COMPARISON OF DIFFERENT ENERGY CROPS FOR SOLID FUEL PRODUCTION IN LATVIA

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Abstract
Linseed and fibre flax (*Linum usitatissimum* L.), hemp (*Cannabis sativa* L.), sunflowers (*Helianthus annuus* L.) and reed canary grass (*Phalaris arundinacea* L.) are grown in Latvia, and these bioenergy crops can be used for the production of solid fuel. Some oilseed crops have large perspective for biofuels. Sunflowers, canary seed and hemp have large biomass, but flax and sunflowers have high calorific value. The ash content is quite high in all plants sheave. Linseed can be used not only for obtaining linseed oil, but also for obtaining solid fuel (briquettes, linseed pellets) from straws. Within the framework of this research 2 sunflower varieties, 11 oil and 3 fibre flax samples, 2 reed canary grass varieties and 10 varieties of hemp 2009 and 2010 were studied in the years. The aim of the research was to evaluate the variety of plant biomass qualitative properties for production of solid fuel. All of these bio-energy plants were studied for the following parameters: biomass content, moisture content of dry matter, ash content of dry material, calorific value, sulphur and chlorine content. The quantity of plant biomass yield depends on many factors. Harmful substances in almost all plants make approximately from 0.15 to 0.22% of dry matter. The average highest calorific value at V=const for dried fuel at 105ºC of sunflower dry matter was 20.6 MJ·kg^{-1}, and of fibre flax - 18.5 MJ kg^{-1}. The growing of hemp is beneficial to the environment, and hemp is also a good resource as a biofuel. By choosing suitable plants, high dry matter biomass solid fuel products can be obtained.
Keywords: energy crops, dry matter, calorific value, ashes.

Introduction

Biofuels represent a potential means to reduce carbon emissions, reduce dependency on increasingly expensive fossil fuels, and provide working places for the local economy. Biofuels can be used as feedstock for production of liquid fuels or for solid fuel for direct combustion for heating. Biomass is a unique fuel and has the potential to play a significant role in the future energy. Unlike other renewables, biomass can provide continuous electricity generation, and is the only widespread source of renewable heat. Increased use of biomass as a source of energy (electricity and heat) will contribute to the reduction of CO^2 emissions, increase energy security, and support sustainable development and regeneration of rural areas (Bridgeman et al., 2008).

Power plants set demanding requirements regarding the biomass properties which include the total ash content, the melting behaviour, and the chemical composition. Compared to coal, biomass contains less ash, but a greater amount of alkaline metals in the ashes, which are usually responsible for fouling heat transfer surfaces (Poiša, Adamovičs, 2011).

At present the meadows and pastures of Europe, which up to now guaranteed feed stocks for animals; fulfil new functions as environmental stabilizers and as an additional option for renewable energy resources, also forming new directions for research in the cultivation of plants (Кулаковская et al., 2010).

Some oilseed crops have large perspective **excess** to biofuels. The ash content is quite high in all plants sheave. Linseed can be used not only for obtaining linseed oil, but also for obtaining solid fuel (briquettes, linseed pellets) from straw. Reed canary grass is used for production of fuel briquettes and granules (Adamovičs et al., 2007; Lazdiņa et al., 2008). In their burning process from reed canary grass less harmful emissions are produced: carbon dioxide that comes into atmosphere does not influence the balance in the nature and does not increase the greenhouse effect if compared to the effects created by fuel oil or petrified fuel heating (Tardenaka, Spince, 2006). In 2006, Latvia exported about 500 thousand tons of granules, which is one of the largest indicators in Europe (Adamovičs et al., 2007). In other countries, for instance, in Finland and Sweden, canary briquettes are made in industrial amounts (Sanderson, Adler, 2008; Lazdiņa et al., 2008; Tardenaka, Spince, 2006).

Hemp is grown for production of hemp oil as for as for obtaining of hemp fibre. In both cases there appears excess. In the process of oil production these are stalks, but in the process of fibre obtaining sheave. This excess can be used in the fuel production. The features of hemp stalks have a large resemblance to the characteristics of wood-pulp. There are cellulose and lignin both in the hemp stalks and in wood-pulp, and the calorific value of stalks is the same as of wood-pulp, and in the burning process less ashes are produced. By briquetting or making granules of hemp stalks, good solid fuel can be produced. 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 (Mańkowski, 2003).

There is relatively little dry mass in sunflower green mass (Adamovičs et al., 2007). The environmental conditions in our research were different each year.

Reed canary grass (*Phalaris arundinacea* L.) is a tall-growing, perennial grass which is widely distributed across Europe and other northern countries. Reed canary grass is better adapted to diverse uses and environmental conditions than most other commonly used perennial grasses. The stems can reach 2.5 m in height (Lazdiņa et al., 2008). Comparing the reed canary grass grown in Latvia according to the chemical content, it can be seen that it contains more alkali metals than other energy crop plants, which is not desirable when used for biofuel production (Biedermann, Obernberger, 2005). Reed canary grass is being cultivated in northern Europe as a biofuel and about 10.000 acres are in production in Scandinavia (Kätterer et al., 1998).

One of the most important quality indicators of fuel material is ashes. Ashes are those mineral substances that remain after the burning of fuel (Белосельский, Соляков, 1980; Cars, 2008) or, in other words, these are non-organic substances. However, big amounts of ashes create problems of automatization of burning processes for consumers (Tardenaka, Spince, 2006).

Energy crops are widely used in various sectors of the economy. They also have a positive effect on the environment, they reduce soil erosion and contamination with chemical substances, and they can be grown in soil which cannot be used for food crops (Poiša et al, 2011; Sanderson, Adler, 2008; Wrobel et al., 2009).

Energy crops have different demand for quality than food and agricultural plants. Heat supply and energy obtaining should be effective, accessible and nature-friendly, which is possible by using the renewable energy resources. The aim of the research was to evaluate the variety of plant biomass qualitative properties for production of solid fuel.

Materials and methods

Energy crops hemp (*Cannabis sativa* L.), fibre flax and linseed (*Linum usitatissimum* L.), sunflower (*Helianthus annuus* L.) and reed canary grass (*Phalaris arundinacea* L.) – were tested in the following locations and under the conditions described in Table 1. Soil type for all plants was the humi-podzolic gley soil.

Meteorological conditions. The climate of Latgale varies somewhere between maritime and continental and in general is favourable for many cultures growing. 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 near the norm.

The following parameters were tested:

- the moisture content - according to standard LVS EN 14774,
- the ash content for dry material - according to standard LVS EN 14775,
- the gross calorific value at V=const for dried fuel at 105ºC - according to standard LVS EN 14918,
- the net calorific value at V=const - according to standard LVS EN 14918,
- the 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

Biomass fuel, the same as fossil fuel, has four important properties: the thermal capacity, the chemical properties, the physical properties, and the combustion properties (Magasiner, van Alphen, Inkson et al., 2002).

Within the framework of this research all varieties (Table 1) in the 2009 and 2010 were studied years.

Growing fibre flax in Latvia conditions, on average 7.3 $t \cdot ha^{-1}$ of straw yield can be obtained, 2.5 $t \cdot ha^{-1}$ is fibre and 4.8 $t \cdot ha^{-1}$ is shove (Fig.1). From linseed three times less straw yield can be obtained on average 2.07 $t \cdot ha^{-1}$; from this amount on average 1.3 $t \cdot ha^{-1}$ are sheave. The earlier hemp varieties 'Bialobrzeskie', 'Beniko', 'Epsilon 68', 'Fedora 17', 'USO 31' and 'Fenola' were studied. In Latvia, the varieties 'Epsilon 68', 'Fedora 17' and 'Santhica 27' reached the height of more than 2 metres, but the height of more than 2.5 metres were reached by later sorts - 'Felina 32' and 'Futura 75', which means that tall plants can be grown in Latvia climate conditions (Пойша, Адамович, 2011). The height and development of hemp plants is largely dependent on temperature conditions (Давидян, 1979). The height of hemp is also influenced by the vegetation year and the quota of nitrogen fertilizer (Poisa, Adamovics, 2010). In Latvia, 14.0 $t \cdot ha^{-1}$ of biomass for solid fuel can be obtained from 2.5-3.5 m tall hemp, from this amount on average 8.9 $t \cdot ha^{-1}$ are sheave.

Sunflower was 12.3 t ha^{-1} dry biomass yields, but other than seeds and leaves sunflower was 8.7 t ha^{-1} sheave yields.

In Latvia, up to 7-10 t ha^{-1} of dry biomass yield of reed canary grass can be obtained (4-8 t ha-1 of dry biomass in loam, and up to 10 t ha^{-1} in peat soil). The variety 'Bamse' was created by Swedish breeders particularly for the needs of bioenergy (Poisa, Adamovics, 2010).

Table 1

Trials' methods in 2009-2010

Plants	**Fibre flax** (*Linum usitatissimum* L.)	**Linseed** (*Linum usitatissimum* L.)	**Hemp** (*Cannabis sativa* L.)	**Sunflower** (*Helianthus annuus* L.)	**Reed canary grass** (*Phalaris arundinacea* L.)
Soil composition	pH_{KCl} = 6.4-7.0; OM, % = 3.0–3.5%; P_2O_5 = 130-145 mg kg^{-1} K_2O = 118–124 mg kg^{-1}	pH_{KCl} = 6.4-7.0; OM, % = 3.0–3.5%; P_2O_5 = 130-145 mg kg^{-1} K_2O = 118–124 mg kg^{-1}	pH_{KCl} = 7.0-7.3; OM, % =3.8 (Turin's method); P_2O_5 = 83-145 mg kg^{-1} ; K_2O = 65-118 (DL method)	pH_{KCl} = 6.4-6.7; OM, % = 3.0–3.5%; P_2O_5 = 85 mg kg^{-1} K_2O = 118–124 mg kg^{-1}	pH_{KCl} = 5.8; OM, % =5.2%; P_2O_5 = 85 mg kg^{-1} K_2O = 90 mg kg^{-1}
N:P:K fertilizers	N:P:K 6:26:30, 300 kg ha^{-1}	N:P:K 5:10:25, 400 kg ha^{-1}	N:P:K 6:26:30, 300 kg ha^{-1}	N:P:K5:10:25 120 kg ha^{-1}	N:P:K 5:10:25, 400 kg ha^{-1}
Sowing time	5 th May	7 th May	4th May-2009; 13rdMay-2010	May 13 -2009 May 13 -2010	12th August -2008; 29th April - 2009
Seeding rate kg ha^{-1}			60-70 kg ha^{-1}	20-30 kg ha^{-1}	70 kg ha^{-1}
Sort or/and varieties	'Ošupes 31' 'Ošupes 30' 'Vega 2'	'37-1'; '37-2'; '37-5'; '37-9/1'; '37-10/1'; '37-28'; '37-34'; '37-49'; '37-50'; '38'; 'ST Lirina'.	Bialobrzeskie Beniko, Epsilon68 Fedora17 Felina32 Santhica27 Futura75 USO31 Finola	'Alyssa' 'Pacific'	'Marathon' 'Bamse'
N fertilizer rate	15 g m^{-2} N	30 g m^{-2} N	N0, N60, N100	N0, N60, N120	N0, N30, N60, N90
Harvesting time	4th September-2009	29 th August	21 st September-2009 14th September-2010	20th September-2009 15th September-2010	6th October

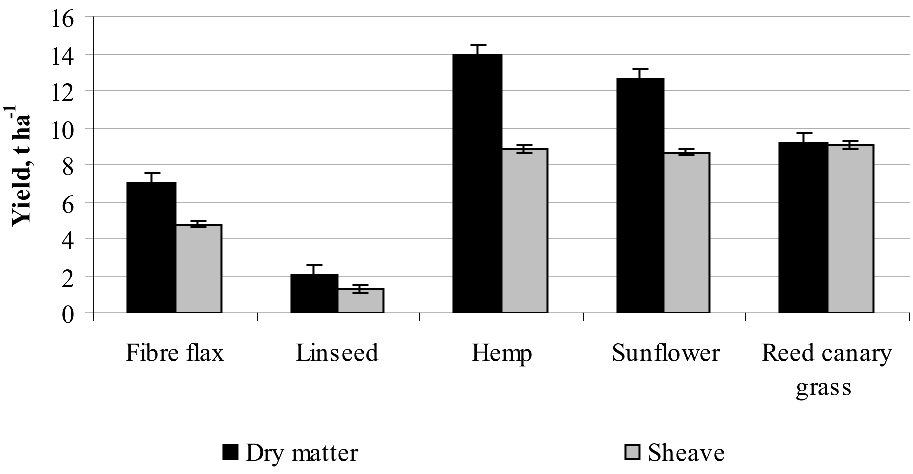

Figure 1. **Average dry matter yield of all species, t ha^{-1} (2009-2010).**
(average from all varieties and harvest dates)

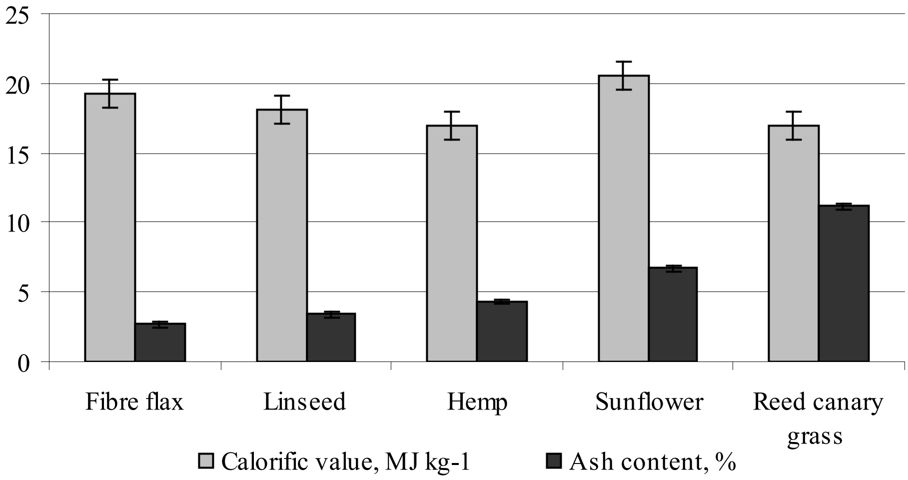

Figure 2. **Average calorific value and ash content in all species dry matter, MJ·kg^{-1}.**

Irrespective of other negative results, sheave of flax, hemp and sunflower has a great calorific value. Hemp stems are used as a fuel, and its average calorific value was 16.98 MJ·kg^{-1} ± 0.5%, which is less than for oil and fibre flax (average calorific value - 18.1-18.05 MJ·kg^{-1}), but the calorific value of flax sheave grown in some other countries varies between 16.9 – 17.8 MJ·kg^{-1}± 0.5%. That highest calorific value at V=const for dried fuel at 105ºC of sunflower straw sheaves was 16.5 MJ·kg^{-1} ± 0.5%, but that of sunflower husk – 25.02 MJ·kg^{-1}± 0.5% (average calorific value was 20.8 MJ·kg^{-1}± 0.5%). The calorific value of reed canary grass was 16.8 MJ·kg^{-1} and 17.1 MJ·kg^{-1} for spring yield that has a little difference from the flax and hemp calorific value.

The ash content is one of the major qualitative characteristics of biomass or plant sheave. The ash content of all plant sheave must be up to 3%. The ash content should not surpass 5-7% under the conditions of correct stockpile. Nevertheless, the experience shows that the ash content can reach even 20%. The ash content of the energy crops was very different and ranged from 3.1 to 12.8% (Fig.2). The average ash content of the flax shove of fibre flax wa 2.7 ± 0.1% and of the flax chaff was 4.9 ± 0.1%. Ash content in hemp shoves exceeds the norm, and in our studies it reached approximately 4.3 ± 0.1%, which is for 0.8 % higher than in linseed and for 2.4% less than in sunflower. The average ash content of the stem in 2009 was higher than in the shoves (Kymäläinen et al., 2004). Ash content in sunflower straw was 6.7 ± 0.1%. Ash content is high in the sunflower heads combustion – 7-8.5 %. It two times exceeds the norm, thus sunflower sheave has much surplus of ashes that can be used as soil fertilizer, if burnt in big stoves.

The ash content in reed canary grass was 9.5-12.8 ± 0.1%. The smallest ash content (on average 11.9 ± 0.1%) was found in variety 'Marathon' which was sown in August, 2008. In comparison with varieties that were sown in 2009 it is seen that variety 'Bamse' has a higher ash content – on average 15.4 ± 0.1%. In our research, the ash content of reed canary grass varieties sown in 2009 was two times higher than reported in other studies (Poiša et al., 2010).

Straw of energy crops can contain comparatively large amount of chlorine and sulphur which have a significant relationship for corrosions and sediment formation. The standard amount of sulphur (according to data of LVMI Silava) is from 0.1 to 0.2% (Lazdiņa, Lazdiņš, Bārdulis et al., 2008). The lowest amount of sulphur and chlorine was in linseed (0.03-0.1± 0.05%), that covers the norm, but the highest content of sulphur was in reed canary grass and it reached 0.245-0.259 ± 0.05% (Platače et al., 2011). The amount of sulphur in reed canary grass was surpassed. Reed canary grass will respond to nitrogen fertilization and to a less extent to potassium and phosphate fertilization (Poiša et al., 2011). Sunflowers contain higher percent of Cl – 0.2 ± 0.05%, but the content of sulphur is two times lower than that of chlorine. The content of sulphur ranges from 0.08 to 0.1 ± 0.05%. Variety 'Alyssa' with a fertilizer dose N120 contains less chlorine (Komlajeva et al., 2011).

Conclusions

Among all studied plants (fibre flax, linseed, hemp, sunflower and reed canary grass), hemp had the highest yield of biomass. Yield at the same climatic conditions depends on the variety, soil type, fertilizer, plants and other factors.

The highest calorific value at V=const for dried fuel at 105ºC of sunflower dry matter was 20.6 MJ·kg^{-1}, which is 2% higher than in hemp and canary, and 1.3 % higher calorific value than in flax.

For production granules and briquettes the varieties with high content of carbon and low amount of ashes should be chosen. Low ash content was in the shove of fibre flax and linseed, but the highest ash content was in reed canary grass (*Phalaris arundinacea* L.), which has a negative sign for solid fuel. The resulting ash quantity in the trials was larger than the permitted, so only hemp can be used as an addition for briquette and pellet production. It is stated that the difference of ash content among one group of plants is insignificant.

Energy crops hemp (*Cannabis sativa* L.), sunflower (*Helianthus annuus* L.) and reed canary grass (*Phalaris arundinacea* L.) – may be an ideal biofuel source, but reed canary grass have a large ash content, which makes it impossible.

In Latvia, the sulphur content for the growing energy crops ranges from 0.1 % to 0.2 %; from the studied energy plants, fibre flax, linseed, hemp and sunflower correspond to the norm of the sulphur and chlorine amount. The plants which biomass is higher than 4 t ha^{-1} and which have lower content of ashes and chemical elements can be suitable for the solid fuel production.

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