EVALUATION OF FLAX (*LINUM USITATISSIMUM* L.) QUALITY PARAMETERS FOR BIOENERGY PRODUCTION

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Abstract. Flax (*Linum usitatissimum* L.) is grown in Latvia and can be used for the production of solid fuel. The cultivation of flax in Latvian conditions can be obtained on average 5.4 – 6.0 t·ha^{-1} straw yields (27.9 to 38.9 % of fiber and 61.1 – 73.1 % wood-pulp). Less straw yield can be obtained of linseed- an average of 2.07 t·ha^{-1}, but the output sheave content is higher in fiber than flax. Fiber flax and linseed have a high calorific value. Linseed can be used not only for obtaining linseed oil, but also for obtaining solid fuel (briquettes, linseed pellets) from straw. In the framework of this work 11 linseed and 3 fibre flax samples in 2009 and 2010 were studied. The aim of the research was to evaluate the variety of flax sheave qualitative properties for the production of solid fuel. Flax was studied for the following parameters: dry matter content, moisture content of dry material, ash content of dry material, calorific value, sulfur and chlorine content. Harmful substances in almost all flax sample dry material are equal from 0.15 to 0.2 %. The highest calorific value at V = const dried at 105 °C has linseed chaff – 21.34 MJ·kg^{-1}.

Keywords: *Linum usitatissimum* L., calorific value, ash, chemicals elements, solid fuel.

Introduction

One of the kinds of biomass found in Latvia is the remainder of flax processing- sheave. Sheave is perfect fuel, the calorific value of which is considerably higher than of wood pulp biomass [1]. The yield of sheave is 2.5 tons for one ton of fiber produced [2]. Flax sheave contains cellulose (53 %), hemicelluloses (13 – 24 %), and lignin (20 – 24 %) at a moisture content of 7.9 % [3 – 6].

Flax (*Linum usitatissimum* L.) is grown in Latvia and can be used for production of solid fuel. The cultivation of flax in Latvian conditions can be obtained on average 5.4 - 6.0 t ha^{-1} straw yields (27.9 to 38.9 % of fiber and 61.1 – 73.1 % wood-pulp). Less straw yield can be obtained of linseed an average of 2.07 t·ha^{-1}, but the output sheave content is higher in fiber than flax.

Linseed can be used not only for obtaining linseed oil, but also for obtaining solid fuel (briquettes, linseed pellets) from straw [7 – 9]. Flax fiber constitutes about 25 – 30 % of the stem [10]. Therefore, a large amount of sheave is available after fiber processing. In oilseed flax, sheave make up from 70 to 85 % of the total straw weight and in fiber flax varieties the sheave make up from 50 to 75 % of the total straw weight [11]. The straw of oilseed flax after the dry peeling and division contains 9 % of dust, 28 % of boon, 37 % boon fiber and 26 % of bast fiber [12]. The quality of the fiber that appeared from boon depends on behavior of raw material, methods of processing and adjustment of the technological equipment. Much boon is also obtained in processing of long-fibred flax [13].

Thus, sheave is a major by-product of flax straw processing plants. Unfortunately, today flax sheave has not found much high value and uses. In Europe and Asia, flax sheave is often used to make particle board, but wood particles are generally very cheap in North America that is not a viable commercial use at this time. Flax sheave is often burnt as fuel or used as horticultural mulch. It is also increasingly being used as horse, livestock and pet bedding. It can also be ground and used as a filler to reduce the weight and cost of certain plastic items [10].

Flax stems constitute the source of bast fibers, which are used in a variety of application (textiles, composites, specialty paper). Sheave is the woody, lignified inner tissues of the stem and is a by-product of fiber production. Bast fiber and linseed already have value-added markets, and interest is increasing for fielding value added uses of the by products, such as the non-fiber part of the stem, to improve the economics [10; 14].

The moisture content of flax sheave grinds ranged from 9.6 to 10.5 % after grinding, using the smaller screens for the biofibre material, while the moisture content ranged from 7.9 to 8.6 % for sheave. In some sources the sheave had the combustion energy of 17.67 MJ·kg^{-1} at a moisture content of 8.1 % [2], and other types of heat energy are reflected in Table 1. One of the most important quality indicators of fuel material is ashes. Ashes are those mineral substances that remain after the burning of fuel or, in other words, these are non-organic substances. However, big amounts of ashes create problems of automatization of burning processes for consumers [9].

Sheave is an excellent fuel; the calorific value is higher than that of wood biomass. The sheave is used for heating the flax processing factory in Kraslava. The factory has bought the press for producing sheave briquettes and pellets and is planning to export them to European countries, where they are demanded [2; 14].

Table 1

The calorific value of different types of fuel

Type of fuel	Fuel lower calorific value, $MJ\cdot kg^{-1}$	Fuel lower calorific value $kcal\cdot kg^{-1}$
Natural gas	33.92	8100
Fuel oil	40.62	9700
Coal fuel	20.25	5000
Wood chips (moisture: 40 %)	10.05	2400
Wood (moisture: 40 %)	12.20	2440
Briquettes (moisture: 10 – 12 %)	17.17	4100
Peat briquettes	15.91	3800
Diesel	46.06	11000
Straw (moisture: 15 %)	14.51	3500
Briquettes and pellets from flax	18.00	4500

Flax fuel briquettes as opposed to coal fuel do not leave any dirt, they virtually do not contain sulphur that diminishes the amount of atmospheric emission, but in the same time the calorific value of briquettes is essentially lower than in coal [12].

They are considered to be environmentally benign and have a high-energy content for heating and generation of electricity, but only after being processed into pellets. Pelleting of flax sheave into fuel pellets improved the handling characteristics, increased the bulk density and energy content [11].

Materials and methods

Within the framework of this work 10 oil flax hybrids “37-1”, “37-2”, “37-5”, “37-9/1”, “37-10/1”, 6 – “37-28”, “37-34”, “37-49”; “37-50”, “38”, one variety “Lirina” and three fiber flax varieties “Ošupes 30”, “Ošupes 31” and “Vega 2” were analyzed. The trial was organised using the methods of the Russia Crop Production Institute.

There is a putrefactive podzolic gley soil in the trial field. The agrochemical characteristics of the soil in the year of trial: the content of organic substances in soil 3.0 – 3.5 %, pH 6.4 – 7.0, the security of potassium K_2O – 118 – 124 $mg\cdot kg^{-1}$ soil. The previous plant was spring wheat. After the first soil cultivation in spring time complex chemical fertilizer NPK 6-26-30 (300 $kg\cdot ha^{-1}$) was worked into the soil.

Meteorological conditions. The climate of Latgale varies somewhere between maritime and continental and in general is favourable for growing of many crops. The harvesting conditions were good in 2009-2010. There were no dramatic temperature deviations, and also precipitation was quite good for sunflower growing.

The air temperature from April to August in the plant growth period was greater than the long-term average, except for September. During April, July and August the precipitation was less than 50 % of the long term average indicators. In June the rainfall amount was 75.7 mm. While the long-term average indicator was 75 mm. During May and September the rainfall amount was close to the norm.

The following parameters were tested:

- moisture content, according to standard LVS EN 14774;
- ash content for dry material, according to standard LVS EN 14775;

- gross calorific value at V = const for dried fuel at 105 ºC, according to standard LVS EN 14918;
- net calorific value at V = const, according to standard LVS EN 14918;
- ash melting behaviour oxidizing atmosphere, according to standard LVS CEN/TS 15289.

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

Growing fibre flax in Latvia conditions on average 7.3 t·ha^{-1} of straw yield can be obtained, 2.5 t·ha^{-1} is fibre and 4.8 t·ha^{-1} is wood-pulp (Fig.1). Three times less straw yield can be obtained from linseed on average 2.03 t·ha^{-1}, from this amount on average 1.47 t·ha^{-1} are sheave.

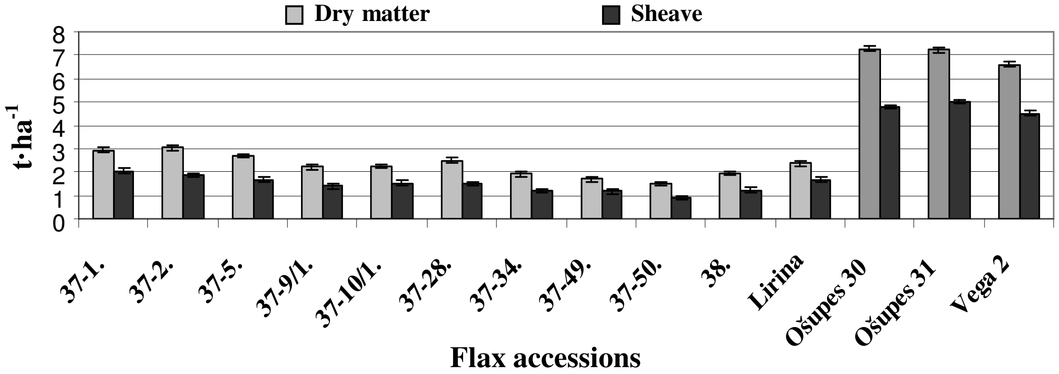

Fig. 1. **Average dry matter yield of flax accessions, t·ha^{-1} (2009 – 2010)**

The ash content is one of the major qualitative characteristics of biomass or plant dry matter. The ash content of all plant of sheave must be up to 3 %. The moisture content (%) of flax sheave was 7 – 8 %. The ash content of the flax sheave of many linseed samples is 3.1 – 3.9 %, above the norm (Fig. 2). But the ash content of the fibre flax sheave of many samples is lower 2.4 – 2.9 %, fully consistent with the norm. The highest ash content was found in the samples of oil flax “37-49”, “37-50” and “38”.The lowest ash content was found in oil flax hybrid “37-1” and “37-34”. There is no essential difference among the ash content in oil flax samples. But the ash content of fiber flax was under the norm and the lowest ash content was in the variety of fiber flax “Vega 2”. There is essential difference among the ash content of oil flax and fiber flax.The average ash content of the chaff was 4.9 ± 0.1 %, but linseed samples are 3.5 ± 0.1 %, above the norm. According to the European standards chaff with so high ash content cannot be used as solid fuel.

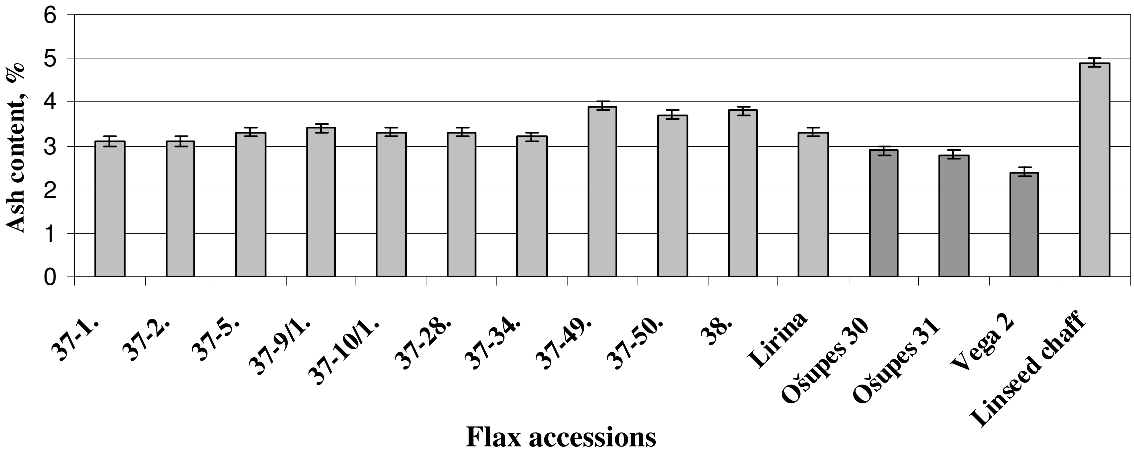

Fig. 2. **Average ash content in flax samples dry matter, MJ·kg^{-1} in 2010 (LSD = 0.1)**

The calorific value of flax differs from the variety or hybrid or part of plant. Latvia is 18.7 – 20.2 ± 0.5 % MJ·kg^{-1} (Fig. 3), or up to 4751 kcal·kg^{-1}, but the calorific value of flax sheave grown in some other countries 16.9 – 17.8 ± 0.5 % MJ·kg^{-1}, or 4200 kcal MJ·kg^{-1}.

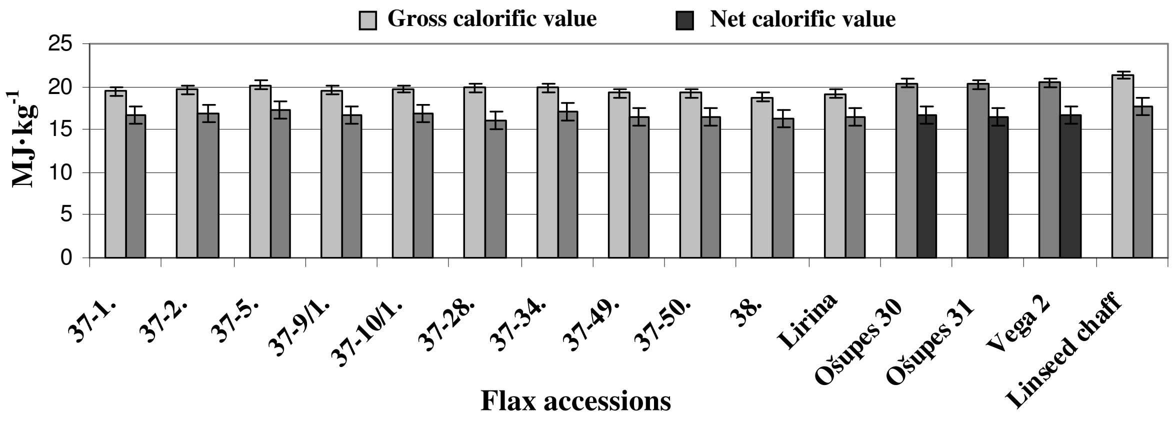

Fig. 3. **Average calorific value in flax samples dry matter, MJ·kg^{-1}**

Gross calorific value at V = const for dried fuel at 105ºC of linseed sheave was 18.79 – 20.15 MJ·kg^{-1}. Gross calorific value at V = const for dried fuel at 105ºC of sunflower head was 22.29 – 30.48.35 ± 0.5 % MJ·kg^{-1}, but of fibre flax sheave was 20.31 – 20.45 ± 0.5 % MJ·kg^{-1}. Net calorific value at V = const of linseed sheave was 16.13 – 17.32 ± 0.5 % MJ·kg^{-1}. Net calorific value at V = const of fibre sheave was 16.51 – 16.65 ± 0.5 % MJ kg^{-1}. The most Gross calorific value at V = const for dried fuel at 105 ºC of linseed hybrids sheave was “37-5” and “37-34”, but linseed variety “Lirina”- 19.15 ± 0.5 % MJ·kg^{-1}. The most Gross calorific value at V = const for dried fuel at 105 ºC of the fibre flax variety sheave was “Vega 2” - 20.45 ± 0.5 % MJ·kg^{-1}. Average Gross calorific value at V = const for dried fuel at 105ºC of linseed hybrids chaff was 21.34 ± 0.5 % MJ·kg^{-1}. This is the highest indicator. There is no essential difference among the oil flax sample Gross calorific value105 ºC of linseed hybrids sheave. There is essential difference among the gross calorific value of oil flax and fiber flax, bet there is no essential difference among the Net calorific value at V = const of fibre and linseed sheave.

Table 2

Ash fusion temperatures – in oxidising atmosphere. Flax (*Linum usitatissimum* L.) in 2010

Linseed hybrids		37-1.	37-2.	37-5.	37-9/1.	37-10/1.	37-28.	37-34.	37-49.	37-50.	38	Average	Standard ”Lirina”	Linseed chaff	Ošupes 30	Ošupes 31	Vega 2	Average
Temperature, °C	**D**	730	650	730	650	740	750	725	730	725	725	716	650	1300	750	730	750	743
	S	750	700	800	710	750	820	815	815	815	810	779	675	1300	800	790	790	793
	H	780	780	1300	780	790	1350	1320	1340	1300	1300	1104	1320	1300	830	820	830	827
	F	1480	1400	1480	1410	1410	1420	1470	1470	1470	1470	1448	1410	1300	900	880	900	893

D – deformation temperature; S – sphere temperature;
H – hemisphere temperature; F – flow temperature.

The main indicators are two temperatures: deformation temperature and flow temperature. In comparison with linseed hybrids, the deformation temperature of fibre flax sheave was lower (Table 2). Average flow temperature in sheave of linseed hybrids was 1448 ºC. The flow temperature of the linseed variety “Lirina” was 1410 ºC, but the variety “Vega 2” had a lower flow temperature of sheave. The flow temperature in sheave of linseed chaff was higher (1300 ºC) than the flow temperature in sheave of fibre flax (880 – 900 ºC). Average flow temperature in oil flax samples was higher than in fiber flax sheave.

Ashes that appear from straw is a good natrium containing fertilizer. But there are also other harmful substances that ooze with plant burning, these are chlorine and sulphur. The content of Cl in linseed hybrids is 0.2 %. Only in some samples of oil flax it is lower and reaches only 0.15 – 0.17 %, but it is fairly high [15; 16]. The content of sulphur in oil flax samples is 0.05 – 0.1 % and in two samples of oil flax hybrid sheave “37-2” and “37-28” the content of sulphur was the lowest. The sulphur content in the samples of linseed and fiber flax does not differ.

Conclusions

The yield of chaff in linseed is lower than in fibre flax. The outlet of sheave yield is 2/3 of dry biomass in the linseed and fibre flax samples. But the common sheave yield on average is higher in fibre flax. There is no essential difference in the sheave yield of the linseed and fibre flax samples. The ash content differs much in linseed and fibre flax. The content of ashes is high in the sheave of linseed, and it exceeds the norm. There is a very high ash content in linseed chaff and it two times exceeds the norm.

The calorific value of linseed and fibre flax sheave is almost equal. But the highest calorific value is in flax chaff -21.34 ± 0.5 % $MJ \cdot kg^{-1}$. Deformation temperature differs and it is higher in 750 ºC oil flax hybrid, for instance, “37-28” and fibre flax varieties “Ošupes 30” and “Vega 2”. The flow temperature differs and is higher in the oil flax samples “37-1”, “37-5”. Average flow temperature of fibre flax was 893 ºC. The sulphur content for the growing energy crops in Latvia ranges from 0.1 % to 0.2 % and from the studied energy plants fibre flax, linseed, correspond to the norm of sulphur and chlorine amount.

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