Agronomy Research **15**(2), 344–358, 2017

Utilization of waste biomass from post–harvest lines in the form of briquettes for energy production

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Abstract. A great amount of herbal waste biomass is produced nowadays during agriculture crop processing; also during 'post–harvest lines' operations. Such waste biomass occurs in the bulk form, thus, is not suitable for direct combustion; it can be improved by using of briquetting technology. Therefore, present paper provides chemical, mechanical and microscopic analyses of waste biomass originating from post–harvest lines and briquettes produced from it. Namely, waste biomass originated from production of oat (*Avena sativa*) – husks, wheat (*Triticum spp.*) – husks and poppy (*Papaver somniferum*) – straw and seed pods and mixture of all mentioned were investigated. Unprocessed materials were subjected to microscopic and chemical analysis and subsequently produced briquette samples were subjected to determination of its mechanical quality. A satisfactory level of moisture and ash content was observed, as well as, materials energy potential; oat – 17.39 MJ kg^{-1}, wheat – 17.04 MJ kg^{-1}, poppy – 14.48 MJ kg^{-1}. Also microscopic analysis proved suitability of all feedstock materials within evaluation of geometrical shapes of their particles. However, evaluation of briquette mechanical quality unsatisfactory results. Process of briquetting revealed unsuitability of oat feedstock for briquette production; other materials proved following values of volume density and mechanical durability (in sequence): wheat – 1,023.19 kg m^{-3}, 89.1%; poppy – 1,141.43 kg m^{-3}, 94.7%; mixture – 972.49 kg m^{-3}, 62.7%. In general, only poppy briquettes achieved requested mechanical quality level for commercial briquette production. However, undeniable advantage of investigated materials is the form they occurred in; no further feedstock preparation (drying, crushing) was needed.

Key words: solid biofuels, renewable energy, cereal husk, mechanical durability, calorific value.

INTRODUCTION

Biomass represents alternative but adequate solution of increasing energy demands and also represents possibility of reduction of net carbon emissions, greenhouse gas (GHG) emissions and harmful environmental pollution caused by fossil fuel consumption (Li & Hu, 2003). Bapat et al. (1997) has proved that biomass is third most extensive source of energy worldwide; specifically provides approximately 14% of the global annual energy supply which is equivalent of 1.25 billion tons of oil (Btoe). Fossil fuels as a coal and oil are still in leading positions, but in contrast with them biomass is considered as an environmental friendly renewable source of energy (Werther et al., 2000; Purohit et al., 2006; Zeng et al., 2007). Biomass can vary in accordance to its origin; a waste biomass originates from agriculture sector in most cases and is produced during technological processing of agricultural crops (Lantin, 2001).

During cereal crops harvesting a great amount of waste biomass is produced; Kim & Dale (2004) have proved that during processing of agriculture crops (oats, wheat, rice, corn or sorghum) approximately 1.5 billion metric tonnes of waste biomass is produced worldwide. Mentioned waste biomass occurs primarily in the form of straw but there is also great amount of waste biomass produced during operations of post–harvest lines which removes remnants of native plants and husks from processed crops. Such waste biomass occurs in the bulk form, thus, is not suitable for transportation and combustion. Technology of briquetting could be appropriate solution of material properties improvement (Sahiti et al., 2015). It is common practise to use agriculture crop straw for solid biofuel production (Kirsten et al., 2016). Niedziółka & Szpryngiel (2014), Tumuluru et al. (2015) and Stasiak et al. (2017) have proved possibilities and advantages of briquette production from wheat, rye, barley, and oats straw.

Focused on the subsequent utilization of waste biomass originating from post-harvest lines, namely husks, seed pods and other plant remnants (Lantin, 2001) previous researches proved advantage of production of briquette fuel from rice husk (Muazu & Stegemann, 2015; Obi & Okongwu, 2016) maize husk (Adetogun et al., 2014) or husk of sunflower, buckwheat and flax (Riga Technical University, 2013). Another source reports mention about the possibility of production of briquettes from poppy wastes materials but detail information are not available (Osobov, 1966). Report of Riga Technical University (2013) proved advantage of briquettes produced from oat and wheat middlings (dust) which are also separated from crops during post-harvest lines processing. Chemical analyses of those briquettes proved required low level of moisture content (8.66%) and ash content (3.61%) of materials as well as satisfactory level of gross calorific value (19.0 MJ kg^{-1}). Within the fuel heat input, tested briquette samples represents great efficiency (31.4 MJ) in compare with buckwheat hulls (31.8 MJ), as well as, with wood (35.2 MJ). However, determination of mechanical quality proved that volume density of briquettes did not exceed the level of 900 kg m^{-3}.

In the context of mentioned facts the main aim of present research was to determine the advantages and suitability of briquette production from waste biomass originating from post–harvest lines, specifically from processing of oat (*Avena sativa*), wheat (*Triticum spp.)* and poppy (*Papaver somniferum*) and partly also barley (*Hordeum vulgare L.*) residues.

MATERIALS AND METHODS

At the beginning of present chapter it should be mentioned that whole process of briquette production (feedstock preparation, technical specifications of machinery) and subsequent quality determination (testing and data evaluation) was conducted to mandatory technical standards. Namely, European Standards EN 14918 (2010), EN 15234–1 (2011), EN 643 (2014), EN ISO 16559 (2014), EN ISO 17225–1 (2015), EN ISO 18122 (2015), EN ISO 18134–2 (2015), EN 15148 (2010), EN ISO 16948 (2016), ISO 1928 (2010) and EN ISO 17831–2 (2015).

Sample production

Waste biomass investigated in present experimental research originated from cereal crop production; concretely from its technological processing by post–harvest lines. Specifically, following cereal crops were chosen for research purposes (feedstock materials for briquette production): (i) oat (*Avena sativa*) and (ii) wheat (*Triticum spp.*) both in the form of husks, (iii) poppy (*Papaver somniferum*) in the form of chopped straw and seed pods and (iv) mixture of oat, wheat and barley husks. Chosen materials occurred in the form perfectly suitable for briquette production (proper feedstock moisture content is stated ± 10% by standard EN ISO 17225–1 (2015) and optimal particle size ranges between 6–12 mm (Brunerová & Brožek, 2016) due to previous crops treatment during harvesting and processing by post–harvest lines. Thus, no further processing or preparation of feedstock materials were needed. A hydraulic piston briquetting press type BrikStar 30–12, Briklis (Malšice, Czech Republic) were used for briquette samples production. There was an issue observed during briquetting of one investigated material; present oat waste material in unchanged raw form obtained directly from post–harvest line was not suitable for briquette production. Process of densification was not successful, thus, oat wastes material remained in its original bulk form and briquette samples were not produced. Mentioned issue might be caused by inhomogeneous composition of material proved by microscopic analysis; material contained except husk also tufts in proportion 1:1 (see in Fig. 5, C). All samples from other feedstock materials were produced under the same operation conditions (used pressure ± 100 MPa, die temperature ± 32 °C) into the cylindrical shape with diameter equal to 50 mm. Mean dimensions of produced briquette samples are expressed in Fig. 1 while statistically significant differences were not proved.

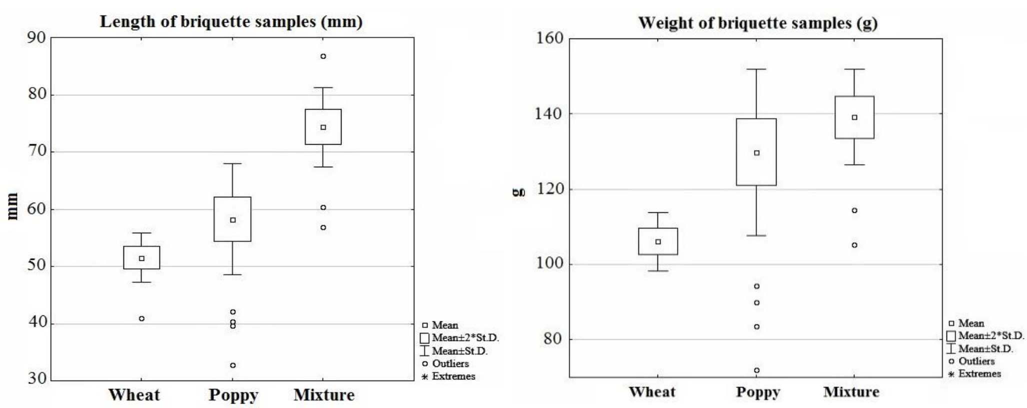

Figure 1. Dimensions of produced briquette samples.

Length of all briquette samples was equal to 61.13 mm in average (with min. 32.80 mm; max. 86.84 mm) and weight of all briquette samples was equal to 125.38 g in average (with min. 72.10 g; max. 160.30 g).

Microscopic analysis

Within the microscopic analysis the shapes and dimensions of selected waste materials were subjected to image analysis by stereoscopic microscope Arsenal, type

SZP 11-T Zoom (Prague, Czech Republic); observed data were processed by evaluation software Quick Photo Industry (Prague, Czech Republic) within what the elementary shape parameters of investigated materials were determined.

Image analysis of specific materials surface was performed by scanning electron microscope TESCAN, type MIRA3 GMU (Brno, Czech Republic). The description of shapes and dimensions of biomass material contributed to understanding of the emergence of solid binding between materials sub-parts. Based on image analysis of materials in comparison with the mechanical properties of final briquettes the proportion of the geometrical arrangement of the material to the final product will be determined. By using of image analysis of briquettes surface and its fractures during different intermediate stage of pressing it was possible to determine the dependence of individual material particles deformation. It leaded to detailed understanding of emergence of the briquettes made from various waste biomass.

Fig. 2 shows an example of detailed surface analysis of selected investigated material (Mixture feedstock material). Fig. 2 part A expresses a macroscopic view of the sample. Fig. 2 parts B, C, D and E were taken by using of SEM technology (scanning electron microscopy) by microscope MIRA 3 TESCAN at the accelerating voltage of the pack (HV) 5.0 kV. Investigated samples were dusted with gold by means of the equipment Quorum Q150R ES – Sputtering Deposition Rate using Gold. Fig. 2 parts B, C, D and E definitely indicated miscellaneous surfaces of investigated sample particles. Observed diverse textures of particles surface will affect final mechanical quality of the briquettes (strength, mechanical durability).

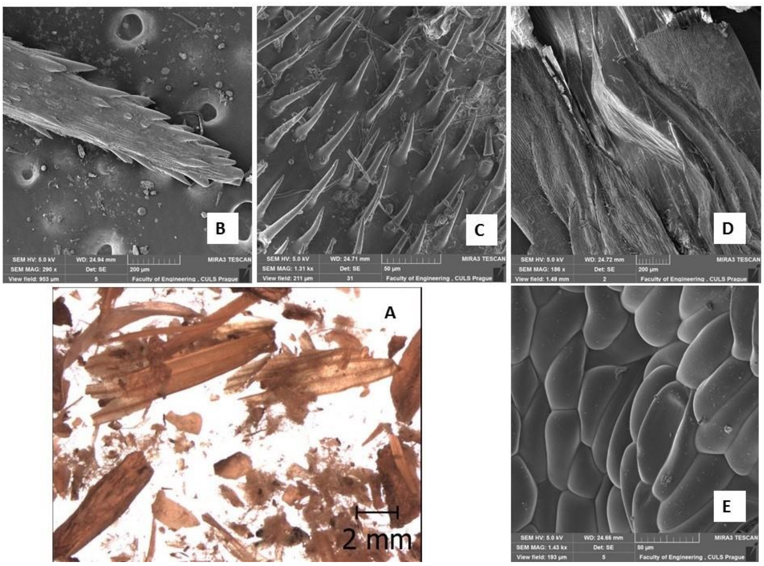

Figure 2. Microscopic analyses of Mixture feedstock material: A – Macroscopic view (MAG 3.5 x); B – SEM images (MAG 290 x); C – SEM images (MAG 1.31 kx); D – SEM images (MAG 186 x); E – SEM images (MAG 1.43 kx).

Chemical analysis

For the purposes of investigated materials chemical analysis were all samples primarily grounded into fine powder (< 0.1 mm) and subsequently dried and subjected to determination of moisture, ash and volatile matter contents, further to elemental composition and also to calorific value statement. The first three parameters were analysed by using of thermogravimetric analyser type LECO TGA 701 (Saint Joseph, United States) in accordance to European Standards EN ISO 18134–2 (2015): Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method, EN ISO 18122 (2015): Solid biofuels – Determination of ash content, EN 15148 (2010): Solid biofuels – Determination of the content of volatile matter.

Elemental composition of investigated materials was analysed according to European Standard EN ISO 16948 (2016): Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen. The experimental measurements were carried out by instrument type LECO CHN628+S (Saint Joseph, United States) with helium as carrier gas in attempt to determined carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) contents. Chosen instrument operated by principle of analysing the flue gases of samples burned in oxygen. C, H and S contents were measured in infrared absorption cells; N content was measured in a thermal conductivity cell.

Gross calorific value was measured by an isoperibol calorimeter type LECO AC 600 (Saint Joseph, United States) according to European Standard EN 14918 (2010): Solid biofuels – Determination of calorific value. The samples were primarily pressed into pellets (or left in powder form if practicable) and subsequently burned. At least three reliable results were acquired for all samples. Gross calorific value was determined using the supplied software. The relationship between gross calorific value Q_s (MJ kg^{-1}) and net calorific value Q_i (MJ kg^{-1}) and was expressed according to European Standard ISO 1928 (2010): Solid mineral fuels – Determination of gross calorific value by the bomb calorimetric method and calculation of net calorific value.

Mechanical analysis

A volume density ρ in kg m^{-3} of produced samples was chosen as a first indicator of briquette mechanical quality; dimensions of each specific briquette sample were measured and following formula was used for calculation of final volume density:

$$\rho = \frac{m}{V} \tag{1}$$

where: ρ – volume density (kg m^{-3}), m – mass of briquette sample (kg), V – volume of briquette sample (m^3).

Subject of next measurements was a rupture force (RF) in Newton of produced briquette samples; this quality indicator is not defined by any mandatory technical standard, but it expressed the maximal stress force which is a briquette sample able to hold before it disintegrates. Present quality indicator can be used for evaluation of briquette biofuel (Lindley & Vossoughi, 1989; Brožek, 2013; Nováková & Brožek, 2016) because it simulates damage caused during transportation, handling and storage of briquettes in real. Experimental testing within rupture force was performed by plate-loading test principle (see in Fig. 3) with a hydraulic universal tensile compression testing machine type ZDM 50 (Dresden, Germany) as a source energy (loading speed 20 mm·min.$^{-1}$, maximal force 500 kN).

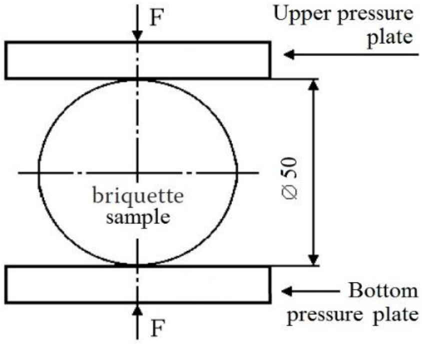

Figure 3. Schema of rupture force plate–loading test.

Determination of mechanical durability, main inficator of briquette mechanical quality, was performed directly after briquette samples production in accordance to European Standard EN ISO 17831–2 (2015): Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 2: Briquettes. Experimental testing was performed by using of electricity powered special dustproof rotating drum with rectangular steel partition inside which is also defined by mentioned standard.

Briquette samples were subjected to controlled deformation testing and final mechanical quality if investigated briquette samples was calculated by following formula:

$$DU = \frac{m_a}{m_e} \cdot 100 \quad (2)$$

where: DU – mechanical durability (%); m_a – weight of samples after testing (g); m_e – weight of sample before testing (g).

RESULTS AND DISCUSSION

Results obtained within experimental testing were divided into several separate parts according to specific parameters of investigated feedstock materials as well as the ‘Materials and methods’ chapter. All parts of ‘Results and discussion’ chapter together subsequently represented overall evaluation of investigated feedstock suitability for briquette production.

Microscopic analysis

Evaluation of geometrical dimensions of investigated waste biomass from postharvest lines and the form of ‘fixed’ bonds between specific feedstock particles were performed.

Measured result values of investigated feedstock materials are presented in the Table 1. As a mean diameter of feedstocks particles were considered dimensions of two orthogonal lengths of largest particles. Fig. 5 presents image analysis of investigated feedstock materials, specifically pictures A, B, C, D. Result images E, F, G and H of

Fig. 4 exhibited evident diverse of investigated materials shape dimensions. Evaluation of microscopic analysis of specific feedstock materials proved smallest particle dimensions for poppy material sample, while, wheat, oat and mixture samples exhibited larger particle dimensions.

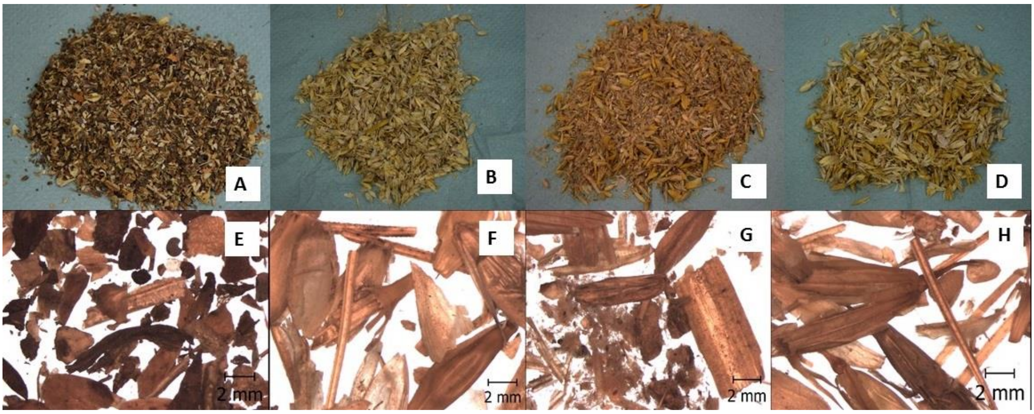

Figure 5. Feedstock materials: A, E – poppy; B, F – wheat; C, G – oat; D, H – mixture.

Observed results also indicated differentiations between specific measured dimensions within one specific feedstock material. It can be highlighted that oat feedstock material exhibited noticeable different values, i.e. differences in oat feedstock average length was equal to approximately 125% and differences in area of oat feedstock particles differed by 163%.

Table 1. Basic geometrical parameters of investigated waste biomass kinds

Waste biomass kind	Average length of particles			Area of particles			Circumference of particles		
	AM (mm)	SD (mm)	CV (%)	AM (mm^2)	SD (mm^2)	CV (%)	AM (mm)	SD (mm)	CV (%)
Poppy	1.93	1.56	81.02	2.88	2.38	82.66	6.93	3.55	51.20
Oat	1.24	1.55	124.86	4.97	8.11	163.16	8.55	8.00	93.59
Wheat	3.60	3.59	99.53	9.24	6.79	73.48	15.01	6.46	43.01
Mixture	3.68	3.73	101.24	12.54	9.90	79.06	17.77	7.61	42.83

(AM – Arithmetic mean, SD – Standard Deviation, CV – coefficient of variation).

For statistical analysis of measured geometric data was used the analysis of variance (ANOVA) using F–test. For the null hypothesis H_0 was indicated state where there between the compared data sets was not (in terms of their mean values) statistically significant difference: $p > 0.05$. Within the statistical analyses of specific kinds of feedstock materials, it was proved that tested materials are statistically inhomogeneous groups, e.i. a difference between geometric shapes of poppy, oat and wheat feedstocks was proved. The null hypothesis H_0 was not accepted; there was a statistically significant differences (in significance level of 0.05) between investigated feedstock materials, i.e. $p < 0.05$ ($p = 0.000$). In general, the difference between geometric parameters of feedstock materials was statistically proved.

More detailed descriptions of investigated feedstock properties are showed in Fig. 6 and Fig. 7. Result values expressed at Fig. 6 clearly explained that poppy and oat feedstock materials contained from 74–79% particles with area < 5 mm^2. Those feedstock materials did not contained particles with area > 20 mm^2. In compare, wheat and mixture feedstock materials contained particles with area < 45 mm^2. If compare mentioned investigations, it can be concluded that considerable differences between feedstock materials within its particles areas were observed.

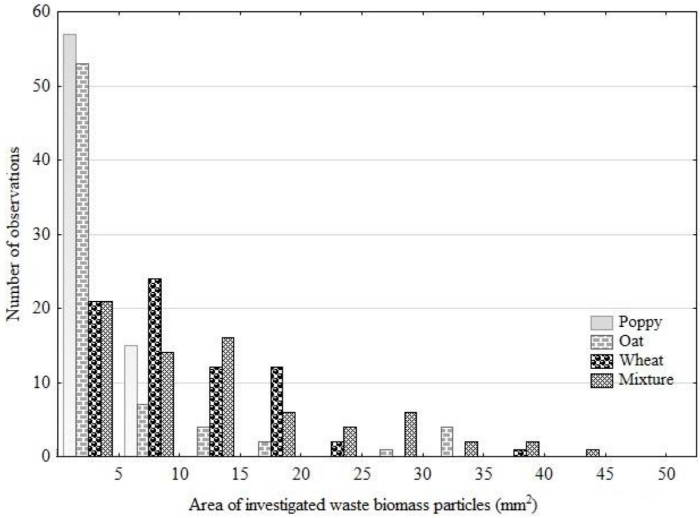

Figure 6. Histogram of areas of particle size of feedstock materials from post–harvest lines.

Similar result values were obtained for average length of particle fraction; detail expression is visible from Fig. 7.

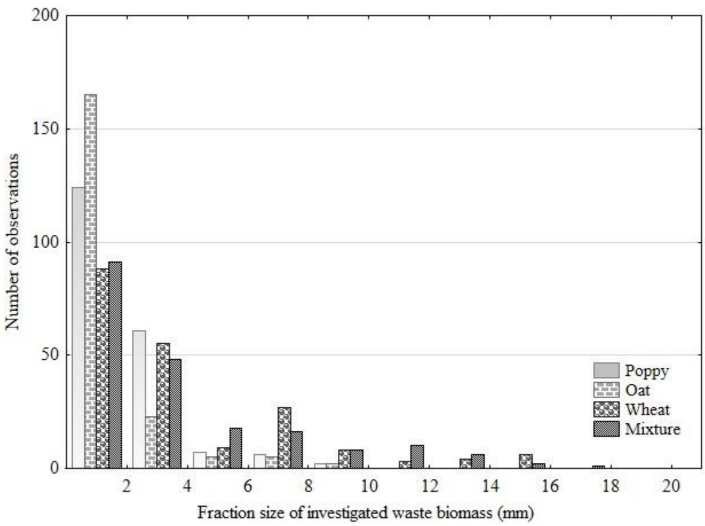

Figure 7. Histogram of average length of size fraction of feedstock materials from post–harvest lines.

The largest faction was measured for oat feedstock material; monitored average length of fraction < 2 mm occurred in 83% of measurements. Evaluation of wheat and mixture result values proved average length of fractions < 18 mm.

Chemical analysis

Final evaluation of chemical parameters of investigated materials were performed according to related technical standards (described in chapter Materials and Methods); in general, all parameters results reached satisfactory level. Specific result values of performed experimental testing are noted in Table 2. Despite the fact that waste biomass originating from processing of oat was not suitable for briquette production, it was subjected to its chemical quality determination as well as all other waste biomass materials.

Table 2. Chemical analysis result of investigated feedstock parameters

	Water content (% wt.)	Ash content (% wt.)	Volatile matter content (% wt.)	Gross calorific value (MJ kg^{-1})	Net calorific value (MJ kg^{-1})
Oat	9.95	2.65	85.86	19.31	17.39
Wheat	6.95	5.01	88.17	18.31	17.04
Poppy	13.70	10.13	85.37	16.78	14.48
Mixture	7.26	3.21	86.30	18.83	17.46

Level of moisture content reached satisfactory level for oat, wheat and mixture materials. Recommended maximum level of moisture content for briquette feedstocks is < 10% (Kaliyan & Morey, 2009). Higher level of moisture content, which was measured for poppy feedstock material (> 13.7%), can negatively influence compaction ability of material (Guo et al., 2015).

Poppy feedstock material also exhibited worse result within ash content experimental testing. A low level of this quality indicator is required while the Kofman (2007) showed that densified biofuels produced from high quality wood indicate ash content < 0.7%. On the other hand, obtained result values of poopy wastes ash content are still acceptable in compare with other cereal waste biomass, namely, rice husks which ash content was determined equal to 20.74% (Brunerová et al., 2017). Focused on different waste materials originating from oat and wheat production, it is commonly straw which is reused for solid biofuel production. Tumuluru et al. (2015) proved following ash content of cereal straw: oat – 2.19%, wheat – 2.36%. Other study of McKendry (2002) proved ash content of wheat straw equal to 4%. High level of ash content influence negatively combustion properties of briquettes due to airflow during burning, and thereby, causes decreasing of calorific value (Malaťák & Passian, 2011). This trend was proved during the calorific value determination and is expressed in Figs 8 & Fig. 9.

According to related technical standard EN 15148 (2009) a lower level of volatile matter content (VMC) is required, but precise allowed value is not stated. All investigated waste materials exhibited VMC higher than 85%. Present result values can be considered as higher in compare with other biomass types. McKendry (2002) has proved following level of volatile matter contents: pine wood – 71.6%, barley straw – 46.00%, rape straw – 35.00% and Miscanthus – 66.8%.

Within energy yield of investigated waste materials the result of experimental measurements proved satisfactory level of oat, wheat a mixture samples and lower result value of poppy samples. For clear comparison a gross calorific values of other commonly used feedstock materials are shown in Fig. 8.

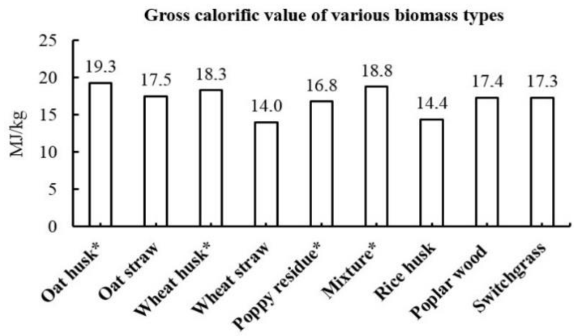

Figure 8. Comparison of investigated materials GCV with other biomass types.
(*Authors data; McKendry, 2002; Sahiti et al., 2015; Brunerová et al. 2017)

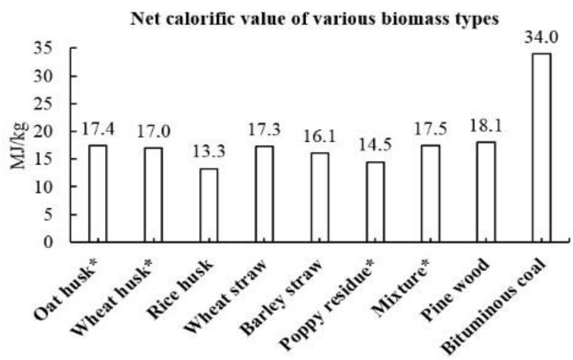

Figure 9. Comparison of investigated materials NCV with other biomass types.
(*Authors data; Stolarski et al., 2013; McKendry, 2002)

Both graphs related to calorific values of investigated materials confirmed its satisfactory level of energy yield in compare with other biomass types (renewable sources of energy); in comparison with bituminous coal (fossil fuel), was observed large difference. However, bituminous coal is non–renewable source of energy which causes environmental pollution, thus, its advantage in the form of higher energy yield is not relevant or sustainable (Montiano et al., 2015).

Mechanical analysis

First investigated indicator of mechanical quality of produced briquette samples was its volume density. Result values of all produced briquette samples were transformed into BoxPlot graph (Fig. 10) for clearer expression.

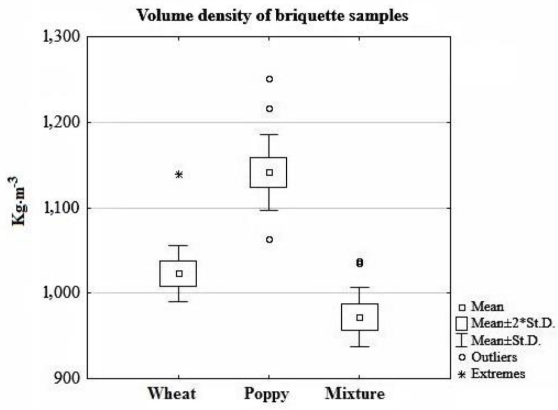

Figure 10. Suitability of investigated feedstock materials for densification process.

As is visible, highest volume density was measured for briquette samples produced from poppy residues (1,141.43 kg m^{-3} in average), then for wheat briquette samples (1,023.19 kg m^{-3} in average) and worst result was obtained by mixture briquette samples (972.49 kg m^{-3} in average). Those results did not supported previously mentioned trend which stated that the briquette mechanical quality decreases with increasing of feedstock moisture content (ASABE, 2015). In conclusion, the relation between lower level of volume density of mixture briquette samples and composition of this mixture can be highlighted. Mixture partly contained also oat husk which was proved as an unsuitable for briquette production, thus, it could have negative influence. However, according to mandatory technical standard all investigated feedstock materials exhibited satisfactory level of volume density, namely ≥ 1,000 kg m^{-3} (ASAE 269.4, 1996). Other studies of Tumuluru et al. (2015) and Adapa et al. (2009) have proved volume density of oat straw briquette equal to 547.4 kg m^{-3} and 930.0 kg m^{-3}; wheat straw briquette volume density was stated equal to 549.52 kg m^{-3} and 868.5 kg m^{-3} (in sequence) while the compaction pressure ranged between 63–94 MPa.

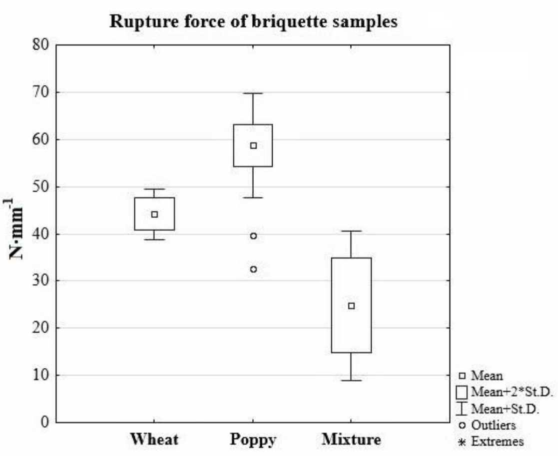

Figure 11. Mechanical strength of investigated briquette samples.

As was mentioned next tested quality indicator was rupture force of produced briquettes. Considering the fact, that this indicator is not stated by any mandatory technical standards, evaluation of obtained result values were performed by comparison with previously published studies. Measured values were noted in N mm^{-1}; this expression considers maximal briquette strength and briquette length. Average rupture force of investigated briquette samples (expressed in Fig. 11) were following: Poppy – 58.73 N mm^{-1}, Wheat – 44.18 N mm^{-1} and Mixture – 24.79 N mm^{-1}. Obtained results occurred at very low level in compare with other materials commonly used for combustion purposes. Namely, rupture force for waste paper briquettes was stated equal to 32 N mm^{-1}, for waste wood briquettes (plane tree chips) was equal to 176.1 and 203.4 N mm^{-1} (depends on feedstock moisture contents) and for waste cardboard briquettes was equal to 153 N mm^{-1} (Brožek, 2015; Brožek, 2016).

Mechanical durability (DU) was the last evaluated criterion of produced briquette samples. All briquette samples must achieved level of mechanical durability ≥ 90% for commercial production according to mandatory technical standards. As is visible from Fig. 12 only briquette samples produced from poppy residues achieved this level which means that other investigated feedstock materials are not suitable for commercial sale.

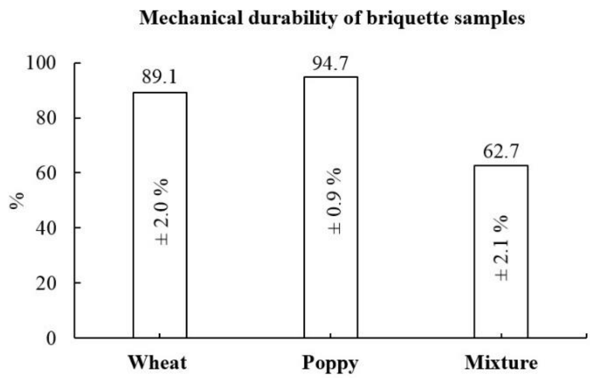

Figure 12. Level of main indicator of briquette mechanical quality determined for investigated briquette samples.

Lowest level (DU = 62.7%) was achieved by Mixture briquette samples as well as in the case of volume density determination. The reason also could be the content of oat husk in the mixture. Mechanical durability level of Wheat briquette samples occurred just below requested level ≥ 90%, while Poppy briquette samples as the only one fulfilled it, thus, proved its suitability for commercial production. Production of oat and wheat straw briquettes indicated higher level of DU, specifically, for oat straw it was stated equal to 78.87% and wheat straw briquettes exhibited DU equal 83.46% (Tumuluru et al., 2015). Low level of most of investigated briquette samples could be caused by low level of lignin, which is natural binder in the cells of lignocellulosic plants. As have been proved by Tumuluru et al. (2015) content of lignin in oat husk is 12.85% and in wheat husk it is 13.88%. Which can be considered as a low level in compare with wood; lignin content in pine wood was stated equal to 34.5% (Klass, 1998).

CONCLUSIONS

Microscopic analysis primarily indicated future issue during briquetting process related to diverse texture and surface of investigated feedstock materials. This observation was subsequently confirmed by low level of mechanical quality of tested briquette samples and complete inappropriateness of oat waste material (husk) for briquette production. Specifically, only Poppy waste material briquette samples achieved mandatory level of mechanical durability for commercial production. On the contrary, chemical analysis of Poppy briquette samples proved lower (but still satisfactory) level of Net calorific value (NCV) while other investigated samples proved high NCV level. Utilization of Poppy waste material (by extension, all tested waste materials utilization) for briquette production can be recommended, however, with necessary improvements related to their mechanical parameters. It can be recommended using of extremely high briquetting pressure (> 60 MPa) or using of external additives, for example wood dust or chips (with high level of lignin), to improve mechanical properties of briquettes. Overall evaluation of all obtained results proved satisfactory level of chemical quality and high energy potential of all investigated materials but low level of their mechanical quality.

On the contrary, chosen materials occurred in the form perfectly suitable for briquette production (proper feedstock moisture content and particle size) due to previous crops treatment during harvesting and processing by post–harvest lines. Thus, no further processing or preparation of feedstock materials were needed. This fact was definitely considered as an indisputable advantage of investigated materials within significant reduction of financial costs and time demands of such briquette production due to no previous feedstock preparation.

ACKNOWLEDGEMENTS. The research was supported by Internal Grant Agency of the Faculty of Engineering, Czech University of Life Sciences Prague, grant number 2017:31140/1312/3112 and further then by the Internal Grant Agency of the Czech University of Life Sciences Prague, grant number 20173005 (31140/1313/3108).

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