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Evaluation of reed canary grass shredding and compacting properties

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Abstract. Reed canary grass biomass is recommended for solid biofuel production. The main conditioning operation before preparation of herbaceous biomass compositions for solid biofuel production is shredding. Shredding can increase bulk density up to 165 kg m^{-3}. Biomass compacting represents technology for the conversion of biomass into a solid biomass fuel in the shape of briquettes and pellets. Compacting of biomass is one of the important processes for effective handling, transport and storage of this biomass fuel material. The purpose of the work was to investigate reed canary grass (*Phalaris arundinacea*) comminuting energy, bulk density and briquetting energy dependence on hammer mill screen opening sizes. For comminuting was used a hammer mill, equipped with four different screens with opening sizes 20, 12, 6 and 1.5 mm. Comminuting energy for these opening sizes was stated within 11–236 kJ kg^{-1}. Bulk density for reed canary grass by comminuting can be increased up to 165 kg m^{-3} if hammer mill screen with opening size 1.5 mm is used. For briquetting experiments were used a hydraulic laboratory press, where for compacting were used five different pressure levels – 90, 120, 150, 180 and 210 MPa. Maximum density 899–964 kg m^{-3} had been achieved for compacting pressure 210 MPa. Summary energy consumption for comminuting and briquetting is approximately 50 kJ kg^{-1} if screen opening sizes are 12 and 20 mm in comminuting. For these sizes briquette density is 899 and 915 kg m^{-3}.

Key words: herbaceous biomass, comminuting, briquetting.

INTRODUCTION

Density of herbaceous biomass like reed canary grass (*Phalaris arundinacea*) after primary treatment has a relationship with transport and storage costs and affects the size of handling systems and processing equipment in the end use facilities. Bulk density has significant effect on material handling and storage aspects in a bio refinery, and depends on material composition, particle size, shape and distribution, moisture content, specific density and applied pressure (Lam et al., 2007). Bulk density of biomass increases during transportation, handling, and storage which can be caused by compaction due to vibration, tapping, or normal load (Emami & Tabil, 2008).

Compacting is a way how to increase herbaceous biomass density. Compacting of biomass represents technology for conversion of biomass into solid fuel in the shape of briquettes and pellets.

European countries have standards (ŌNORM 7135, SS 18 71 20 and DIN 51731) (Matúš & Križan, 2010; Alakangas, 2011) concerned with wood pellets and briquettes properties. Demand of mentioned biofuel density is > 1,000 kg m^{-3} in standards. For lower quality biomass solid fuel permissible density is > 900 kg m^{-3}.

In this study, shredding and compacting properties of reed canary grass was investigated using hammer mill and laboratory hydraulic press equipment.

The purpose of the work was to investigate reed canary grass comminuting energy, bulk density and briquetting energy dependence on hammer mill screen opening size.

MATERIALS AND METHODS

In experiments was used reed canary grass material which was stored in round bales. Bales were spread out before comminuting. The length of reed canary grass stalks was within 0.1 and 0.5 m.

For reed canary grass stalk comminuting a hammer mill was used. The machine was equipped with 15 kW electric motor and four different screens with round shaped opening size 1.5, 6, 12 and 20 mm. Hammer mill was equipped with instantaneous power measuring equipment. Electric motor was connected to a voltage transformer and to the *Pico Data Logger*. All data were collected with computer and processed with Microsoft Excel software. Before material comminuting, hammer mill idle power was determined. Specific cutting energy was calculated:

$$E_{SC} = \frac{E_{\Sigma} - E_{ID}}{m}, \quad (1)$$

where E_{SC} – specific cutting energy, kJ kg^{-1}; E_{Σ} – total consumed energy for comminuting, kJ; E_{ID} – calculated idle energy during experiment, kJ; m – comminuted material weight during experimenting, kg.

Bulk density for comminuted reed canary grass material was measured according DD CEN/TS 15103:2005.

Laboratory compaction experiments had been carried out in closed die (Fig. 1) with diameter 35 mm by means of laboratory hydraulic press equipment. The dosage of 35 grams of grinded reed canary grass was used for every briquette pressing. Grinding of reed canary grass was realised with a hammer mill using four different screen opening sizes 1.5, 6, 12 and 20 mm. Moisture of material was 17.6%. The moisture content was determined according to the standard BS EN 14774-2:2009, where oven drying of the samples was carried out at 105 ± 2 ºC. During compacting of an individual briquette, the force – displacement data were recorded by *Pico Data Logger* and computer. Energy requirement for compacting was obtained from force – displacement curves by graphical integration. Total specific energy of reed canary grass compacting was calculated by equation:

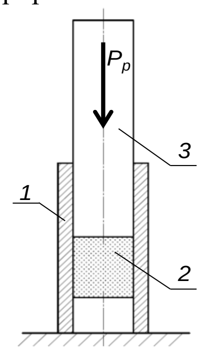

Figure. 1. Close die pressing scheme: 1 – die; 2 – pressing material; 3 – pressing piston.

$$E_{sp} = \frac{W}{m_b}, \qquad (2)$$

where E_{sp} – specific compacting energy, kJ kg^{-1}; W – compacting energy, kJ; m_b – mass of briquette, kg.

The briquettes with different density had been obtained as a result. For density calculation the weight of briquette was measured on electronic scales Sartorius GM312 with division 0.01 g and size of briquettes was measured with sliding calipers (division 0.1 mm). Briquette density has to be evaluated after briquette ejection from die.

For compacting of reed canary grass were used five different maximal pressure levels 90, 120, 150, 180, 210 MPa.

RESULTS AND DISCUSSION

Comminuted reed canary grass material bulk density is within 101 ± 2 kg m^{-3} (if screen with opening size 20 mm is used) and 165 ± 1 kg m^{-3} (if screen with opening size 1.5 mm is used). Using Microsoft Excel program was determined comminuted reed canary grass material density dependence on hammer mill screen size (Fig. 2). The trend line shows hammer mill screen size influence on material bulk density.

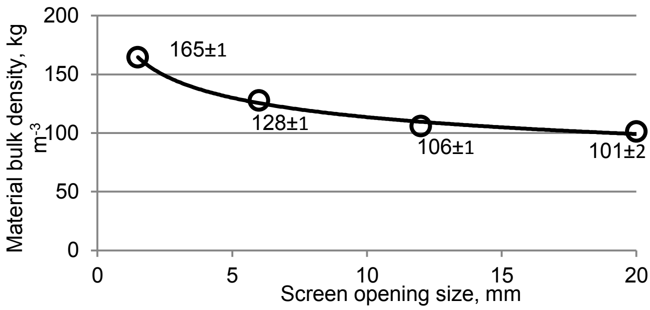

Figure 2. Bulk density dependence on hammer mill screen size.

Screen size influence on bulk density trend line formula was:

$$\rho = f(D) = 180 \cdot D^{-0.2}. \qquad (3)$$

where ρ – bulk density, kg m^{-3}; D – Hammer mill screen opening diameter, mm.

Reed canary grass material cutting energy for all screens was determined (Fig. 3). Screen size influence cutting energy trend line formula was:

$$E_{SC} = 435 \cdot D^{-1.23}. \qquad (4)$$

Specific cutting energy per mass unit is growing considerably when screen opening with size less than 12 mm is used.

Compacting pressure is a factor which influences mainly on briquette strength and density. In Fig. 4 is shown average density of reed canary grass depending on compacting pressure and material particle size. For material particle size characteristic was used hammer mill screen opening size. The result shows that the highest average value of briquettes density was obtained compacting reed canary grass particles which were produced using hammer mill screen opening size 1.5 mm, but the lowest values are for screen opening size 20 mm.

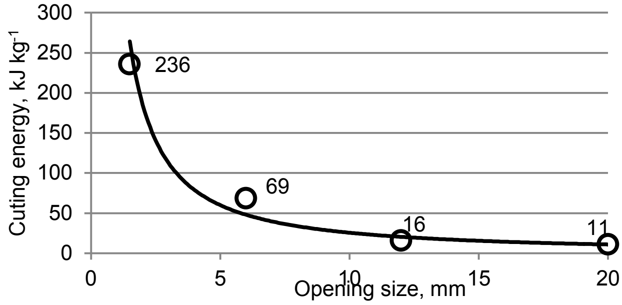

Figure 3. Cutting energy dependence on hammer mill screen opening size.

Fig. 4 shows that the briquettes density for all particle size groups increased with an increase in pressure. The mean density value of briquettes increase from 746 ± 11 to 915 ± 25 kg m^{-3} (screen opening size 20 mm), from 781 ± 14 to 899 ± 20 kg m^{-3} (screen opening size 12 mm), from 888 ± 12 to 951 ± 19 kg m^{-3} (screen opening size 6 mm) and from 917 ± 18 to 964 ± 23 kg m^{-3} (screen opening size 1.5 mm), if compacting pressure increases from 90 to 210 MPa. Satisfactory values of briquettes density for each material particle groups were obtained at the maximal compacting pressure – 210 MPa.

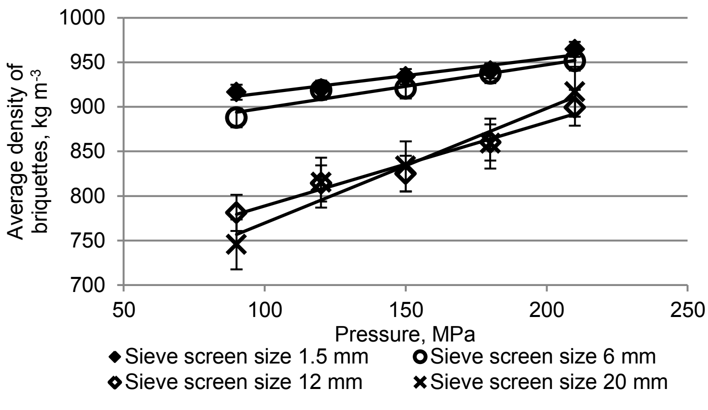

Figure 4. Reed canary grass briquettes density.

For obtained results correlation evaluation was done using a linear trend line. The coefficient of determination R^2 for results ranged between 0.92 and 0.97.

Pressing energy consumption had been obtained from force – displacement curves by graphical integration. Fig. 5 shows the pressing energy consumption for briquetting of the same ground reed canary grass. For all four particle size groups, specific energy significantly increased with an increase in pressure from 90 to 210 MPa.

The mean specific compacting energy value increases from 24.2 ± 0.5 to 39.3 ± 4.9 kJ kg^{-3} (screen opening size 20 mm), from 22.0 ± 2.5 to 32.5 ± 5.3 kJ kg^{-3} (screen opening size 12 mm), from 16.5 ± 0.3 to 24.0 ± 4.0 kJ kg^{-3} (screen opening size 6 mm) and from 16.6 ± 0.8 to 23.9 ± 0.3 kJ kg^{-3} (screen opening size 1.5 mm), if compacting pressure increases from 90 to 210 MPa.

For obtained results correlation evaluation was done using a linear trend line. The coefficient of determination R^2 for results ranged between 0.92 and 0.98.

Obtained results show that specific compacting energy depends on particle size used for briquetting (Fig. 5). Lowest specific briquetting energy consumption is for particle size obtained with hammer mill screen opening size 1.5 mm compared with screen opening 20 mm.

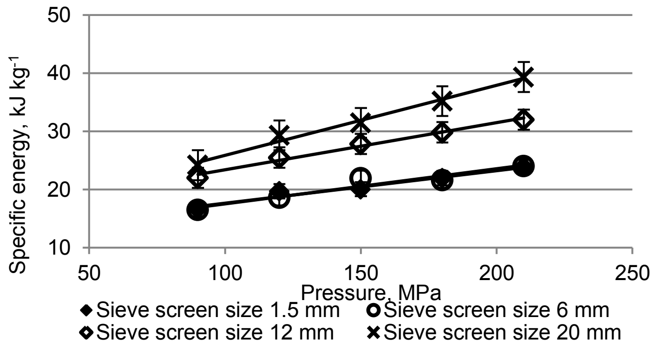

Figure 5. Specific energy of briquetting.

Summary reed canary grass conditioning energy can be calculated as a sum of cutting and compacting energy. Obtained results at maximal compacting pressure 210 MPa are shown in Fig. 6. Comparing specific cutting energy and specific compacting energy results show that total energy consumption is 260 kJ kg^{-1} (if screen with opening size 1.5 mm is used) and 48 kJ kg^{-1} (if screen with opening size 12 mm is used). The total specific conditioning energy consumption difference is 212 kJ kg^{-1} for used screen sizes.

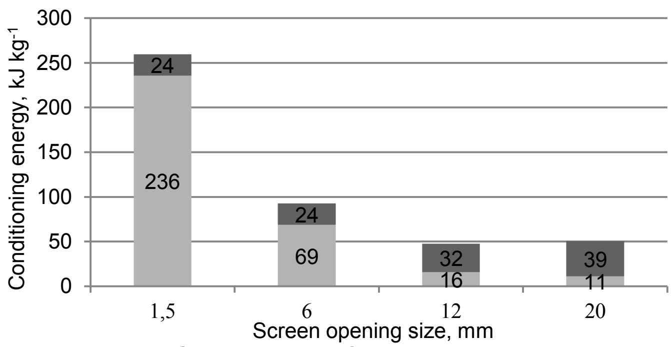

Figure 6. Conditioning energy dependence on screen opening size.

CONCLUSIONS

Comminuted reed canary grass material bulk density is within 101 ± 2 kg m^{-3} (if screen with opening size 20 mm is used) and 165 ± 1 kg m^{-3} (if screen with opening size 1.5 mm is used).

Specific cutting energy per mass unit is growing considerably when hammer mill screen opening size is less than 12 mm.

During compacting the mean density value of briquettes increase from 746 ± 11 to 915 ± 25 kg m^{-3} (screen opening size 20 mm), from 781 ± 14 to 899 ± 20 kg m^{-3} (screen opening size 12 mm), from 888 ± 12 to 951 ± 19 kg m^{-3} (screen opening size 6 mm) and from 917 ± 18 to 964 ± 23 kg m^{-3} (screen opening size 1.5 mm), if compacting pressure increases from 90 to 210 MPa.

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Maximum of specific conditioning energy is 260 kJ kg^{-1} (if screen with opening size 1.5 mm is used), but minimum is 48 kJ kg^{-1} (if screen with opening size 12 mm is used). The total specific conditioning energy consumption difference is 212 kJ kg^{-1} for used screen sizes.

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REFERENCES

Alakangas, E. 2011. European standards for fuel specification and classes of solid biofuels. In Grammelis P. (ed.): *Solid biofuel for energy: lower greenhouse gas alternative*. Springer, New York, pp. 21–41. ISSN1865-3529.

Emami, S., Tabil, L.G. 2008. Friction and compression characteristics of chickpea flour and components. *Powder Technology* **182**, pp. 119–126.

Lam, P.S., Sokhansanj, S., Bi, X., Mani, S., Womac, A.R., Hoque, M., Peng, J., Jaya Shankar, T., Naimi, L.J., Narayan, S. 2007. Physical Characterization of Wet and Dry Wheat Straw and Switchgrass – Bulk and Specific Density, Paper No. 076058. ASABE, St. Joseph, Michigan.

Matúš, M., Križan, P. 2010 Influence of structural parameters in compacting process on quality of biomass pressings. *Journal of Applied Mathematics*. Volume **3**, Number **3**, p. 87–96.