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PHYSICAL AND MECHANICAL PROPERTIES OF BRIQUETTES PRODUCED FROM ENERGY PLANTS

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Abstract

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The study deals with the use of energy crops for the production of thermal energy in the form of briquettes and devising appropriate parameters for their production. Briquettes were produced from seven kinds of energy crops, *Salix viminalis, Miscanthus sinensis, Rosa multiflora, Polygonum sachalinensis, Helianthus tuberosus, Sida hermaphrodita and Spartina pectinata*, specifically. In the production of briquettes, moisture is the most important properties of material to be pressed, which ranges from 8 to 15 % as it was observed. At a higher humidity it has not been possible to produce briquettes farther in the study conditions. Another important condition for the successful production of briquettes was the particle size of chopped mass. The optimum particle size range from 8 to 20 %. The briquettes were pressed at a pressure of 21 MPa and with diameter of 50 %. Subsequently, physical and mechanical properties (density, moisture, mechanical resistance) and chemical properties (chlorine, iron, nitrogen, calcium, ash, lignin content) were measured. The briquettes density reached from 800 to 900 $kg.m^{-3}$ with calorific value from 14 to 19 $MJ.kg^{-1}$ which refers to fact that energy crops are competitive to fossil fuels by their calorific value.

Keywords: energy crops, physical and mechanical properties, chemical properties, biomass

INTRODUCTION

From the perspective of the combustion of biomass its properties are essential where the main indicators of quality are values such as moisture content in biomass, chemical content of biomass, volatile matter content and calorific value (Maga and Piszalka, 2006). The usable biomass comes from a variety of plants and includes a wide range of chemicals and even though its energy content is in most cases similar. Calorific value of dry biomass is typically in the range from 15 to 19 $MJ.kg^{-1}$. The heat from biomass materials can be obtained directly by combustion or indirectly, e.g. by cooling of the engines combusting the biogas or by electricity generation. In the case of direct way of energy production it means the combustion of plant or woody biomass. And in combination with more currently advanced energy source devices defined by increased thermal efficiency it means less bio fuel requirements for the same amount of energy produced (Piszczalka and Jobbágy, 2011).

The harvest of energy crops can be realized by different technologies. An annual willow or grass crops can be harvested by using machinery which is designed for harvest of the maize (Urbanovičová, 2011). Chopped biomass can be used for additional purposes such as production of briquettes. The particle fractions are one of the most important features of chopped biomass (Lisowski *et al.* 2010). However, the harvest of crops has a high energy demands and therefore it is inevitable to optimize the whole harvest process (Lisowski *et al.*, 2009). On the other hand, strength and flexibility of energy crops in the cut are not well known.

For this reason the aim on the study was to evaluate the particle size of different energy crops harvested by a chopper. From harvested material the briquettes were produced and then their physical and mechanical properties were measured.

MATERIAL AND METHODS

The materials used were energy crops: *Salix viminalis, Miscanthus sinensis, Rosa multiflora, Polygonum sachalinensis, Helianthus tuberosus, Sida hermaphrodita and Spartina pectinata*, cultivated on research facility at Skiernewice in Poland. This crops were selected because of the possibilities of their cultivation on soil which are not suitable for common farming due to their less qualities.. The harvest of those crops was performed by chopper Sipma Z 374 aggregated with light tractor (Fig. 1) where hydraulic drive enables continuous length regulation of chopped material.

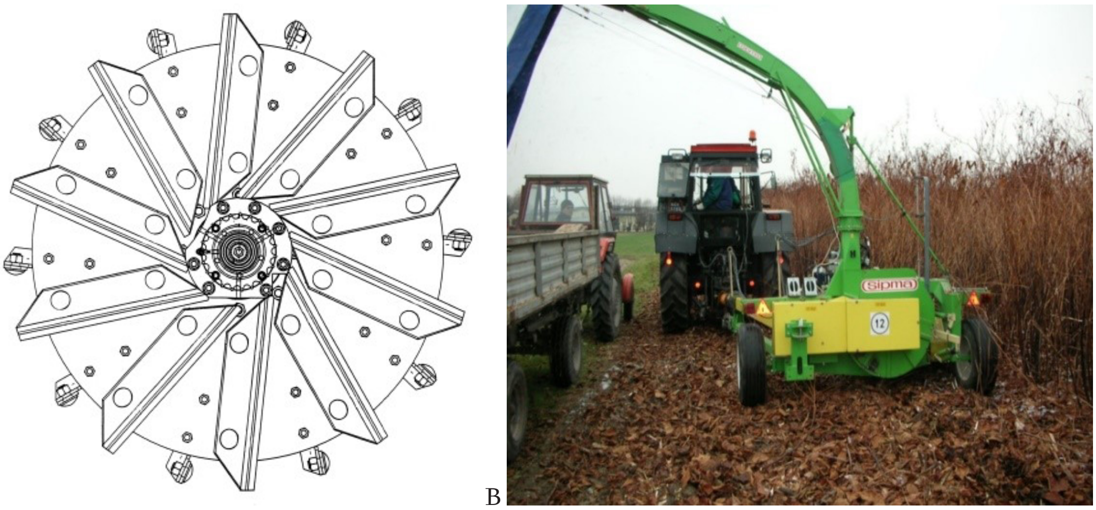
The degree of chopped material of energy crops was conducted on sieved separator developed according international standard ANSI/ASAE S424.1. Subsequently, ten repetitions were made for all of the selected crops.

Sieved separator consists of the five individual sieves; with squared perforations of 19.0, 12.7, 6.3, 3.9 and 1.1 % diagonals; and the bottom collector (Fig. 2). The briquettes were produced on hydraulic press designed for briquettes production Alchemik with pressure set on 21 MPa.

RESULTS AND DISCUSSION

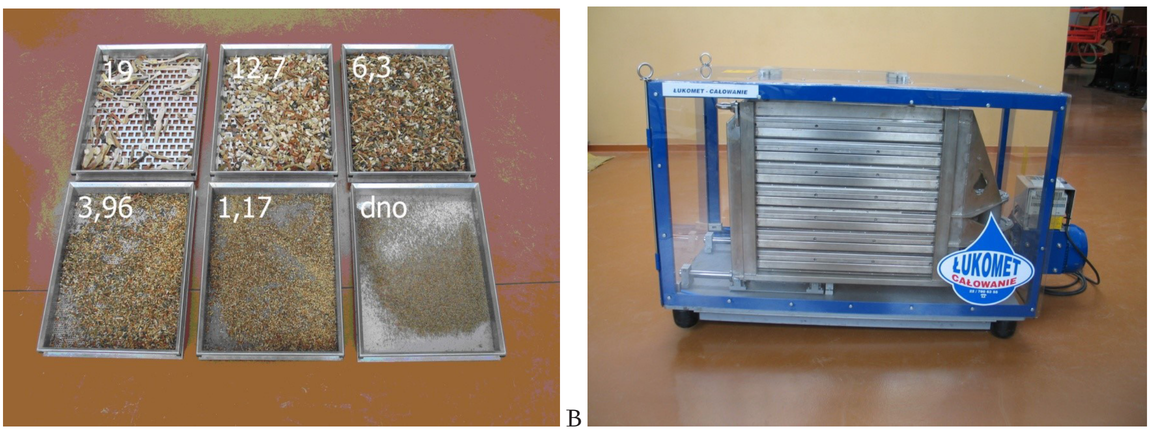
Measurement of the length of chopped material on the sieved separator

The harvest of energy crops were performed in December with suspended chopper Sipma Z–374 (Fig. 1A and B). Cutting mechanism consists of 10 blades with nominal operating speed 1000 RPM. The theoretical length of chopped material was 8.80 %. The moisture content of harvested crops ranged from 22.6 to 52.2 % by volume. The separation of chopped material into



A B

1: *A – chopper mechanism and B – suspended chopper Sipma Z–374*

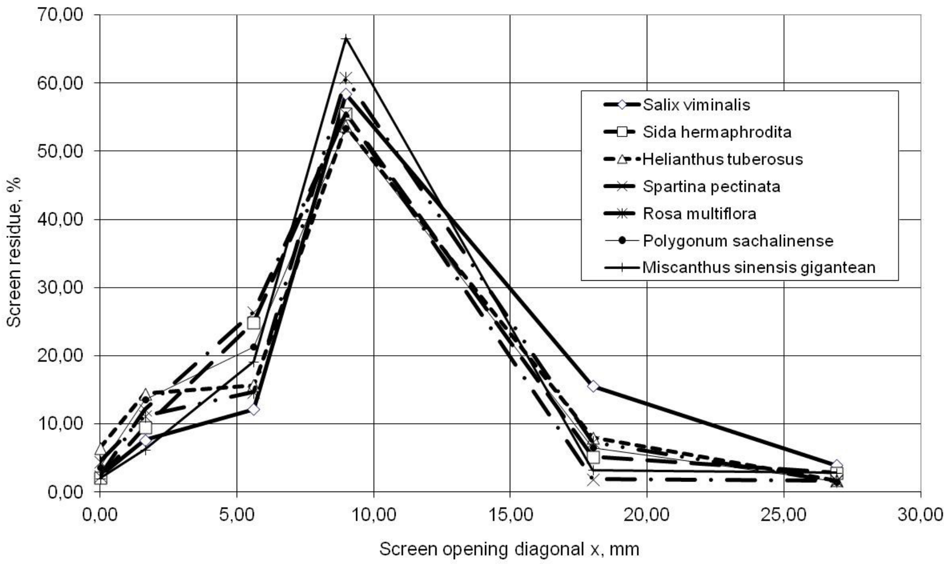


A B

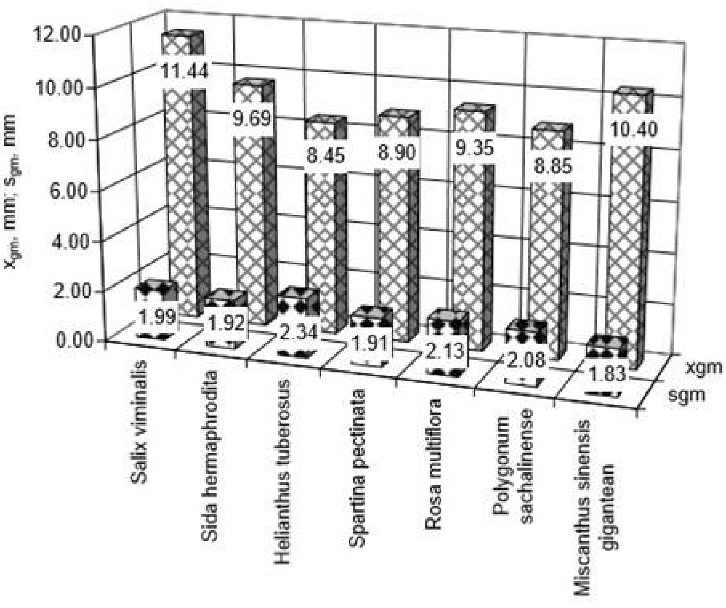
2: *A – Selected sieves of the sieved separator and B – Sieved separator in folded position* the individual fractions was completed on sieved separator described in methodology chapter and presented at Fig. 2 (A and B).

Fig. 3 show the results of chopped material length divided into individual particle size distribution. At chart it is possible to see that the progresses for all energy crops were symmetrical and centred on a screen with an aperture of 8.98 % which is associated with a theoretical cutting length (8.80 %). Prevalent occurrence of short particles was observed. However, statistically significant differences between the individual fractions were not found. Since from 50 to 65 % of chopped material was captured on sieve with an aperture of 8.98 % which meets the requirements of optimal length for production of briquettes.

The progress summary of the percentage of chopped material particle size per individual sieves for individual crops is shown at Fig. 3. The chart that the percentage for individual fractions of all selected energy crops vary at small intentions however, from the perspective of briquette production processes the fraction from 8 to 12 % is considered as the most important as stated Lisowski *et al.* (2010). As shown at Fig. 4 the progress it can be concluded that adjustment of the cutting system for all crops had constant parameters and was not altered. The individual values of the geometric mean and standard deviation of the particle length after harvest were also displayed at the same figure. Geometric mean as an indicator was used due to utilization of dimensions and geometric shape of individual



3: *Length distribution of chopped plant material particle.*



4: *Comparison between geometric mean values and standard deviation of particle length*

5: *A – Alchemik press machine and B – briquettes from Miscanthus sinesis*

sieve openings. For this reason and more accurate description of the separated material particle size it is used as a parameter through the geometric mean.

Measurement of physical properties of briquettes

For production of briquettes Alchemik APT 35 a hydraulic pressing machine was used (Fig. 5A). These pressing machines are designed for production of briquettes from various types of materials, e.g. sawdust, hay, straw, wooden chips, paper and other types of organic material, with hourly performance from 25 to 30 $kg.h^{-1}$. This type of pressing machine produce the cylindrical briquettes with a diameter of 50 %. The main advantage of this type of press machines is their simple operation, low installed power and low operational costs. Operational pressure is 21 MPa.

Among the fundamental physical properties of briquettes which were observed belong the density, durability, moisture content and calorific value (Lisowski *et al.* 2010). The bigger value of the calorific value it is the more thermal energy is produced by its combustion. The calorific value was conducted according to nationally adopted an international standard STN ISO 1928 (441352), 2003, Solid fuels: Determination of the combustion heat by calorimetric method in the pressure tank and calculation of the calorific value. Calorific values were determined by Calorimeter C5000 (IKA®-Werke GmbH & Co. KG, Germany).The relative humidity of the fuel is the weight of water contained in the fuel. Water content was assessed gravimetric method according to international standard CEN/TS 14774-3, 2004. Humidity were measured by laboratory oven dryer Venticel 55 Standard (MMM Medcenter Einrichtungen GmbH, Germany). Following data processing were conducted by utilization of MS EXCEL sheets and analysed by statistical software STATISTICA CZ (StatSoft CR s.r.o., Czech Republic).

Durability is a measure of resistance to shocks or abrasion of the compacted fuels due to handling and transportation. The tests were performed at the sieved separator with 12 × 12 % apertures of individual sieves with 2.4 Hz frequency of oscillation for 3 minutes.

The quality of briquettes is defined by its density since this property of briquettes is essential for transport, speed of combustion, stability of briquettes etc. Briquettes have to be also coherent to prevent their fracture, cracks and separation of fine particles what is not acceptable (Lisowski *et al.* 2010). In addition, density of briquettes belongs to mechanical indicators of quality defined in international standard CEN/TS 15150, 2005. The results of physical and mechanical properties of briquettes are showed in Tab. I.

According to Hussein and Nozdrovický (2009) moisture content plays a major role in determining density and strength of the densified masses. An increase in biomass materials moisture content considerably decreased the pellets density even at

I: *Physical and mechanical properties of briquettes*

Energy plant	Density, $g.m^{-3}$ (±s.d.)	Durabilty, % (±s.d.)	Moisture content, % (±s.d.)	Calorific value, $MJ.kg^{-1}$
Salix viminalis	0.82 ± 0.02	89 ± 0.2	10.4 ± 1.25	14–17.5
Miscanthus sinesis	0.85 ± 0.01	91 ± 0.1	8.0 ± 0.84	16–18
Rosa multiflora	0.78 ± 0.01	88 ± 0.2	10.5 ± 1.63	18.9
Polygonum sachalinensis	0.79 ± 0.01	85 ± 0.2	9.6 ± 0.45	15
Helianthus tuberosus	0.94 ± 0.02	92 ± 0.2	11.5 ± 2.61	16
Sida hermaprodita	0.82 ± 0.03	95 ± 0.1	11.0 ± 1.87	15
Spartina pectinata	0.80 ± 0.01	95 ± 0.2	10.0 ± 2.45	14–17

n = 20; Duncan's test; $\alpha = 0.05$

high applied pressures. Grover and Mishra (1996) recommended low feed moisture content (8–10 %) for biomass materials to produce strong and crack-free pellets. Briquettes produced in our study were observed as very solid and were not cracking while their moisture content varied in range 8–11 % and therefore those conclusions can be confirmed.

Measurement of chemical properties of briquettes

Recently, attention has begun to focus also on the chemical composition of the biomass, mostly on chlorine, which is considered as a reason of interior chamber damage during the briquettes combustion (Petříková and Punčochář, 2007). Frequently opinions have spread that biomass of plant origin – not from wood is not suitable for combustion in cauldrons where the internal chambers could be damaged caused mainly by the chlorine content of this kind of biomass (Lisowski *et al.* 2010).

Another important property of biomass is content of lignin which serves as sealant during production of briquettes or they are produced without chemical additives. Lignin is released by heat produced during the pressing process (Lisowski *et al.* 2010). Chemical analysis of briquettes of each energy crops was performed at Department of animal nutrition and Department of plant biology and ecology, Slovak university of agriculture in Nitra (see Tab. II).

As a most important observation can be point out the content of chlorine in produced briquettes. Petříková and Punčochář (2007) concluded that chlorine content in straw vary from 0.8 to 0.9 % and straw is used as biofuel and during its combustions were not observed negative effects on corrosion of internal chambers of burning devices. As it is shown in Tab. II, our measurements revealed that the chlorine content in briquettes ranged from 0.11 to 0.60 % which is even less value that it was observed in case of straw utilization and therefore it is not a limitation factor for briquettes utilization made from all of tested cultivars of plants.

II: *Chemical properties of briquettes (x – not recorded value)*

Plants	N	P	K	S	Fe	Ash	Dry matter	Lignin	Cl
	g.kg^{-1} (±s.d.)					% (±s.d.)			
Salix viminalis	4.83 ±0.16	1.25 ±0.31	2.50 ±0.21	0.26 ±0.06	0.062 ±0.02	1.81 ±0.11	92.38 ±0.21	15.04 ±0.12	0.60 ±0.04
Miscanthus sinesis	11.14 ±0.43	1.65 ±0.19	3.75 ±0.17	0.49 ±0.09	0.105 ±0.08	3.20 ±0.24	91.34 ±0.28	x	0.44 ±0.02
Rosa multiflora	4.13 ±0.36	0.72 ±0.21	2.00 ±0.41	1.23 ±0.06	0.198 ±0.02	3.25 ±0.34	91.87 ±0.37	7.63 ±0.14	0.27 ±0.08
Polygonum sachalinensis	1.55 ±0.12	0.60 ±0.10	3.75 ±0.28	0.31 ±0.04	0.124 ±0.04	1.93 ±0.22	92.85 ±0.26	11.96 ±0.23	0.27 ±0.06
Helianthus tuberosus	3.07 ±0.34	0.70 ±0.12	1.93 ±0.34	0.71 ±0.07	0.112 ±0.03	3.40 ±0.18	92.78 ±0.16	14.41 ±0.14	0.11 ±0.03

n = 20; Duncan's test; $\alpha = 0.05$

CONCLUSION

The focus of this study was on the possibility of using energy crops (straw and wood origin) which were processed by pressing on the form of briquettes. The main objective was to evaluate whole pressing process, physical, mechanical and chemical properties of produced briquettes. The particle size significantly affects the quality of briquettes. The moisture content is essential condition for secure pressing process of biomass. As another essential property of briquettes appear to be mechanical resistance which is important from the perspective of transportation and handling and prevents separation of fine particles to dangerous quantity (danger of explosion). Only two of selected energy crops meets the standard (≥ 95 %), *Sida hermaprodita* and *Spartina pectinata*, specifically. For other tested energy crops lower results was observed. Practical use of suitable biomass for the production of solid biofuels is linked with relatively large variations in their quality. Determination of methodology and description for meeting requirements of quality and it gives an assurance that they met the required properties of fuels based on biomass.

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