SIZE REDUCTION AND DENSIFICATION OF HERBACEOUS BIOMASS
AUGU BIOMASAS IZMĒRU SAMAZINĀŠANA UN KOMPAKTĒŠANA

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Abstract. *Herbaceous biomass can be obtained using delayed harvesting method with moisture content less than 15% and directly densified without drying. Size reduction experiments of common reed stalks as cutting, flattening and densification have been carried out. As the result of reed stalk flattening, more than 8 strips can be obtained from this tubular structure. Average energy consumption 273 – 380 J kg*$^{-1}$ *had been stated for reed stalk flattening. Specific cutting energy* E_{scq} *value varies in 8 – 16 kJ m*$^{-2}$ *in dependence of punch orientation angle according cross-section of reed specimen. Specific cutting energy for flattened stalk materials for reed density 600 kg m*$^{-3}$*, varies* E_{sc}*=13.3 – 27 J m kg*$^{-1}$*. Densification experiments of compositions from peat particles, coarse wheat stalk and reed material particles from (1 - 2 mm) group with pressure 230 MPa indicated influence of peat proportion. Density 1.0 g cm*$^{-3}$ *has been obtained in densification of straw stalk material particle compositions with peat, if peat proportion exceeds 20%.*

Keywords: *herbaceous biomass, size reduction, densification.*

Introduction

Latvia as a European community country has the tasks for greenhouse gas (GHG) emission mitigation in future. Essential condition of the global sustainable development is the development of renewable energy resources. The more significant part (74%) of renewable energy sources in White Paper of European Union (1997) had been planned for Biomass energy. At the same time agricultural policy in Latvia should provide for the use of approximately 0.92 million ha of the unused now agricultural land and its sustainable development. Recent advances in biomass feedstock development and conversion technologies have created new opportunities for using agricultural land as a means of producing renewable fuels and raw materials.

Herbaceous biomass can be obtained with delayed harvesting method with moisture content less than 15% and used for densification without drying. This opportunity is important both for solid biofuel and construction material production. The main resources of herbaceous biomass for agro - ecotechnologies are cereal straw residues, herbaceous energy crops and emergent vegetation (mainly common reeds) from wetlands. In Latvia cereal crop residues that could be used for energy production are 171 000 t of straw annually. Only one part of straw residue (20-30%) is planned to use for heat production, but another part will be used as organic fertilizer. Common reeds (Phragmites Australis) can be used like straw material both for energy and fertilizer production and also as industrial raw material. More than 230 million tons of peat is available for bio fuel production in Latvia. Energy crops would be as the main basis for solid biofuel production in agricultural ecosystem in future. Total production of oilseeds in 2002 was 32.7 thousand tons. In proportion with this amount 21.8 thousand tons of rape seed cakes and 42.5 thousand tons of rape straw are available as solid bio fuel resources. As chemical fertiliser production consumes great amount of energy, biomass usage directly for energy production or as organic fertiliser are activities with equal importance in agriculture.

Mentioned agricultural ecosystem biomass can be denominated as resources only if there are mechanisation tools and equipment for collection and utilisation processes. Solid biofuel production chain includes size reduction operations and densification of herbaceous biomass with moisture content less than 15%. Mainly different plant stalks determine properties of agricultural biomass for solid biofuel production.

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The main size reduction operations are stalk material flattening, cutting before densification (pelleting and briquetting). As additive materials in production of pellets and briquettes peat and rape seed cakes are most prospective.
The aim of the present study was to investigate interconnection between particle sizes of chopped stalk material and density obtainable before and after densification. Energy consumption in size reduction and densification operations had been determined and used for assessment.

Materials and methods

Experimentally earlier had been stated values of wheat stalk ultimate tensile (118.7 ± 8.63 N mm^{-2}) and shear (8.47 ± 0.56 N mm^{-2}) strength, modulus of elasticity (13.1 ± 1.34 GPa) and shear modulus (0.643 ± 0.043 GPa) in order to find methods for mechanical conversion with minimal energy consumption. Reed canary grass stalks (stems) are more useful with delayed harvesting for fuel production than leaf blades. Experimental investigation of common reed stalk conditioning properties as flattening and cutting can characterize maximum of energy consumption in these operations for all group of mentioned stalk materials because reeds have higher tensile strength (~200 N mm^{-2}) and accordingly another strength parameters.
Cutting and flattening of different length reed specimens with moisture content of 10% had been investigated by means of Zwick material testing machine TC-FR2.5TN.D09. Zwick material testing machine has force measurement accuracy 0.1 N, displacement measurement accuracy 0.01 mm and maximal force value 2.5 kN. Computer controls testing machine using software for force, displacement and other data collection. Software provides possibility obtain energy consumption data output.

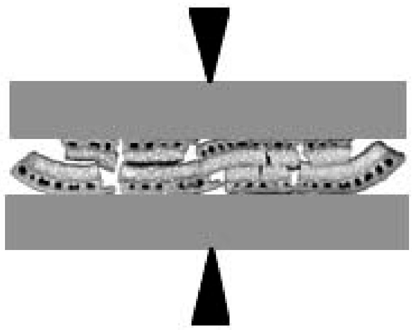

Fig. 1. **Reed stalk flattening**

During cutting operation with counter shear stalk flattening occurs at first. For this reason flattening of reed specimens with moisture content of 10% previously had been investigated. Different length reed specimens were flattened between two plates of material testing machine (Fig.1)

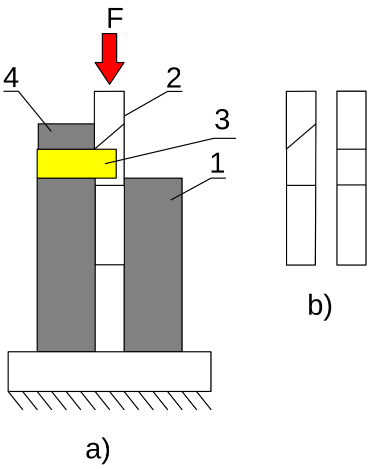

Fig. 2. **Flattened reed cutting device**

Cutting device was designed specially for flattened stalk material cutting. Cutting device (Fig. 2a) consists of die 1 and knife 2. Flattened reed specimen 3 is fastened with plate 4 to die. Cutting using two types of knives – with edge angles 20° and 90° (Fig. 2b) had been investigated. Displacement, stress and energy consumption data were collected on computer.
Stalk material size reduction by cutting is realised with aim to reduce biomass volume and increase density. Chopped to different length reed stalk biomass with moisture content less than 10% was used for density measurements. All chopped stalk material particles had been sieved and distributed to several fineness groups. Fineness of stalk material particles had been determined with diameter of sieve's openings

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(round section). Every fineness group of particles is marked with diameter of opening on which particles retained and lower diameter of openings (in millimetres), which particles passed through. Thus marking 2-3 indicates particles larger than 2 mm and smaller than 3 mm. For density measurement had been used following fineness group particles: 2-3; 1-2; 0.5-1; 0.25-0.5 and <025. Measurements were realized filling determined volume (200 cm^3) container with particles and weighing it. The density was calculated on the basis of weighing results.

Densification experiments had been carried out in closed die by means of hydraulic press equipment. Wheat straw and reed stalk material biomass with moisture content of 10% were chopped to different length and had been used for densification. Experiments were carried out with particles from different fineness groups. Mixed peat and stalk material particles were used as briquetting compositions. Force and displacement had been recorded in densification process and the calculations let to find the energy requirement for it. Maximal pressure 230 MPa had been achieved in densification.

Results and discussion

As the result of reed stalk flattening, more than 8 strips can be obtained from this tubular structure. Average energy consumption 273 – 380 J kg^{-1} of DM had been stated for reed stalk flattening.

Specific cutting energy E_{scq} value was determinated with 90° edge angle knife and varies in 8 – 16 kJ m^{-2} mainly in dependence of reed specimen strength. Specific cutting energy of flattened reed stalk materials for density 600 kg m^{-3}, varies E_{sc}=13.3 – 27 J m kg^{-1}. It is the same order as alfalfa stem [1] cutting energy 38 J m kg^{-1}.

Cutting properties of knives with edge angles 20° and 90° were compared. It was not sufficient differences in the energy consumption values for single flattened reed stalk cutting ~0.2 J. For cutting two and three layers of flattened reed stalks the knife with edge angle 90° shows twice more energy consumption than knife with edge angle 20°.

Experimentally is stated, that density of evenly distributed in container reeds is ~ 0.11 g cm^{-3}. Density of chopped straw and reed particles from different fineness groups shows Fig.3.

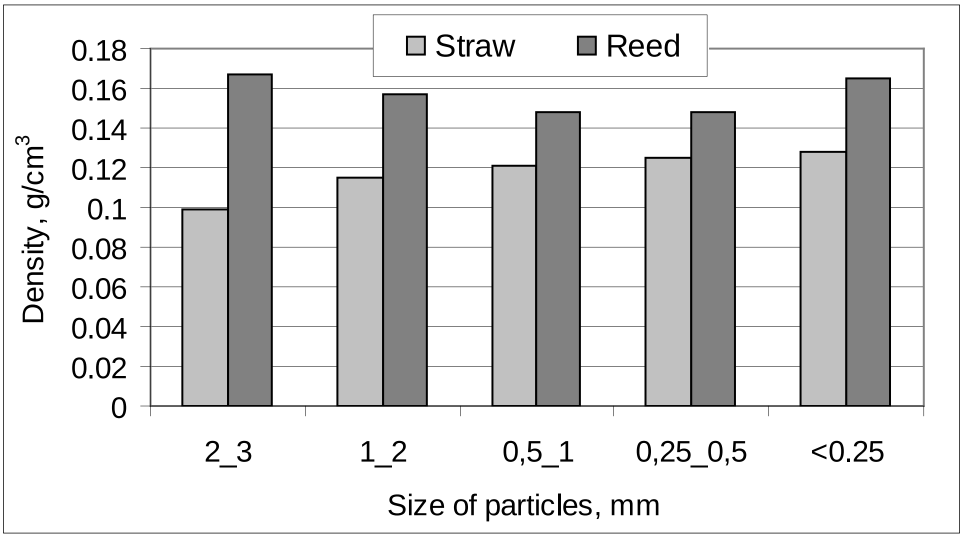

Fig. 3. **Density of biomass of particles**

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Particle size reduction for chopped straw affects density insignificantly. It changes from 0.1 g cm^{-3} (2-3 mm particles) to 0.13 g cm^{-3} (particles <0.25 mm). For reed particles density varies between 0.15-0.17 g cm^{-3}.
Experimentally is stated that flattening of reed stalk material and father densification with very low pressure 0.002 Mpa let obtain density 0.22 g cm^{-3}.
Density obtained in densification different size wheat straw and reed stalk particles with pressure in closed die 230 MPa shows Fig. 4.

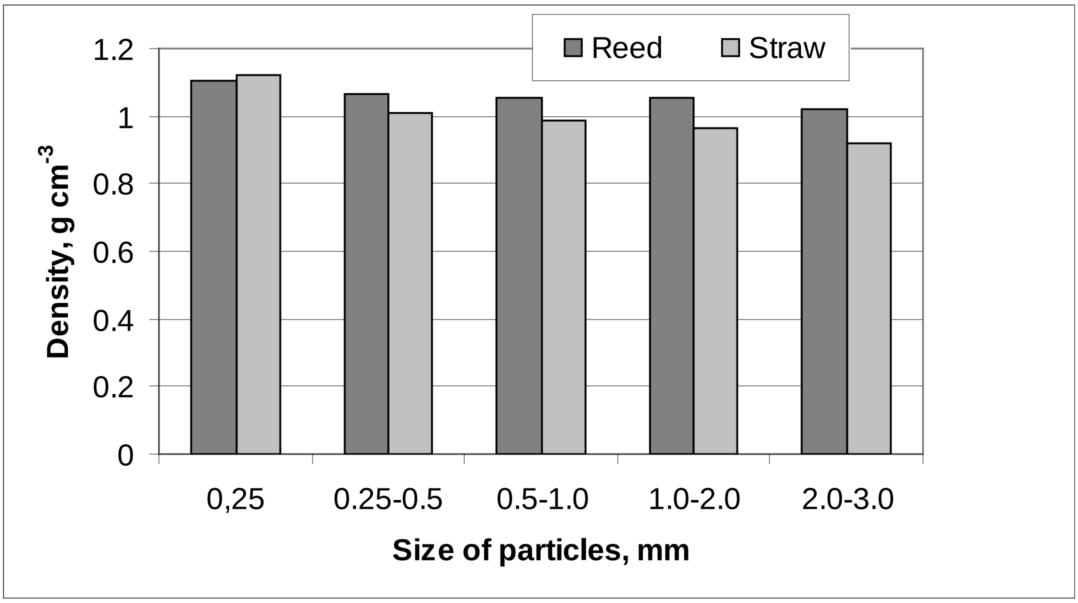

Fig. 4. **Density of compacted herbaceous biomass**

Density > 1.0 g cm^{-3} is recommend in standards (ŌNORM 7135, SS 18 71 20 and DIN 51731), concerned with wood pellet and briquette properties. This value had been used for evaluation of herbaceous material densification results. For reed particles with size <3 mm density > 1.0 g cm^{-3} can be obtained in densification. In densification of wheet straw particles with the same pressure 230 MPa density > 1.0 g cm^{-3} is obtained only for size <0.5 mm.
Ordinals briquettes in the production of wood sawdust briquettes develop pressure in biomass 100-160 MPa. For this reason size reduction of biomass particles is preferable. Another possibility to improve density of briquettes is using of binding additives. Peat can be used as such binding additive and biofuel at the same time. It is very very urgent problem, because more than 230 million tons of peat is available for biofuel production in Latvia
Densification experiments of compositions from peat particles, coarse wheat stalk and reed material particles from (1 - 2 mm) group with pressure 230 MPa indicated influence of peat proportion to density of briquettes. Density 1.0 g cm^{-3} has been obtained in densification of straw and reed stalk material particle compositions with peat, if peat proportion exceeds 20%.
Total energy grass production and pelleting energy analysis [2] converted in proportion illustrate possible positions for technology and equipment improvement (Fig. 5.). Canadian experience of switchgrass production as energy crop for biomass pellet production can be used for planning reed canary grass production for energy purposes in Latvia conditions. High level of fertilization and application energy input – 37% for energy grass production shows necessity to utilize biomass for fertilizer production. Low energy input for transportation is caused with calculation condition that switchgrass can be sourced within a 20 km radiuss of a pelleting plant. Density increasing of harvested herbaceous biomass let increase also this distance from field to pelleting plant. Energy input for pellet mill operation is rather high 19% with the major costs associated with hammer milling and pelleting. More efficient equipment creating is current task for herbaceous biomass size reduction.
Net energy output (18.5 GJ/t) to production input (1.27 GJ/t) is assessed with ratio 14.6:1.

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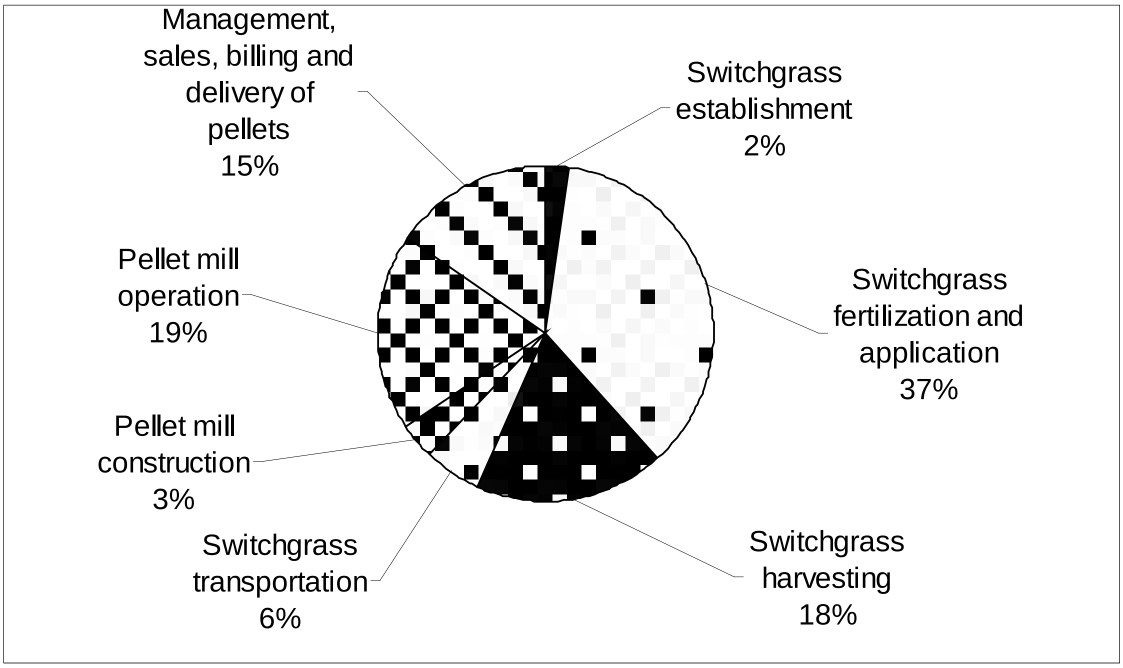

Fig. 5. **Energy input proportion for switchgrass pellets**

Conclusions

Delayed harvesting method let obtain herbaceous biomass with moisture content less than 15% and use it for densification without drying.

Average energy consumption 273 – 380 J kg^{-1} of DM had been stated for reed stalk flattening.

Specific cutting energy of flattened reed stalk materials varies E_{sc}=13.3 – 27 J m kg^{-1}.

There are not sufficient differences in the energy consumption values for single flattened reed stalk cutting ~0.2 J with knife edge angles 20° and 90°. Therefore thin herbaceous biomass layer cutting is recommended for shredder design.

Particle size reduction for chopped straw affects density insignificantly. Flattening of reed stalk material and futther densification with very low pressure 0.002 Mpa let obtain density 0.22 g cm^{-3}.

Density 1.0 g cm^{-3} has been obtained in densification of straw and reed stalk material particle compositions with peat, if peat proportion exceeds 20%.

More efficient equipment creating is current task for herbaceous biomass size reduction.

Acknowledgements

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