trial plots were 20 m^2 in three replicates. The seed norms for hemp were 70 kg ha^{-1}. The nitrogen fertilizer (ammonium nitrate – 34 % N) was given as follows 0 $kg \cdot ha^{-1}$ nitrogen, 60 $kg \cdot ha^{-1}$ nitrogen, 100 $kg \cdot ha^{-1}$ nitrogen as a pure ingredient (designation N_0, N_{60}, N_{100}) when the hemp had formed 3-6 leaves for a couple. Pesticides were not used. Hemp growth was within the optimal dates corresponding to the plant development phases and meteorological conditions in the vegetation period.

Hemp (*Cannabis Sativa* L.) variety "Bialobrzskie" (registered in the year 1968) is a resultant hybrid from various monoecious and dioecious hemp plants. Local hemp variety "Pūriņi" has been cultivated for more than 200 years in the Vidzeme region Rūjiena municipality, farm "Piksāres".

Insufficient moisture was noted during April for the whole 2008 – 2010 year period, which presented good conditions for sowing, but could promote non–uniform germination. June (2009), July

(2009, 2010) and August (2008) were excessively damp. The optimal moisture requirement was observed in June (2008) July (2008) and September (2009, 2010), which is likely to have helped the hemp growth and seed ripening.

Hemp samples were used without leaves (i.e flowerheads) and roots (plant was cut 8 – 10 cm above the ground). Above ground hemp samples were divided in two parts – whole plant and shive.

The phloem fiber and shive content was determined as arithmetic average for the three repeat samples.

The chemical analysis of the plant samples was performed using established standard methods:

- sample dry matter was determined at 105 ºC; drying to constant weight;
- ash content for dry matter – A – (IS0 1171 – 81);
- thermal capacity greater than V = const established from dried samples at 105°C – *Qa*. (LVS CEN/TS 14918) with a calorimeter IKA C 5003
- ash melting conditions in oxidising atmosphere – Dt, St, Ht, Ft , (ISO 540);
- calcium (Ca), potassium (K), sodium (Na), silicon (Si) elemental concentration was established with an inductive plasma optical emission spectrometer Perkin Elmer Optima 2100 DV (X – ray fluorescence method, atom absorbtion spectroscopy (ISO 11466)).

The analysis results were statistically processed using descriptive and variable statistics; correlation and dispersion analysis with Microsoft Excel for windows 2000 and the SPSS program package[6].

Results and discussion

For the hemp variety "Pūriņi" the ash content in shives was 3.54 ± 0.21 % and in the stem – 2.99 ± 0.23 % of the dry matter respectively, while for the variety "Bialobrzeskie" the shive ash content was 2.16 ± 0.07 % and in the stem it was 3.02 ± 0.08 %, (Figure 1). The ash content for the hemp was affected differently by the nitrogen fertilizer: for the local hemp variety "Pūriņi" the fertilizer rate increased, the ash content decreased; but for the variety "Bialobrzeskie" – it was the opposite – by increasing the nitrogen fertilizer rate, the ash content increased (Figure 1).

In Austria and Germany a standard has been introduced for granule production-DIN plus, which indicates that the ash content should not exceed 0.5 % [7]. The European Community standard CEN/TC335 has recommended the ash content 0.7-1.5 % [8]. The ash content for hemp is very variable and on average it is greater than the level recommended for fuel 1.5 % (standard DIN) [9]. In the wood pulp granule standard EN14961, a maximum allowable level for ash content has been stated at 1.5 % or 3 % dependent on the granule type [10].

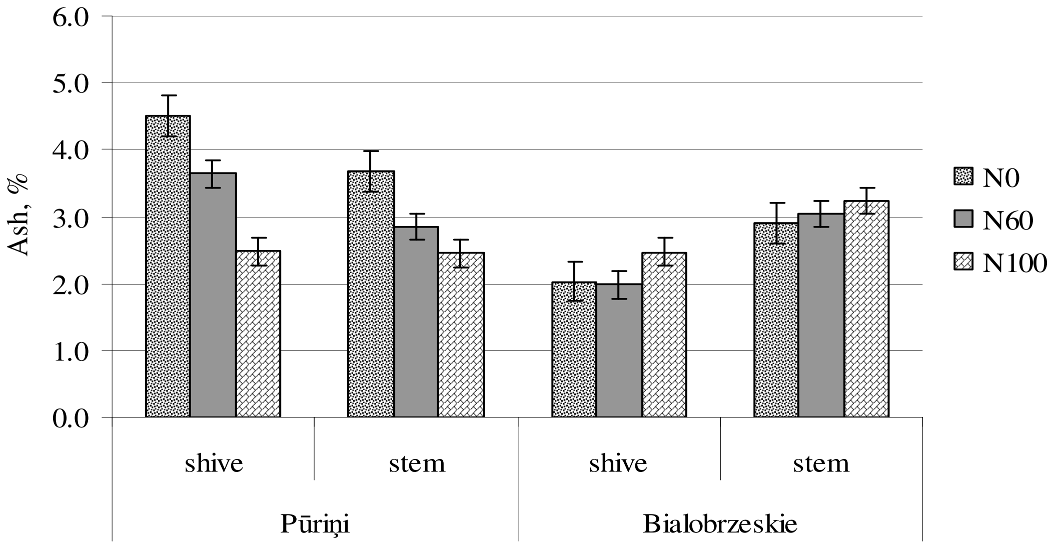

Fig. 1. **Hemp ash content as function on the variety, the stalk components and nitrogen fertilizer rate**

The thermal capacity for the local hemp “Pūriņi” stems was 18.68 ± 0.02 MJ·kg^{-1} and for the shives – 18.61 ± 0.02 MJ·kg^{-1}, for the variety “Biolobrzeskie”for the stems – on average 18.68 ± 0.10 MJ·kg^{-1} and shives – 18.16 ± 0.07 MJ·kg^{-1}. The highest burning heat was defined when 1 kg of fuel was completely burnt and the water vapor, which is smoke gases and for which the distributed heat from the fuel was partially used, was completely condensed and the condensate cooled to ºC, by that means not losing the vaporized heat [11]. The nitrogen fertilizer rate for the hemp affected the thermal energy for the variety “Pūriņi” less; but for the variety “Bialobrzeskie”, using a nitrogen fertilizer rate N_{100}, the difference was observed as a partial interval of 1 MJ·kg^{-1} (Figure 2), which was not substantial. That could be explained with the development stages of hemp, as “Pūriņi” started to flower in July and “Biolobrzeskie” in August, and the same for the mass seed ripening stage. Hemp with the start of the flowering stage tends to become woody.

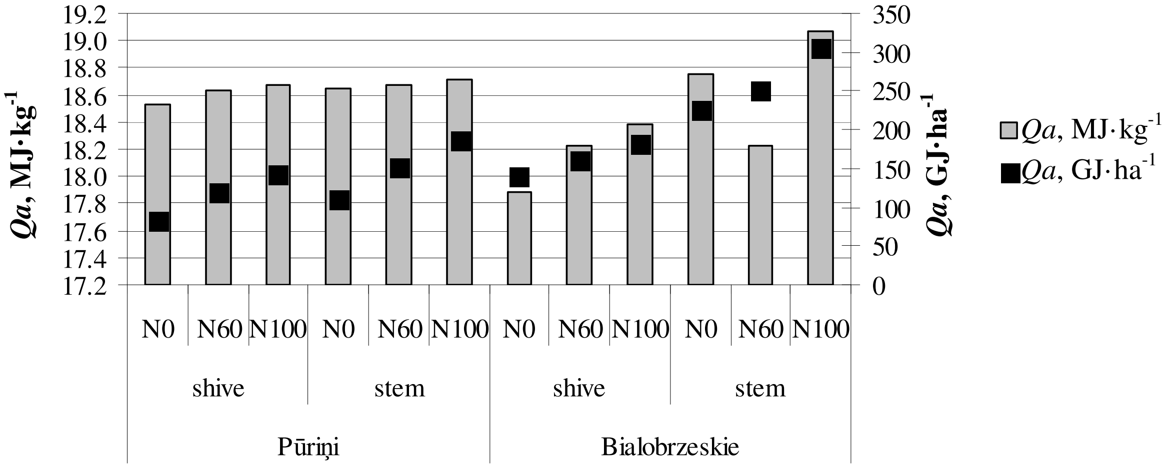

Fig. 2. **Impact of the nitrogen fertilizer rate on the hemp thermal capacity (*Qa*)**

For the hemp stems and shives the thermal capacity from one hectare was possible, if the nitrogen fertilizer rate was increased (Figure 2). Even though the thermal capacity for both hemp varieties was similar per mass unit, the productivity was different, therefore, the calorific yield from one hectare was fundamentally different.

In this research it has been established that for the thermal energy there was a positive ($p < 0.001$) relationship with the harvested yield (Figure 2). For the hemp the nitrogen rate changes for the resultant thermal capacity from one hectare, increased for the shives by 73 % (“Pūriņi”) and 31 % (“Bialobrzskie”); for the stalks by 66 % (“Pūriņi”) and 36 % (“Bialobrzskie”). For the sown hemp the *Qa* was on average 171.71± 18.31GJ ha^{-1}. Nitrogen fertilization increased the energy yield obtained from hectare.

Evaluating various factor influencing proportions on the calorific thermal capacity (*Qa*) for the hemp variety “Biolobrzeskie”there appears an essential influence for the nitrogen fertilizer rate (η = 23.1 %) and the stem parts (η = 33.2 %) and interaction between the stem parts and the nitrogen fertilizer rate (η = 17.2 %) (Table 1). For the local hemp variety “Pūriņi” (*Qa*) there was essentially influenced by the agrometeorological conditions of the trial year (F_A) the nitrogen fertilizer rate (*Fc*) and the stem parts, but the greatest influence on (*Qa*) had the interaction between the factors A and C (η = 46.6 %). In the research an essential ($p < 0.05$) stem part proportional influence was observed **–** for “Biolobrzeskie”**–** 33.2 % and “Pūriņi” **–** 12.0 %; therefore, to achieve the highest thermal capacity, it is important to evaluate, if it was rational to use the whole of the stem or only the shives as a fuel. Hemp stalk contains on average 75 % shives [12-15].

The rate of nitrogen fertilizer did not influence the point of formation of softening temperature *Ht* and flow temperature, when liquid ash dissipates along the surface *Ft* for the hemp and was above 1500 ºC (Figure 3). The ash melting deformation temperature decreased for the hemp shives and hemp stem if the nitrogen fertilizer rate was increased. The highest ash melting temperature is for the hemp stems (1393.17 ± 32.05 ºC), not for the shives (1368.85 ± 45.03 ºC). The ash melting deformation temperature decreased for the hemp shives and hemp stalks if the nitrogen fertilizer rate was increased.

For the harvested hemp the ash melting temperature reached 1500 ºC, which was the maximum temperature, which was recorded by the laboratory.

Table 1

The influencing factor proportion on the hemp variety "Pūriņi" and "Bialobrzeskie" quality parameter, *η*, %

Factors	"Pūriņi"		"Bialobrzeskie"	
	ash content	highest thermal capacity	ash content	highest thermal capacity
Growing year (A)	72*	15*	18*	ns
Plant part (B)	3*	12*	36*	33*
N fertilizer rate (C)	19*	18*	5*	23*
Interaction (A and B)	0	0	26*	10*
Interaction (A and C)	3*	47*	11*	ns
Interaction (B and C)	1*	4*	1*	17*
Interaction (A and B and C)	1*	3*	2*	ns
Effect of unexplored factors	1	1	0	12

* significant at the 0.05 level
ns – none significant at the 0.05 level

For the hemp stems the ash melting deformation temperature forms a positive linear connection with Si (r = 0.74, n = 15, p < 0.05) but a negative one with K (r = -0.59, n = 15, p < 0.05) also with Na (r = -0.63, n = 15, p < 0.05), but for the hemp shives the ash melting deformation temperature forms a positive linear connection with Si (r = 0.56, n = 15, p < 0.05) and a negative connection with K (r = -0.89, n = 15, p < 0.001) also with Na (r = -0.61; n = 15; p < 0.05). For the hemp a negative influence was noted for the alkaline and alkaliearth elements on the ash melting temperature, therefore, analyzing the quality parameters for extraction of hard biofuel it also must be evaluated, which factors influence the plant chemical content. One of these factors was the nitrogen fertilization rate.

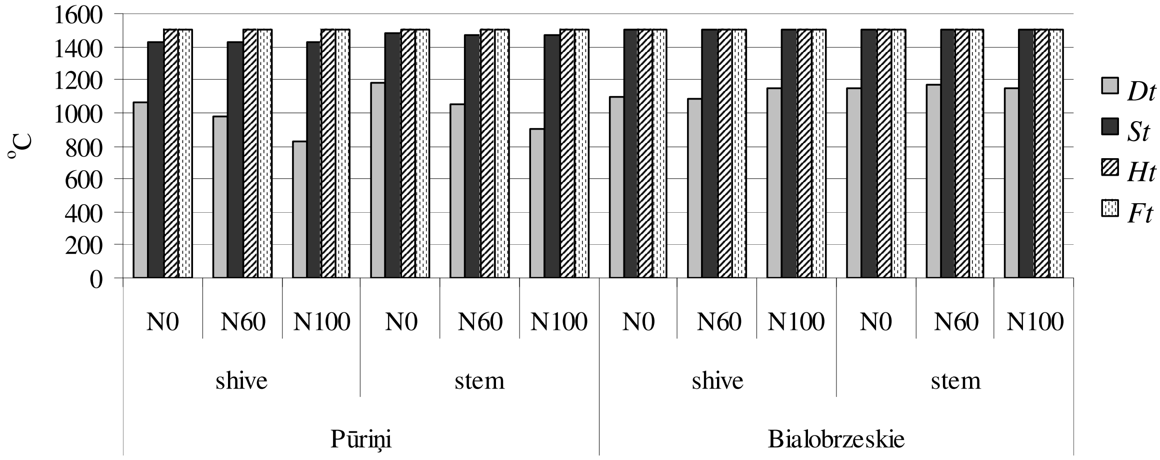

Fig. 3. **Nitrogen fertilizer rate and stem part impact on the hemp ash melting temperature:** *Dt* – initial point of deformation: the sharp peak is rounding; *St* – softening temperature; *Ht* – the point of formation of softening temperature; *Ft* – flow temperature, liquid ash dissipates along the surface

In several occasions it has been found that plants with wider applications have higher use perspectives and lower costs for mass unit [17; 17]. Hemp with its rich leafage suppresses weeds, and leaves left on the soil after harvesting improve the soil structure [18]. Hemp is a plant with wide application and usage possibilities. Local hemp seed could be used for food application as components for vegetarian food. Latvian national foods – hemp spread, butter, hemp milk, oil are popular local food meal components. Today hemp has widespread options of use: building material, food, feed and alternative energy – solid fuel.

Conclusions

1. The ash content in the hemp dry matter was dependant on the nitrogen fertilizer rate. For the variety "Pūriņi", with increased nitrogen fertilizer rate, the ash content decreased; but for the variety "Bialobrzskie" it was the opposite.
2. Thermal capacity per mass unit for the local hemp variety "Pūriņi" and variety "Bialobrzeskie" was unchanged with increased nitrogen fertilization rate.
3. The increase of the nitrogen fertilization rates increases the hemp thermal capacity per hectare for the shives by 73 % ("Pūriņi") and 31 % ("Bialobrzskie"), and for the stalks 66 % ("Pūriņi") and 36 % ("Bialobrzskie"). For the hemp the thermal capacity was 171.71±18.31 $GJ \cdot ha^{-1}$.
4. Comparing the ash melting temperature for the hemp varieties "Biolobrzeskie"and "Pūriņi" it emerges that the ash melting phases *St*, *Ht* and *Ft* were not affected by the plant nitrogen fertilizer rates.
5. For the ash melting deformation temperature to increase, the ash content in hemp needs to be smaller ($p < 0.05$).
6. With increased nitrogen fertilizer rate the ash melting deformation temperature for hemp stems and shives was lowered.

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