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EVALUATION OF GIANT KNOTWEED AND MISCANTHUS AS PERSPECTIVE ENERGY PLANTS AND ASSESSMENT OF PRODUCED BIOFUEL QUALITY INDICATORS

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Giant knotweed (*Fallopia sachalinensis*) was chosen as a perspective energy plant because it is not a soil demanding plant and belongs to the most efficient herbs in Central Europe as regards high biomass yield. Miscanthus (*Miscanthus sinensis*) was chosen as a control one. Knotweeds are comparable to wood briquettes and pellets because of their similarparallel mechanical and thermal features. These plants grow in forest environment with an approximate yield productivity of 15 t ha^{-1} d.b. (dry basis). Experimental research investigations were performed in the laboratories of Aleksandras Stulginskis University. Giant knotweed and miscanthus biomass was cut, chopped, milled and granulated with a small capacity granulator (250–300 kg h^{-1}). Quality parameters of plant preparative and use for energetical objectives were determined. Plant chaff and mill fraction compositions were determined, and quality indicators of the produced pellets were measured – moisture content, density, resistance to compression, elemental composition, ash content and calorific value, also bulk density, fall and natural slope angles. Moisture content reached 7.8 ± 0.8 %; pellet density was 1227.3 ± 48.6 kg m^{-3}. Resistance to compression of giant knotweed pellet was 850 N. Determined ash content was 4.3 ± 0.01 %, and net calorific value of knotweed dry mass was of sufficient height and reached 18.96 ± 0.28 MJ kg^{-1}. Bulk density reached 509.9 kg m^{-3}, natural slope angle was 31.7 ^{0} and fall angle was 49.3 ^{0}.

Keywords: ash content, calorific value, density, elemental composition, knotweed, miscanthus, pellets.

INTRODUCTION

At present, just about 7 % of energy production in Europe is from renewable energy sources. The European Union imports about 48 % of energy from Russia and Norway. In the year 2006, EU sustainable development strategy forecasted that in 2020 energy production from renewable energy sources would reach 20 %. In Lithuania, just 15 % of energy production is produced using renewable energy sources (Janisevičius, 2014). Until the year 2020, heat generation from solid biofuel in Lithuania will reach 67 % (Verbickas et al., 2015).

Wood biofuel is the most widely used sort of fuel in Lithuania. Apart from this sort of solid fuel, other local resources (raw materials) used for energy purposes: straw, waste products of agriculture, peat and energy plants. Energy plants such as willow (*Salix viminalis* L.), virginia mallow (*Sida hermaphrodita* L.), fibrous hemp (*Cannabis sativa* L.), stinging nettle (*Urtica dioica* L.), cup plant (*Silphium perfoliatum* L.), miscanthus (*Miscanthus sinensis*), as well as giant knotweed (*Fallopia sachalinensis*) can be successfully used in the energy market of Lithuania. These plants are not soil demanding and prefer cool climatic conditions (except miscanthus).

In this paper we would like to introduce the data from the investigations of two energy crops – knotweed and miscanthus (as control one).

Giant knotweed (*Fallopia sachalinensis*) is native to eastern Asia; it can grow from 1.5 m to more than 3.5 m tall. Knotweed is a perennial plant that sprouts from a woody base each year. These plants can reach high productivity of about 15 t ha^{-1} d.b. (dry basis). There are several species of knotweed: Japanese knotweed (*Fallopia japonica*), Giant knotweed *(Fallopia sachalinensis*), Bohemian knotweed (*Fallopia × bohemica*), Himalayan knotweed (*Persicaria wallichii*), etc. (Prather *et al.*, 2009).

Miscanthus (*Miscanthus sinensis*) was brought to Europe from the East Asian climatic zone. It is a perennial plant with stems that are of 4 metres height. Miscanthus is sensitive to frost. Under favourable conditions and sufficient moisture in the soil, miscanthus is capable of producing up to 25 t ha^{-1} d.b.. The stems of these plants for fuel in the same area can be grown for 20 – 25 years (Jakienė et al., 2013).

There are different methods of biomass processing for energy purposes. The most popular technology is to produce pellets from biomass in the late decade of the year.

The aim of this work is to research giant knotweeds and miscanthus pellets quality indicators: ash content, density, humidity, calorific value, and deformation strength.

MATERIALS AND METHODS

One sort of knotweed and miscanthus was explored. Knotweeds are grown in forest vicinities and miscanthus is cultivated in the test station.

Chopping and milling qualities of the plants that are prepared for solid biofuel production should satisfy the requirements of the combustion chamber of biofuel boiler, chopped mass transportation machinery and storage. Drum chopper of Maral 125 forage harvester used for the first step of stem chopping. Mill Retsch SM 200 used for milling prepared chaff (Streikus et al. 2016).

Fractional composition. Plants flour mass fractional composition determined using sieves with different diameter holes: 0 mm, 0.25 mm, 0.5 mm, 0.63 mm, 1 mm and 2 mm. For this experiment, sieve shaker Retsch AS 200 (Fig 1.) used. The complect of sieves was set on the siewe shaker, and was vibrating 3 minutes with 10 seconds intervals every minute in a horizontal flat. Every fraction part persentage of the remaining mass of sieves is weighed and calculated. In addition, according to research data reliability estimation calculated measurements average with deviation. Each test repeated 3 times.

For *pellet production* we used granulator with horizontal granulator matrix. Its capacity was 7.5 kW.

Humidity. Pellets packed into cruets and weighed. Afterwards, it was put into a drying chamber (Fig 2.). Samples were dried for 24 hours at 105 °C temperature. Both the dried samples and empty cruets were weighed . The humidity of all the samples, as well as average humidity with deviation, was calculated.

Pellet density. For the determination of pellet density, various plants pellets weighed and their mass *m* was determined. Also, were measured by trammel pallets length and diameter measured using trammel pallets and the volume *V* of the pallets was calculated. According to equation $\rho = m/V$, a single pellet density calculated.

Resistance to compression. The research is done in laboratory using a device INSTRON 5965 (Fig 3.). 5 pellets were selected for each sort of plants. Pellet was pressed until it was damaged. The entireprocess was controlled by a special computer program and data were and fixed in the computer memory disc.

Bulk density determined after filling pellets to a cylindrical plate of the measured volume (*V*) (which was equal 5 dm^3) and not pressing weighed by scale to determine their mass (*m*), bulk density was calculated by formula: $\rho = m/V$ (Solid biofuels. 2005).

Fly angles. Natural slope angle α_n and fall angle α_{gr} determined using a special stand which is in Agriculture Engineering and Safety Institute (Siaudinis et al., 2015).

Figure 1. Sieve shaker Retsch AS 200

Figure 2. Drying cupboard

Figure 3. INSTRON 5965

Ash content and calorific value. Tests was done in Lithuanian Energy Institute, Thermal devices test and research laboratory applying standard methodology that is valid in Lithuanian and European countries. Ash content was determined in research device No. 8B/5 according to LST EN 14775:2010 standard requirements. Calorific value determined in research device No. 8B/2 according to LST EN 14918:2010 standard requirements.

RESULTS AND DISCUSSION

The particle size distribution of chopped by drum chopper and milled by hammer mill giant knotweed and miscanthus determined.

The particle size distribution or farctional composition of knotweed mill (%) is given in Fig. 4. Estimated fractional composition of mill, it had been noticed that there was no fraction on a sieve with holes of 2 mm diameter, and after the milling of giant knotweed chaff very small fraction was produced. A large mill fraction found on 0.25 mm sieves (45.4 ± 3.6%), and the highest amount of dust found – 46.7 ± 3.2%.

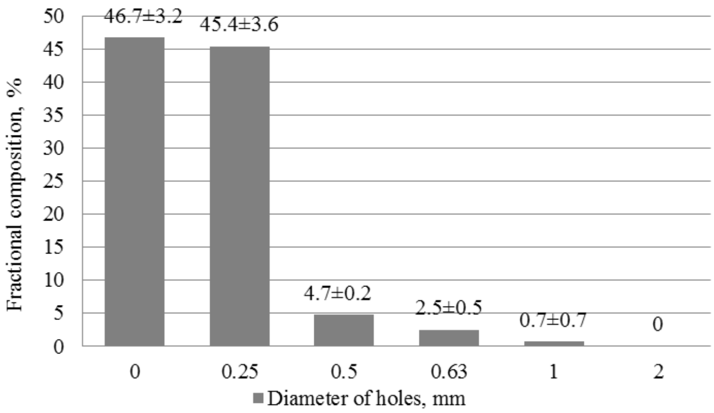

Figure 4. Fractional composition of knotweed mill

The dependance of miscanthus mill fraction (%) from the holes of sieves is given in Fig. 5. Research results show that if compared to giant knotweed mill, produced miscanthus mill fraction was significantly coarser. The biggest fraction of plant mill accumulated on a sieve with the holes of 0.63 mm diameter – 46.4 ± 0.6 %, the second biggest on a sieve with the holes of 2 mm diameter – 31.0 ± 0.0 %, and there was no fraction on a sieve with holes of 0.25 mm diameter.

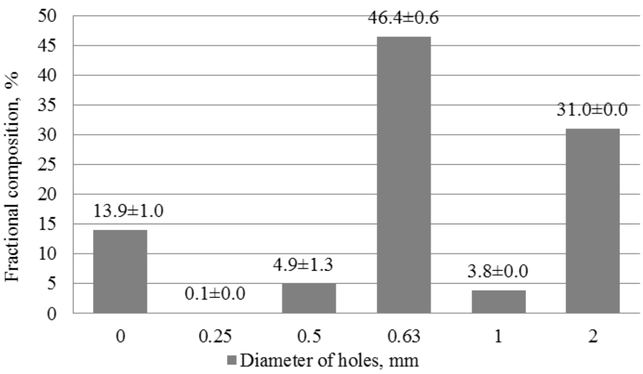

Figure 5. Fractional composition of miscanthus mill

The humidity and density of pellets showed in Table 1 have been determined. Results of investigations show that pellets humidity varies from 7.8 to 8.4 %. Density of investigated plants pallets was sufficiently high and reached 1131.6 – 653.6 kg m^{-3} d.b.

Table 1. Main physical-mechanical characteristics of pellets

Pellets	Humidity, %	Pellet density, kg m^{-3}
Giant knotweed	7.8 ± 0.8	1227.3 ± 48.6 1131.6 ± 48.6 d.b.
Miscanthus	8.4 ± 0.07	713.5 ± 67.1 653.6 ± 67.1 d.b.

d.b. – dry basis

The bulk density of giant knotweed pellets reached 509.9 kg m^{-3}, natural slope angle α_n was 31.7 ^{0} and fall angle α_{gr} was 49.3 ^{0}.

Resistance to compression is an significant parameter for the transportation and storage of pellets. Resistance to the compression of giant knotweed was 850 N, whereas resistance of the compression of miscanthus was only 196 N.

The quality indicators of investigated energy plants pellets in burning facility showed in Table 2 and Fig.6.

Table 2. Pellets ash contents and calorific value (d.b.)

Pellets	Ash content, %	Calorific value, MJ kg^{-1}
Giant knotweed	4.28 ± 0.01	8.84 ±0.90
Miscanthus	18.96 ± 0.28	18.95 ±0.58

Ash content of miscanthus was the biggest and reached 8.8 %, a lower ash content was of the giant knotweed and reached 4.3 %.

The average calorific value of giant knotweed and miscanthus pellets of d.b. was very similar and reached 19.0 MJ kg^{-1}. Compared to the calorific value of some wood species, the calorific value of these plants pellets is quite great, for example birch has a calorific value of 18.5 MJ kg^{-1} (Jasinskas and Zvicevičius, 2008).

Other researchers conducted the tests with other species: Japanese knotweed (*Fallopia japonica*) and Bohemian knotweed (*Fallopia × bohemica*). The results were as follows: productivity was 13.23 – 21.41 t ha^{-1} d.b. of Japanese knotweed and 6.84 – 17.74 t ha^{-1} d.b. of Bohemian knotweed. Moisture content was 16.6 – 32.3 %, ash content – 3.12 – 4.60 % (Strašil and Kara, 2010).

The pellets of knotweed were investigated by other scientists, and they got the following results: moisture content was 5.93 %, ash content – 3.99 %, calorific value – 17.62 MJ kg^{-1} (Malatak and Passian, 2011).

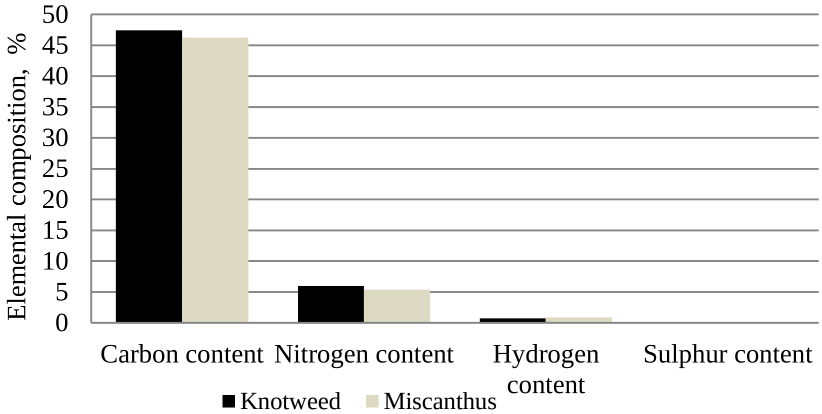

Figure 6. Pellets elemental composition

Having performed the research of knotweed pellets properties, it can be stated that it is proper to use as biofuel due to the fact that its characteristics are close to the properties of wood-based biofuels. Knotweeds yield can be produced in one year, but the price of this plant pellets can be higher than the price of wood pellets.

CONCLUSIONS

1. The technical means of giant knotweed, and the preparation and usage for energy purposes of miscanthus explored. Technique for plant chopping, milling and pelleting investigated.
2. By establishing the fineness of plant mill fraction it can be said that knotweed was milled into too small fraction, because too high amount of knotweed dust (less than 0.25 mm) was found – 46.7 ± 3.2 %, and there was no fraction on a sieve with 2 mm diameter holes.
3. Determined miscanthus mill fraction was coarse, because the biggest mill fraction was on 0.63 mm diameter sieve – 46.4 ± 0.6 %.
4. Set pellets humidity varies from 7.8 to 8.4 %. Density in dry basis (d.b.) of investigated plants was sufficiently high; it reached 1131.6 – 653.6 kg m-3 d.b.
5. 5. The ash content of miscanthus was the highest and obtained 8.8 %, ash content of giant knotweed was about twice as low and reached 4.3 %. Determined calorific value of giant knotweed and miscanthus pellets was high enough, it was even 19.0 MJ kg-1 d.b.
6. After evaluation of knotweed pellets properties, it can be stated that it is proper to use as solid biofuel, because its characteristics are very similar to the properties of wood biofuels.

REFERENCES

1. CEN/TC 14774-1. 2005. Solid biofuels – Methods for the determination of moisture content Oven dry method – Part 1: Total moisture – Reference method.
2. Instruction manual of pellet mill. 2011. Granulator Peleciarka 7.5. Company POLEXIM, Poland, pp. 7.
3. Jakiene, E., Liakas V., Klimas, E., Bačkaitis, J. 2013. Technologies for growing energy crops and woody plants. Akademija, 199 p. [In Lithuanian].
4. Janisevičius, G. 2014. Wood and agro-biofuel. Sustainable development strategy and practice Research work. pp. 143.

5. Jasinskas, A., Simonavičiūtė, R., Šiaudinis, G., Liaudanskienė, I., Antanaitis, Š., Arak, M., Olt, J. 2014. The assessment of common mugwort (Artemisia vulgaris L.) and cup plant (*Silphium perfoliatum* L.) productivity and technological preparation for solid biofuel. *Zemdirbyste-Agriculture*, Vol. 101, No. 1, pp. 19–26 https://doi.org/10.13080/z-a.2014.101.003
6. Jasinskas, A., Zvicevičius, E. 2008. Biomass production engineering: Educational book. Akademija, 99 p. [In Lithuanian].
7. LST EN 14775:2010 standard. Ash content test.
8. Macak, M., Nozdrovicky L., Hussein, A.O. 2015. Effect of preheating and different moisture content of input materials on durability of pellets made from different phytomass content. *Acta Technologica Agriculturae,* Vol. 1, pp. 22–27. https://doi.org/10.1515/ata-2015-0006
9. Malatak, J., Passian, L., 2011. Heat-emission analysis of small combustion equipments for biomass. *Research in Agricultural Engineerin*g. Vol. 57, pp. 37–50.
10. Niedziołka, I., Szpryngiel, M., Kachel-Jakubowska M., Kraszkiewicz, A., Zawislak, K., Sobczak, P. & Nadulski, R. 2015. Assessment of the energetic and mechanical properties of pellets produced from agricultural biomass. *Renewable Energy,* Vol. 76, pp. 312–317.https://doi.org/10.1016/j.renene.2014.11.040
11. Prather T.S., Miller T.W. & Robins S.S. 2009. Knotweed shrubs: identification, biology and management. Available at: https://catalog.extension.oregonstate.edu/pnw 610.
12. Solid biofuels. Determination of bulk density. 2005. LST CEN/TS 15103.2005 [In Lithuanian].
13. Strašil, Z., Kára, J. 2010. Study of knotweed (Reynoutria) as possible phytomass resource for energy and industrial utilization. *Research of Agricultural Engineering*, Vol. 56, pp. 85–91.
14. Streikus, D., Jasinskas, A., Arak, M., Jotautienė E., Mieldažys, R., Čekanauskas, S., Jankauskienė, Z. 2016. Investigations of fibre plants preparation and utilization of solid biofuels. *Agronomy research,* Vol. 14, No. 1, pp. 259–268
15. Šiaudinis, G., Jasinskas, A., Šarauskis, E., Steponavičius, D., Karčiauskienė, D., Liaudanskienė, I. 2015. The assessment of Virginia mallow (Sida hermaphrodita Rusby) and cup plant (Silphium perfoliatum L.) productivity, physicoemechanical properties and energy expenses. *Energy,* Vol. 93, *Iss.* 1, pp. 606–612. https://doi.org/10.1016/j.energy.2015.09.065
16. Verbickas, D., Juknys, R. & Kleišmantas, A. 2013. The use of solid biofuels in Lithuania for heat production, future prospects and the impact on the environment. *Energetika,* Vol. 59, No. 3, pp. 144 [In Lithuanian].