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HERBAL PLANTS PREPARATION FOR BIOFUEL AND ANALYSIS OF PELLETS PROPERTIES

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For research investigations were used the herbal unconventional energy plants – cup plant (*Silphium perfolatium L.)* and Virginia mallow (*Sida hermaphrodita*), which were grown in Lithuanian Research Centre for Agriculture and Forestry, and the knotweed (*Reynoutria*), which grew naturally in the forest glade. The productivity of these herbaceous plants are very high – 7-20 t ha^{-1} dry mass yield. Plants were cut by manual motorized chainsaw and chopped by drum chopper. Prepared chaff was milled by hummer mill and produced mill was granulated by small capacity granulator (250-300 kg ha^{-1}). In presented work were determined investigated plant mill and pellet properties. After investigation of mill fractional composition was determined, that the smallest mill fraction was produced of milled knotweed plant stems: the biggest mill fraction accumulated on sieve with holes 0.25 mm diameter – 45.4 %, and dust – 46.7 %. The cup plants mill biggest fraction accumulated on sieve with holes 0.63 mm (37.6 %), Virginia mallows mill – on sieve with holes 0.5 mm (45.9 %). Also it was determined pellets quality parameters: humidity, density, ash content and calorific value. Determined biggest humidity was of knotweed – 22.3 %, it was too big, but produced knotweed pellets was sufficient hard and burning efficiency was a normal. The pellet density was significant high and ranged from 945.5 to 1072.3 kg m^{-3} dry matter (DM). The ash content of investigated plant pellets varied from 4.28 to 9.96 %, and was too high compared with wood. The average calorific value of investigated energy plants pellets varied from 16.8 to 17.7 MJ kg^{-1}. Using laboratory equipment INSTRON 5960 were determined pellet disintegration force: the biggest force was for knotweed plant – 847 N, and about two times less for cup plant (463 N) and Virginia mallow (344 N). After analysis of test results it should be concluded, that knotweed pellets are sufficiently resistant to static force.

Key words: biofuels, knotweed plant, Virginia mallow, cup plant, mill, pellets, properties, disintegration force.

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INTRODUCTION

During the last decades, the bigger attention in agriculture science field is taken notice of the new plants biomass usage for energy purposes. Biomass is one of the general renewable energy resources. Compared with fossil fuel, the use of plant-based bio-fuel significantly reduces the “greenhouse” effect, because the amount of CO_2, which is released during combustion, is used for the production of organic material during photosynthesis (Agriculture, 2014). Common mugwort, cup plant, fibrous nettle, reed canary grass, miscanthus, reed, fibrous hemp, giant knotweed are the most popular ones. They are characterized as soil undemanding and high productivity crops. These forms of fuel are considered to be the fuels of the future due to their low moisture content, high calorific value, low ash content, easy handling and environmentally friendly impact (Ivanova, 2012).

Knotweed (*Reynoutria*) belong among the most effective crops in the Central Europe as regards the phytomass yield. They were introduced in Europe from the Asian temperate zone (Strasil, Kara, 2011). These plants are perennial, in one place can grow 25 and more years (Dzenajaviciene *et al*., 2011). Knotweeds dry mass productivity is 8-11 t ha^{-1} (Karpinskaite, 2010).

Cup plant (*Silphium perfoliatum* L.) also known as sylfia, is a large, acervate perennial of the aster family (Asteraceae) as well as sunflower and topinambour (Wrobel *et al*., 2013). It came from North America. Growing up to 2.5-3 meters high. The plant is able to adapt to a different types of soils and is frost – resistant (Karpinskaite, 2010).

Virginia mallow (*Sida hermaphrodita*) native of the North America. Suitable dry climate conditions with 500 – 600 mm precipitation. The plant grows 3-4 meters high. It multiplies by tubers and seeds. Planting on April or May, plant productivity reach 8-20 t ha^{-1} of dry mass. The yield is taken in winter when plants moisture decrease less than 10 % (Siaudinis *et al*., 2015).

According to National renewable energy resources development strategy the part of renewable energy resources compared with total energy consumption should reach 23 % in 2020 (Resolution, 2010). Perspective energy plants plantations would be useful economically decreasing dependence on fuel import also environmentally reducing emissions and socially creating new working places as well. It is indicated that during the last twenty years the global share of herbaceous biomass from agriculture (predominantly it is the wood) in the total consumption of primary energy sources increased by 8% (Malatak, Passian, 2011). The harvesting technology for unconventional energy plants depends on many factors, the biological properties of the mature plant, humidity, and weather conditions. The literature analysis offers two harvesting technologies, direct – plant harvesting and milling or indirect – removal of plant stems and pressing or loose stem harvesting, storage and chopping.

The pellets are convenient for small, medium and large-scale thermal plants because the pellet supply and combustion operations can be fully automated; however, a general problem for big thermal plants is the space required for biomass storage.

The aim of this work is to evaluate the peculiarities of herbal unconventional energy plants: knotweed (*Reynoutria*), Virginia mallow (*Sida hermaphrodita*) and cup plant (*Silphium perfoliatium* L.) preparation for biofuel and to determinate the mill fractional composition, pellets physical-mechanical properties and compression force.

MATERIALS AND METHODS

Experimental plants – cup plant and Virginia mallow were grown in the field of Lithuanian Research Centre for Agriculture Institute Branch of Vėžaičiai. The knotweed was grown naturally in the forest environment. The yield was taken in March 2015.

The stems were crushed up with mechanical - electrical equipment. Obtained material was chopping by a harvester's "Maral 125" ("Fortshritt", Germany) drum chopper with 8 blades at a rotation frequency of 913 revolutions per minute. The fractional composition of chaff was determined using standard methodology (DD CEN/TS 15149-1:2006), commonly employed in the European Union, using a vibratory device Haver EML Digital plus (DD CEN/TS 15149-1:2006). It was used 400 mm diameter sieves, where sieves with round pore are put one on other (in the order from the top sieve): diameter of 63 mm, 45 mm, 16 mm, 8 mm, 3.15 mm and 1 mm. The mass remaining on the sieves was weighed, and the sample fraction percentages were calculated (Scholz *et al*., 2006).

Prepared chaff was milled with Retsch SM 200 mill. According to DD CEN/TS 15149-1:2006 methodology the fractional composition was determined using a vibratory device Retch AS 200. It was used 200 mm diameter sieves, where sieves with round pore are put one on other (in the order from the top sieve): diameter of 2 mm, 1 mm, 0.63 mm, 0.5 mm and 0.25 mm. The mass remaining on the sieves was weighed, and the sample fraction percentages were calculated (Jasinskas *et al.*, 2014).

For the pellets production was used a small capacity 200-350 kg h^{-1} granulator ("Polexim", Poland) 7.5 kW with a horizontal granulator matrix, the diameter of pellets was 6 mm.

Pellet compressive strength was measured using INSTRON 5960 testing equipment. It was determined disintegration force and deformation dependence (Jasinskas *et al*., 2015).

All tests were done in Agricultural Engineering and Safety Institute and Experimental Station of Aleksandras Stulginskis University.

Pellet ash content and calorific value were determined at the Lithuanian Energy Institute (LEI) Thermal equipment research and testing laboratory in accordance with the valid Lithuania and EU countries standard methodology (BS EN 14918:2009. Solid biofuels).

RESULTS

Dependance of a part of plants mill fraction (%) from the holes of sieves is presented in Table 1. It was determined that knotweeds mill fraction was the smallest. The highest knotweeds mill fraction was on a sieve with holes 0.25 mm diameter and dust, and it varied form – 45.4 % to 46.7 %. Cup plants the highest mill fraction was on a sieve with holes 0.63 mm diameter – 37.6 %. Virginia mallows the highest mill fraction was on a sieve with holes 0.5 mm diameter – 45.9 %.

Moisture content has a great influence on biofuel heating values. Pellets quickly absorb ambient moisture, may swell, disintegrate and turn into its original state as before pelletizing. Dry raw materials with the moisture content up to maximum 15 % should be used for pellet production. Moisture content affects energetic indices of pellets, combustion efficiency and calorific value. Therefore, it was estimated biofuel‘s humidity, which ranged from 9.6 to 22.3 % (Table 2). Determined humidity of knotweed – 22.3 % was too big, but produced knotweed pellets was sufficient hard and burning efficiency was a normal.

Table 1. Mill fractional composition, %

Plant	Diameter of sieve holes, mm					
	2.0	1.0	0.63	0.5	0.25	0
Knotweed	0	0.7	2.5	4.7	45.4	46.7
Cup plant	29.6	12.3	37.6	3.0	0	17.4
Virginia mallow	13.9	31.0	3.8	45.9	5.0	0.4

The ash content varied from 4.28 to 9.96 %, which is high compared with wood. The knotweed had the lowest ash content – 4.28 % (Table 2).

The pellet density was significant high and ranged from 945.5 to 1072.3 kg m^{-3} dry matter (DM). The density of knotweed reached 1072.3 kg m^{-3} (Table 2).

The average calorific value of investigated energy plants pellets varied from 16.8 to 17.7 MJ kg^{-1} (Table 2). This calorific value of pellets was relatively high, close to calorific value of some woody plant species.

Table 2. Pellets quality indicators

Plant	Humidity, %	Density, kg m^{3} (DM)	Ash content, %	Calorific value, MJ kg^{-1} (DM)
Knotweed	22.3	1057.5	4.28	17.73
Cup plant	11.6	1072.3	9.96	16.82
Virginia mallow	9.6	945.5	6.07	17.43

Were determined the pellet resistance to degradation, which is an important parameter of pellets, especially for pellets transportation and storage. After resistance to degradation tests of selected biofuel pellets, were obtained the results which are presented in Figures 1, 2 and 3.

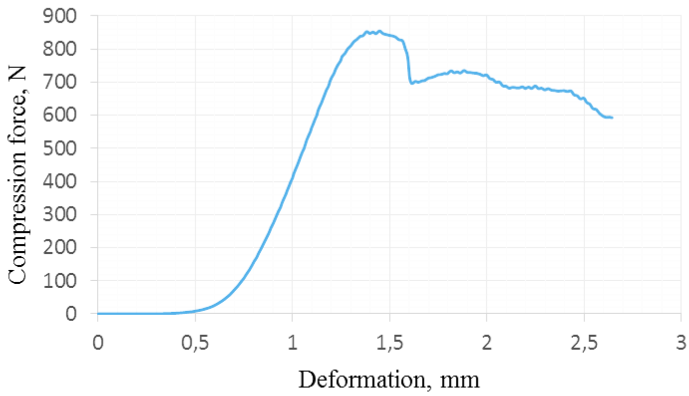

Figure 1. Deformation of knotweed pellet and compression force

Analyzing the cup plant pellet deformation curve we see, that the pellet compression force completely reached about twice lower 463,0 ± 22.1 N force with 1.15 mm deformation (Figure 2).

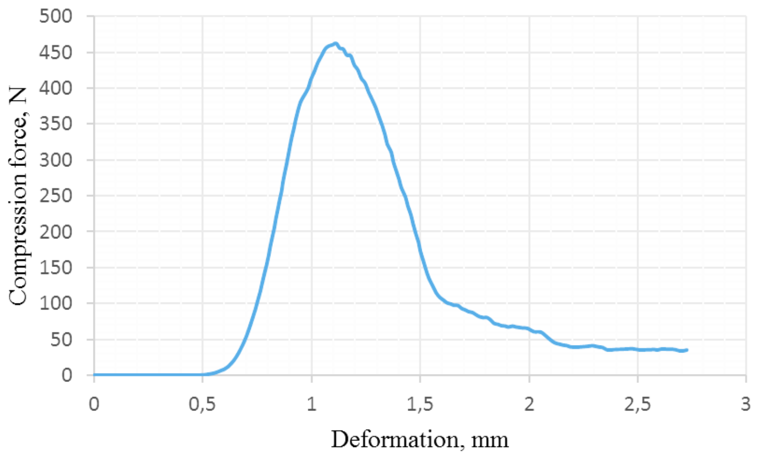

Figure 2. Deformation of cup plant pellet and compresssion force

After analysis of Virginia mallow pellet compression force it was determined, that these pellets were the least resistant to the impact force, which reached 344.2 ± 19.6 N force with 0.6 mm deformation (Figure 3).

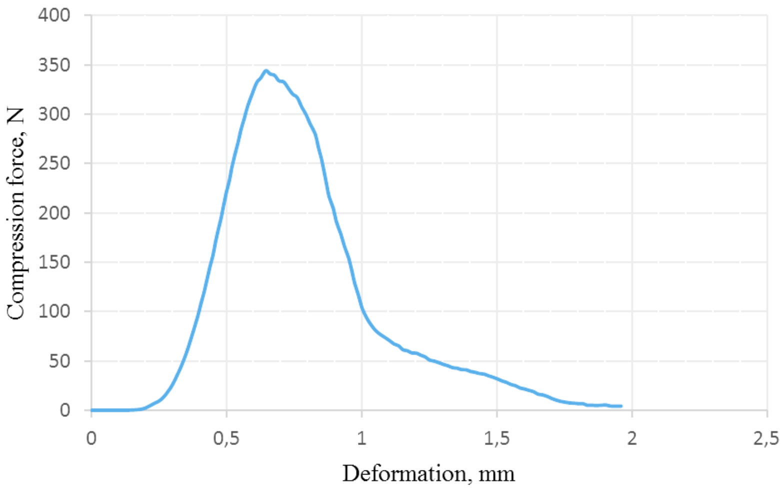

Figure 3. Deformation of Virginia mallow pellet and compression force

The analysis of pellet resistance to degradation test results it should be stated, that considering size of the force, its displacement and pellet moisture content (22.3 %), it is possible to decide that knotweed pellets are sufficiently resistant to static force and do not disintegrate quickly even if moisture content was higher than the requirements for the production of fuel.

CONCLUSIONS

1. It was determined knotweed (*Reynoutria*), Virginia mallow (*Sida hermaphrodita*) and cup plant (*Silphium perfoliatium* L.) mill fractional composition. It was determined that the highest knotweeds mill fraction was selected on a sieve with holes 0.25 mm diameter (0.25-0.5 mm) and dust, it varied form – 45.4 % to 46.7 %.

2. It was determined plants pellets quality indicators: humidity, density, ash content and calorific value. Determined humidity of knotweed – 22.3 % was too big, but produced knotweed pellets was sufficient hard and suitable for storage, transportation and burning.

3. The pellet density was significant high and ranged from 945.5 to 1072.3 kg m^{-3} dry matter (DM). The density of knotweed reached 1072.3 kg m^{-3}.

4. The ash content of investigated plant pellets varied from 4.28 to 9.96 %, which is too high compared with wood. The knotweed had the lowest ash content – 4.28 %.

5. The average calorific value of investigated energy plants pellets varied from 16.8 to 17.7 MJ kg^{-1}. The calorific value of pellets was relatively high, close to calorific value of some woody plant species.

6. Using equipment INSTRON 5960 was determined plants pellets resistance to degradation. After analysis of test results it should be stated, that knotweed pellets are sufficiently resistant to static force and do not disintegrate quickly even if moisture content was too high (22.3 %).

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