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AN ESTIMATION OF PHYSICAL PROPERTIES OF BRIQUETTES PRODUCED FROM PLANT BIOMASS

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Summary. The article presents the results of research on physical properties of briquettes produced from plant biomass. The external and internal diameter, length, mass as well as density of briquettes were defined. The value of durability coefficient as well as the crush losses in briquettes produced from the studied materials in a cochlear briquetting machine were determined.

Key words: plant biomass, briquettes, physical properties, coefficient of durability

INTRODUCTION

Fuel briquettes production from plant biomass is becoming more and more common and it may be predicted that it will be highly significant for agricultural production. Considering the variety of biomass sources, from the field plant production, through waste from agriculture, agri-food industry, households as well as communes, to wood waste from forestry, furniture industry and cellulose-paper industry, these raw materials have had great popularity, not only for heat energy production but also for the possibility of promotion of the regions where they are produced and processed [Grzybek 2003, Kościk 2003, Niedziółka et. al. 2006].

The current trends in professional energetics development aim at the growing use of renewable energy sources, particularly of biomass. It is one of the main unconventional energy sources in Poland. The solid fuel from biomass is ecologically-friendlier than coal (closed CO_2 circuit, low contents of sulphur, chlorine and low ash). But, with respect to certain physico-chemical properties, this fuel is less attractive than the conventional one. This is, among others, connected with too low density of the uprocessed biomass, which makes its transport, storage and loading to kettles more difficult [Szyszlak-Bargłowicz 2008, Wisz and Matwiejew 2005]. Also, high moisture of biomass (reaching even as high as 60%) as well as low energy concentration per volume unit cause some problems with distribution and usage, especially in kettles used for individual and communal heating. Hence the tendency for the compacting of solid biomass by its briquetting or pelleting. This causes a higher mass and energy concentration per volume unit and significantly facilitates the distribution and usage of this biofuel [Denisiuk 2008, Mani et. al. 2006, Wach and Szajner 1997].

Plant biomass, especially straw, needs a lot of storage space. That is why, in order to improve the energetic efficiency of the fuel, it should be properly processed. Fuel briquettes production from plant biomass gives the best results.

Combustion of biomass in such a form also allows for the automation of its feeding to the kettle furnace. Briquettes are formed in the process of agglomeration under pressure, where the crushed material, due to the action of both external (compacting impact) and internal (intermolecular bonding) forces takes on a solid shape of specified geometric dimensions. Depending on the applied constructional solutions of the compacting devices, they can take on different shapes (cylindrical, square, hexagonal etc.) and have different properties [Zuchniarz et. al. 2009].

Energetic value is one of the basic thermophysical parameters of solid biofuels. It is dependent on their moisture. The growth of this parametr results in the drop of combustion heat and the fuel value of biomass [Kamiński 2001, Niedziółka and Zuchniarz 2006]. Hence some types of plant biomass need to be additionally dried to obtain the required combustion parameters and adequate energetic value of the fuel. The main parameters decisive for briquettes value include also the density and mechanical durability [Plištil et. al. 2005].

According to Hejft [2006] the density of good quality briquettes should stay in the 650-950 $kg \cdot m^{-3}$ range. Whereas Adamczyk et. al. [2006] claims that the quality of briquettes can also be determined on the basis of their endurance coefficient as well as the crush losses of the plant material during durability testing. Briquettes with good durability properties are these for which the durability coefficient's value exceeds 0.9 [Fiszer 2008]. The value of this coefficient is largely dependent on the density degree. The higher the density the more durable the briquettes are. Depending on the briquettes application they should be durable, they should not crush and they need to have high density ensuring long combustion time. Besides, e.g. in the case of using fuel briquettes for burning in a fireplace, also their aesthetic qualities are to be considered. On the other hand, in professional energetics, where compact plant biofuels are crushed before combustion, high durability of briquettes is a disadvantage. In this case, the processing of plant biomass into briquettes is performed mainly in order to facilitate its transport to remote destinations.

MATERIALS AND METHODS

The briquettes were produced from maize straw, cereal straw, meadow hay as well as stalks of *Sida hermaphrodita*. Maize straw and *Sida hermaphrodita* stalks were obtained from the experimental fields of the Department of Special Plants Cultivation of the University of Life Sciences in Lublin. The other raw materials were collected from farms in the Lublin District. Before the briquetting all the plant materials were crushed using drum chaff-cutter and theoretical cut length of 20 mm. Briquettes from the tested plant materials were produced in the cochlear briquetting machine JW-08. The temperature in the compaction chamber in this briquetting machine was 200, 225 i 250°C. For the research purposes the steady moisture of approximately 10% was assumed for the compacted materials. The moisture of particular plant materials was determined by the drier-weight method according to the PN-ISO 6540 standard. In the cochlear briquetting machine the diameter of compaction chamber was 80 mm. After producing the briquettes, their external and internal diameter was determined as well as their length and mass. External and internal dimensions and the length of the produced briquettes were measured with a caliper (with measurement precision to 0.1 mm), and the mass was determined using laboratory scales WPT 3/6 (with measurement precision to 0.2 g). On the basis of these measurements the briquettes density was calculated.

The measurements of briquette durability were performed on the testing set consisting of a cuboid drum sized 300×300×460 mm, walled with 10×10 mm mesh. The drum's average rotational velocity was 15 rpm^{-1}, testing time 5 min, and the mean sample's mass approximately 1000 g. On the basis of tests performed in five replications the durability coefficient of the briquettes was determined as well as the crush losses for the tested plant materials. The durability coefficient of the briquettes was determined from the following dependency (1):

$$\psi = \frac{m_{br}}{m_b}, \tag{1}$$

where:
ψ – durability coefficient,
m_{br} – briquette mass after durability test, [g],
m_b – briquette mass before durability test, [g].

The briquette crush losses (S_{sk}) (2) were determined from the dependency (1):

$$S_{sk} = (1 - \psi) \times 100, \text{ [\%]}. \tag{2}$$

The obtained results of tests on the physical properties of briquettes were statistically analysed using one- and two-factor variance analysis as well as Tukey's test, at the 95% confidence interval in the STATISTICA 6.0. programme.

TESTS RESULTS AND ANALYSIS

On the basis of the obtained tests results (Tab. 1) it is possible to assume that in cochlear briquetting machine, independently from the set compaction chamber temperature and the used raw material, both the internal and external diameters of the produced briquettes differed insignificantly (about 2 mm on average). Much larger differences were found out in case of the length of the obtained briquettes. While analysing the temperature's influence it was noticed that together with its growth also the briquette length was growing. The temperature growth from 200 to 225°C caused the briquette length growth by about 27%. Whereas further temperature growth (to 250°C) caused a much smaller briquette length growth (5 mm on average).

Table 1. Average sizes of briquettes produced in the cochlear briquetting machine [Zuchniarz 2009]

Material	Temperature, [°C]	External diameter, [mm]	Internal diameter, [mm]	Length, [mm]	Mass, [g]
Maize straw	200	87.0	26.5	63.5	145.6
	225	86.7	27.0	86.6	320.4
	250	86.4	27.7	91.6	392.7
Cereal straw	200	87.0	27.9	56.1	105.4
	225	86.2	27.9	58.6	138.7
	250	85.9	28.0	66.2	220.6
Meadow hay	200	87.4	28.7	50.6	101.4
	225	87.3	28.7	55.1	148.6
	250	87.3	28.6	73.7	221.2
Stalks of Sida hermaphrodita	200	86.9	27.0	74.8	207.8
	225	86.8	27.9	97.6	286.3
	250	86.6	28.0	99.3	338.1

Comparing the mass of maize straw briquettes to the mass of briquettes from other materials it was noticed that at 200°C they did not differ significantly. At 225°C the maize straw briquettes reached the average mass of about 320 g and significant differences were found out between them and the cereal straw briquettes and meadow hay briquettes. However, no mass differences were found between maize straw briquettes and *Sida hermaphrodita* stalks briquettes whose average mass reached 280 g. At the highest compaction chamber temperature, maize straw briquettes had the greatest mass when compared to the other briquette types (app. 390 g).

Figure 1 presents density of maize straw briquettes compared to density of briquettes from other plant materials produced in cochlear briquetting machine. The performed tests showed that the compaction chamber temperature growth from 200 to 225°C resulted in the maize straw briquettes density growth. At 200°C the average density of the obtained agglomerate reached 446 kg·m^{-3}, whereas when the temperature grew to 225°C, the density grew to 667 kg·m^{-3}. Temperature growth to 250°C caused the density growth to 836 kg·m^{-3}.

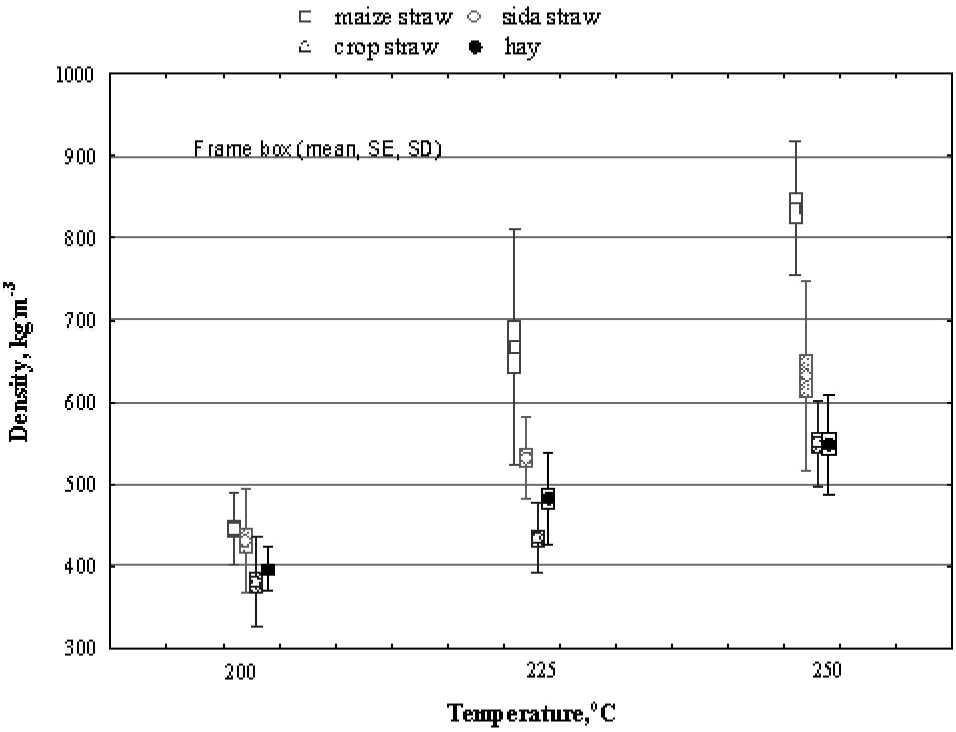

Fig. 1. Density of briquettes produced in the cochlear briquetting machine at different temperatures of compaction chamber [Zuchniarz 2009]

The density of briquettes from the other materials at 200°C did not significantly differ, and the highest density was achieved by maize straw briquettes. The lowest density at 200°C was recorded for cereal straw briquettes (380 kg·m^{-3}). The greatest differences in the briquette density were recorded at the highest temperature in compaction chamber (250°C).

The maize straw briquettes had the average density of about 836 kg·m^{-3}, the *Sida hermaphrodita* ones about 628 kg·m^{-3}, and the cereal straw and meadow hay ones had similar density values of about 552 kg·m^{-3}.

Figure 2 presents values of durability coefficient for the briquettes produced at three temperature levels in the compaction chamber of cochlear briquetting machine. While analysing the research results it is possible to observe that when the temperature in the briquetting machine compaction chamber changed from 200 do 225°C, the durability coefficient slightly grew for maize straw. For the other materials the value of the coefficient remained practically the same.

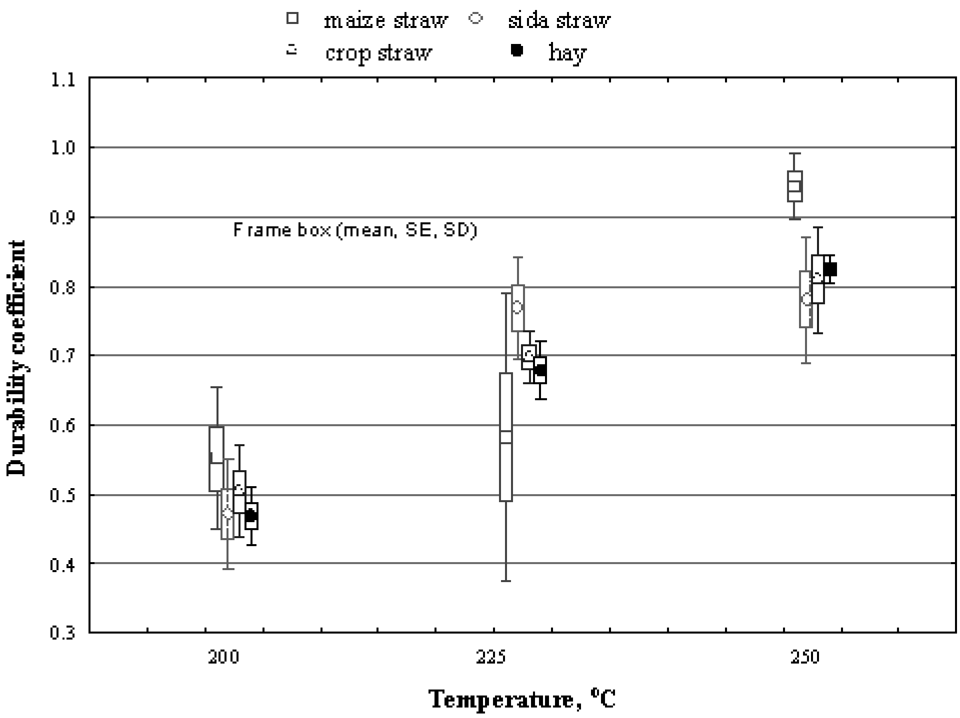

Fig. 2. Values of durability coefficient of briquettes produced in cochlear briquetting machine [Zuchniarz 2009]

Durability of maize straw briquettes grew significantly after setting the briquetting machine compaction chamber temperature at 250°C. Then the value of durability coefficient reached 0.94. These briquettes had over 40% higher durability than the ones produced at the lowest temperature. Briquettes from the other materials produced at the same temperature had a slightly lower durability coefficient of about 0.8. It should be observed, however, that both at the lowest and at the highest compaction chamber temperature the maize straw briquettes turned out to be the most durable. Figure 3 presents mean percentage values of crush losses for briquettes produced in cochlear briquetting machine from the tested plant materials. The highest crush losses occured for briquettes produced at the lowest compaction chamber temperatures ranging from 45 to 52%. A variety of losses were recorded for compaction chamber temperature at 225°C (ranging from 22 to 42%). Whereas significantly lower losses occured for briquettes produced at the highest compaction chamber temperature. They ranged from 6% for maize straw briquettes to 21% for the *Sida hermaphrodita* ones. These results have shown that both the compaction chamber temperature and the kind of the used plant material have an influence on crush losses in the produced briquettes.

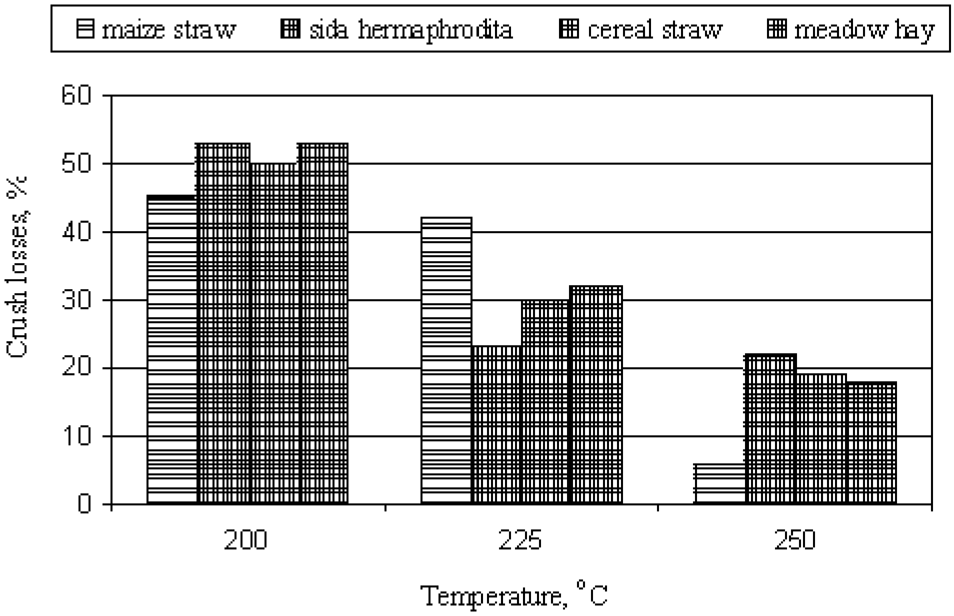

Fig. 3. Average values of percentage crush losses of briquettes produced in cochlear briquetting machine [Zuchniarz 2009]

CONCLUSIONS

Comparing the results of the conducted tests it was observed that the difference, both for the external and internal diameters of briquettes produced in cochlear briquetting machine is insignificant, independently from the used material or compaction chamber temperature. The significant difference was found out for length and mass of briquettes. The range of the latter results was relatively wide and depended both on the kind of material used for briquetting and on compaction chamber temperature (the higher the compaction chamber temperature the greater length and mass of the produced briquettes).

On the basis of statistical analysis also a significant influence was observed of the briquetting machine compaction chamber temperature on the properties of briquettes produced from all the tested plant materials (maize straw, cereal straw, meadow hay and stalks of *Sida hermaphrodita*). With temperature growth (from 200 to 250°C) the density and durability of briquettes significantly increased and their crush losses decreased.

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OCENA CECH FIZYCZNYCH BRYKIETÓW WYTWORZONYCH Z BIOMASY ROŚLINNEJ

Streszczenie. W pracy przedstawiono wyniki badań cech fizycznych brykietów wytworzonych z biomasy roślinnej. Określano średnicę zewnętrzną i wewnętrzną, długość, masę oraz gęstość brykietów. Wyznaczono także wartości współczynnika trwałości oraz wielkości strat okruszania brykietów wytworzonych z badanych surowców w brykieciarce ślimakowej.

Słowa kluczowe: biomasa roślinna, brykiety, cechy fizyczne, współczynnik trwałości

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