Technological evaluation of non-traditional energy plant cultivation and utilization for energy purposes in Lithuania

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Abstract

Presented paper provides the research results of non-traditional energy plants, which were grown in Lithuanian climate zone, cultivation, preparation and utilization for solid biofuel: elephant grass (Miscanthus x giganteus), sida (Sida hermaphrodita), cup plant (Silphium perfoliatum L.) and seeder hemp (Canabis sativa). These investigations were carried out in the fields and laboratories of Aleksandras Stulginskis University and Lithuanian Research Centre for Agriculture and Forestry in 2010-2013. There were presented research results of non-traditional energy plants chaff and mill preparation quality, in justice of use the drum chopping and hummer milling equipment prepared chaff and mill fractional composition, and mill pelleting quality. There were determined physical-mechanical properties of investigated non-traditional energy plants – moisture content, bulk density and pellet calorific value. The average calorific value of these plants varied from 17.9 to 18.5 MJ kg⁻¹.

Keywords: non-traditional, plants, utilization, solid biofuel.

1. Introduction

Biomass – is an eco-friendly local fuel: wood, straws, energy crops. Plant biomass is one of the most important renewable energy sources in Lithuanian and already makes a quite big part of the local fuel. Comparing with traditional energy sources and some kinds of renewable energy, biomass has many advantages due to relatively low costs, less dependence on short weather changes, the promotion of regional economic structures’ development and alternative sources of income for farmers.

The various non-traditional tall grasses can be used for cultivation and preparation for solid biofuel in Lithuania: elephant grass (Miscanthus x giganteus), sida (Sida hermaphrodita), cup plant (Silphium perfoliatum L.) and seeder hemp (Canabis sativa), etc.

1.1 Elephant grass

Elephant grass (Miscanthus x giganteus) – is a perennial herbaceous plant of Poaceae family. Miscanthus genus, with glossy, sloping leaves, sometimes growing even up to 4 m height (Aleksynas, 2004). Main advantages of this tall, long-lived plant: has great potential to convert solar energy, accumulates relatively high biomass yield during the photosynthesis. It is very important that they grow in arid and barren soils, which are unsuitable for most other plants. The use of their biomass is very wide, because they are like a potential source of energy with low nitrogen oxide emissions, like a stock for lignin cellulose production, more than other plants they accumulate a higher concentration fiber than nitrogen.
Elephant grass naturally grows in African and South Asian tropics and subtropics, in the East Asian climate zone, etc. It came to Europe as an ornamental plant. The biomass yield of elephant grass is highly dependent on the soil moisture, and crop watering almost every year brings extra yield. Under favorable conditions and sufficient moisture in the soil, elephant grass is capable to produce up to 25 t ha\(^{-1}\) of dry mass. The stems of these plants for fuel in the same area can be grown for 20-25 years. To granulate the stems, simple herb mills are used. Such dry granulated mass can be immediately used in boiler-houses. Also elephant grass can be used as raw material in biogas powerhouses, and elephant grass gives probably the biggest methane gas production (Christian et al., 1997).

As the growing experience and scientific research in Germany showed, one the most limiting factors of the elephant grass yield is water. Water transpiration rate of elephant grass is 2.2-2.5, compared to wheat 1.1-1.9, potatoes 1.45-2.1. It is estimated that water demand for 10 t ha\(^{-1}\) dry mass yield is about 250 mm rainfall. According to the amount of rainfall, Lithuanian has favorable conditions for elephant grass growing. Elephant grass, especially older crops, provide themselves with all nutrients, so additional fertilizer is not necessary (Jasinskas & Scholz, 2008).

### 1.2 Sida

Sakhalin, Japanese and hybrid sida (*Sida hermaphrodita*) is the non-traditional big stem plant. Sida (*Sida hermaphrodita*) is a plant of warmer climate conditions – is grown in research fields of Lithuanian Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry. According to the scientists, even if the majority of imported energetic plants grow in Lithuania, it is necessary to take into consideration the purpose of green mass. Conventional permanent grasses are also suitable for biogas production.

It is considered that energetic value of sida is similar to that of pine and fir (more than 18 MJ kg\(^{-1}\)). However, taking into consideration growth velocity of sida, from one hectare annually it may give twice higher amount of energy than from one hectare. The same machinery may be used for collection of other big stem tall plants (Heneman & Cervinka, 2007).

### 1.3 Cup plant

Cup plant (*Silphium perfoliatum* L.) – is a plant belonging to aster family *Silphium* genus. According to various sources, this genus contains up to 33 sorts. Till now, these unconventional to agriculture plants attracted attention as decorative and suitable for forage plants. The following sorts have been mostly researched: *S. perfoliatum* L., *S. integrifolium* Michx. and *S. laciniatum* L. (Kowalski, 2007; Slepetys, Kadziuliene, Sarunaite, Tiliukienë, Kryževiciene, 2012). It is characteristic that these plants accumulate up to 28.8 t ha\(^{-1}\) of dry materials (DM) (Clifton-Brown et al., 2001). According to the data of long-term research made in Russia, the average annual harvest of cup plant is 15.6 t ha\(^{-1}\). Cup plant was researched as possible forage for pets. However, it was proven by research that, comparing to corn (another big-stem plant), cup plant is characterised by lower forage value. In the recent years, much attention has been paid to possible usage of cup plant for production of biofuel (Jasinskas & Scholz, 2008). Still, there is not enough data on this issue and it is purposeful to continue research in this field.

### 1.4 Seeder hemp

Hemp (Latin – *Cannabis*) – a plant belonging to the hemp family. Hemp is one of the oldest cultivated plants. There are three main types of hemp: Seeder hemp (*Cannabis sativa*), Indian hemp (*Cannabis indica*) and Rubbish hemp (*Cannabis ruderalis*). Hemp originated in Central Asia (Hadders, 1997; Jasinskas & Vrubliauskas, 2000; Zaltauskas, Jasinskas, Kryževiciene, 2001).

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In Lithuania hemp has been cultivated since ancient. The dry hemp yield per hectare often exceeds 15 tones – it is almost twice more than the yield of willow mass grown for fuel (Burbulis, Blinstrubiene, Masiene, Jankauskiene, Gruzdeviene, 2012). Cultivating oily types of hems, after getting in the harvest, straws can be burned in boiler-houses. Hemp is not climate-demanding, although they grow better in milder and wetter climate areas (Scholz, Lorbacher, Spikermann, 2006).

Researches were carried out for hemp preparation and use for energy purposes. It was found out that hemp is very promising as a biofuel stock. Comparing hemp with other agricultural plants’ parts suitable for biomass (canola, wheat straws), during burning hemp releases the biggest amount of energy (more than 18 MJ) and leaves the least ashes (about 1.2%). Growing hemp the soil is not only impoverished, but it is even enriched by restoring taken nutrients in form of leaves and roots. Therefore, these plants are irreplaceable in crop rotation. In addition, having a heavy metal absorption properties, hemp can be used bringing back to agriculture contaminated and abandoned fields (Jasinskas & Scholz, 2008; Jankauskiene & Gruzdeviene, 2010).

The possibilities of analyzed non-traditional energy plants utilization and usage for energy purposes in Lithuania has been poorly investigated, researches have been carried out in Aleksandras Stulginskis University and Lithuanian Institute of Agriculture. Non-traditional energy plants are not yet widespread in Lithuania and need for deeper analysis and research investigations.

The aim of this work – to investigate the technological and technical means of elephant grass, sida, cup plant and seeder hemp plants mass preparation for biofuel, to assess quality indicators of these non-traditional energy plants’ chopping, milling and pelleting, to determine the basic physical mechanical properties of plant biomass prepared for fuel.

2. Materials and methods

Non-traditional energy plants’ chopping quality, mill and prepared pellets used for fuel should satisfy requirements for combustion chamber, chopped, milled and pressed mass transportation machinery and storage. During experimental research of non-traditional energy plants’ the drum chopper of forage harvester Maral 125 was used for chopping of elephant grass, sida, cup plant and seeder hemp (Siaudinis, Jasinskas, Slepetiene, Karciauskiene, 2012).

For production of pellets it is necessary to mill prepared chaff mass to the mill consistency (to 1-2 mm particles). Mill Retsch SM 200 was used to this purpose. Milling quality was determined using the methodology widespread in European Union countries (Scholz, Lorbacher, Spikermann, 2006). Mass fraction composition of these plants was determined using sieve shaker Retsch AS 200 and sieves with holes of various diameters: 0.25 mm, 0.5 mm, 0.63 mm, 1 mm and 2 mm. The mass remaining on sieves is weighted, and sample part of every fraction in percentage is calculated (EU DD CEN/TS 15149-1:2006).

Density of chaff, mill and pellet were determined in the 6 dm³ cylinder vessel, which were fulfilled by mass till the upper edge and weighted. Moisture of chopped mass was determined in chemical laboratory according to the standard methodology (Jasinskas, Ulozeviciute, Sarauskis, Sakalauskas, Puskunigis, 2011). For mill pressing and pellet of 6 mm diameter production was used the low-power granulator with a horizontal array. Calorific value of investigated non-traditional energy plant pellets was determined by a calorimeter C 2000 (IKA, Germany), by the standard methodology (Siaudinis et al., 2012).

Each test is repeated 3 times. The analysis of variance with three replications design was performed on the data of the fulfilled experiments, using analysis of variance (ANOVA) to determine significance at 95% probability level (LSD05).
3. Results and discussion

First step of energy plant preparation for biofuel is chopping and milling. There were determined main physical-mechanical properties of non-traditional energy plant stems chopped by forage harvester *Maral 125* by drum chopper and milled by mill *Retsch SM 200* – moisture content and bulk density (Table 1).

**Table 1. Physical-mechanical properties of non-traditional energy plant stems chaff and mill**

<table>
<thead>
<tr>
<th>Non-traditional energy plants</th>
<th>Moisture content [%]</th>
<th>Bulk density [kg m(^{-3})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant grass</td>
<td>Chaff</td>
<td>14.9±0.9</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
<td>1.1±0.3</td>
</tr>
<tr>
<td>Sida</td>
<td>Chaff</td>
<td>14.1±0.3</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
<td>5.9±0.6</td>
</tr>
<tr>
<td>Cup plant</td>
<td>Chaff</td>
<td>15.2±0.7</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
<td>8.2±0.4</td>
</tr>
<tr>
<td>Seeder hemp</td>
<td>Chaff</td>
<td>9.0±0.6</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
<td>0.2±0.1</td>
</tr>
</tbody>
</table>

Determined bulk density of seeder hemp chaff is the smallest – 28.2 kg·m\(^{-3}\) DM (dry matter), and the density of cup plant is the biggest – 87.3 kg·m\(^{-3}\) DM. Bulk density of seeder hemp mill is the smallest – 101.0 kg·m\(^{-3}\) DM, and determined density of sida is the biggest – 224.5 kg·m\(^{-3}\) DM.

When preparing plant chaff for pellet production it was broken up in the form of mill using a hammer mill. Fraction composition of non-traditional energy plant mill was determined by using sieves with holes of various diameters. Fractional composition of prepared mill (%) dependence on sieves holes diameter (mm) is presented in Fig. 1, Fig. 2, Fig. 3 and Fig. 4.

Dependance of a part of Elephant grass mill fraction (%) from the holes of sieves is presented in Fig. 1. The biggest part of elephant grass mill fraction was noticed on 0.63 mm diameter perforation sieve – 46.4±0.6%, a bit less on 2 mm diameter perforation sieve – 31.0±0.0%. The smallest part of elephant grass fraction was noticed on 0.25 mm diameter perforation sieve – 0.1±0.0%.

**Fig 1. Elephant grass mill fractional composition (%) dependence on sieves perforation diameter (mm)**
Fraction composition of sida stem mill is presented in Fig. 2. Having evaluated fraction composition of mill, we may see that the highest fraction of sida mill accumulated on a sieve with holes 0.5 mm diameter – 45.9±3.5%, and high amount of fraction accumulated on a sieve with holes 1 mm diameter too – 31.0±2.2%. When sieving mill of sida, dust was not found.

![Fig 2. Sida mill fractional composition (%) dependence on sieves perforation diameter (mm)](image)

Dependance of a part of cup plant mill fraction (%) from the holes of sieves is presented in Fig. 3. After evaluation of mill factional composition from the chart we can see that the highest fraction of cup plant mill accumulated on a sieve with holes 0.63 mm diameter – 37.6±2.9%, little less on 2 mm diameter holes sieve – 29.6±2.5%. There was no fraction on a sieve with holes 0.25 mm diameter, and too big amount of dust was found – 17.4±2.2%.

![Fig 3. Cup plant mill fractional composition (%) dependence on sieves perforation diameter (mm)](image)

Fractional composition of prepared seeder hemp mill (%) dependence on sieves perforation diameter (mm) is presented in Fig. 4. After evaluation of mill factional composition from the chart we can see that the biggest hemp powder fraction has collected on 0.5 mm perforation diameter sieve – 77.4±0.6% factional part. And similar to the cup plant mill, there was no fraction on a sieve with holes 0.25 mm diameter.
Fig. 4. Seeder hemp mill fractional composition (%) dependence on sieves perforation diameter (mm)

It has been estimated that seeder hemp preparation for burning – chopping and milling is complicated due to the specific hemp fiber properties. Other investigated non-traditional energy plant – elephant grass, sida and cup plant preparation for the biofuel process is less complicated, require of less time and about 15-20% lower power consumption.

All non-traditional energy plants are suitable for burning after appropriate preparation. In order to continue using for energy purposes, investigated energy plants were pressed in pellets and were determined pellet physical-mechanical properties: moisture content, bulk density and calorific value when burning them (Table 2).

Table 2. Physical-mechanical properties of non-traditional energy plant pellets

<table>
<thead>
<tr>
<th>Non-traditional energy plant pellets</th>
<th>Moisture content [%]</th>
<th>Bulk density (DM) [kg m⁻³]</th>
<th>Calorific value (DM) [MJ kg⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant grass</td>
<td>8.2±0.7</td>
<td>713.5±20.1</td>
<td>18.5</td>
</tr>
<tr>
<td>Sida</td>
<td>6.1±0.3</td>
<td>999.3±36.4</td>
<td>18.4</td>
</tr>
<tr>
<td>Cup plant</td>
<td>6.4±0.4</td>
<td>909.8±21.3</td>
<td>17.9</td>
</tr>
<tr>
<td>Seeder hemp</td>
<td>6.0±0.1</td>
<td>877.8±18.2</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Determined bulk density in dry matters (DM) of elephant grass pellets was the smallest – 713.5±20.1 kg m⁻³, and the density of sida pellets was the biggest – 999.3±36.4 kg m⁻³.

The average calorific value of investigated non-traditional energy plant pellets varied from 17.9 to 18.5 MJ kg⁻¹. This calorific value of grassy plant pellets was relatively high, close to calorific value of some wood species.

4. Conclusions

1. In Lithuania, wood is the most widely used biomass fuel (firewood, kindling, sawdust) which may be changed by various non-traditional energy plants – elephant grass, sida, cup plant and seeder hemp.

2. Evaluating the milling quality of investigated non-traditional energy plants – elephant grass, sida, cup plant and seeder hemp was determined the fractional composition on sieves with holes of various diameters.
3. After evaluation of mill factional composition of non-traditional energy plants there were determined that the biggest fraction has collected on 0.5 mm perforation diameter sieve of hemp mill – 77.4±0.6% factional part. And there were no fraction on a sieve with holes 0.25 mm diameter of hemp and cup plant mill.

4. In order to continue using for energy purposes, investigated energy plants were pressed in pellets and were determined pellet physical-mechanical properties: moisture content, bulk density and calorific value. Determined bulk density in dry matters (DM) of elephant grass pellets was the smallest – 713.5±20.1 kg m$^{-3}$, and the density of sida pellets was the biggest – 999.3±36.4 kg m$^{-3}$.

5. The calorific value of elephant grass, sida, cup plant and seeder hemp was relatively high, close to calorific value of some wood species. Determined average calorific value of investigated non-traditional energy plant pellets varied from 17.9 MJ kg$^{-1}$ to 18.5 MJ kg$^{-1}$.

5. Acknowledgements

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6. References


