Quality evaluation of briquettes made from wood waste

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Abstract

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At logging and at the subsequent wood and wood semi-products treatment the fine grained loose waste arises, e.g. wood dust, saw dust, shavings, chips, bark etc. One of possibilities of its meaningful utilization is the briquetting technology, products of which are briquettes determined for energetic utilization (combustion). In the paper the experimental results are published. The briquettes quality evaluation was their aim. For the briquetting tests bark (pine), shavings (about 90% spruce + 10% pine), sawdust (spruce), birch chips and poplar chips were used. The basic physical-mechanical properties were the evaluation criteria. Following properties were determined: gross calorific value, total moisture content, density, rupture force, length, diameter, density and mechanical durability.

Keywords: briquetting; density; rupture force; mechanical durability

The more comfortable human life is paid by excessive energy increase in all its forms. The reserves of not renewable energy sources (coal, crude oil, natural gas) are not limitless, they gradually get exhausted and their price continually increases. Nevertheless they cover about four fifth of the energy consumption.

In last decades the renewable energy sources are preferred, e.g. wind energy, water energy, solar energy and biomass energy. The effort results of more extensive utilization of the wind energy and solar energy are not conclusive in the conditions of the Czech Republic. But the utilization of the biomass energy appears as the perspective. Compared with other countries we are still lagging behind. According to various published information in the Czech Republic only a few per cent of consumed energy is produced from biomass. At the some time in some countries even tens per cent are produced. There are several causes of this fact – from the potential user's small knowledge of the biomass utilization advantages to the not quite sufficient subsidy policy in this field (http://cs.wikipedia.org/wiki/Biomasa)

Biomass is an organic mass of vegetable origin. It can be obtained by two methods:

- from biomass grown on purpose – e.g. herbs (annual, biennial, multi-annual or perennial) or from short rotation woody crops,
- from waste biomass – e.g. municipal waste, waste from agricultural basic production or waste from wood logging and processing (Stupavský 2008; http://cs.wikipedia.org/wiki/Biomasa).

The biomass processing depends especially on its properties. At present the following processes are mostly used:

- thermochemical – gasifying, combustion,
- biochemical – methane fermentation, alcoholic fermentation,
- chemical – esterification,
- biological – composting, wastewater treatment (http://cs.wikipedia.org/wiki/Biomasa).

For combustion the biomass is prepared to the suitable size and form. Wood fuels (so called dendromass) are usually supplied as logs, bark, chips, sawdust, shavings, briquettes and pellets. Fuels made from energy plants are usually supplied as bale goods, chaff, briquettes (Basore 1929; Sheridan, Berte 1959; Plíštil et al. 2004) and pellets (Plíštil 2005; Nováková, Brožek 2008; Punko, Gavrilovich 2009).

In the literature the pieces of information are published about a lot of plant species suitable for growing on purpose and for further energy utilization. In the Czech Republic conditions the growing of poplars, locusts, willows, alders and birches is convenient for these purposes as the best. They grow on plantations and after a short time (about 2–8 years) are harvested and processed. By the plantations establishing of quick growing trees it is possible to utilize practically the loose or not utilized farmland e.g. along highways, roads, on mine wastes or ash disposal sites, localities endangered by air pollutants etc.

In this paper we engage in problems of dendromass – biomass acquired from wood, namely from waste resulting from its logging (pine bark) and following processing (sawdust spruce, shavings 90% spruce and 10% pine). For generalization of obtained pieces of knowledge two on purpose grown biomass in form of chips (birch and poplar), were tested.

Heating using firewood in various forms is today in the Czech Republic still relatively financially advantageous. The year-long costs for family house (consumption 80 GJ/year) at wood chips are heating about 16,000 CZK, at firewood heating about 21,900 CZK. The heating using wood waste is a bit more expensive (using pellets 23,900 CZK, briquettes 29,300 CZK). In the pellets and briquettes price their production costs are included. The year-long heating costs using brown coal are about 23,500 CZK, hard coal about 30,200 CZK, natural gas about 36,500 CZK and electric power about 50,200 CZK (http://www.tzb-info.cz/tabulky-a-vypocty/269-porovnani-nakladu-na-vytapeni-podle-druhu-paliva) (for information: March 30, 2011 the exchange rate was 1€ = 24.52 CZK).

But the briquetting technology is not limited only to non-metallic materials (Brožek 2001a; Brožek, Nováková 2009). It is used also for processing of chips resulting from metallic materials machining be it on the ferrous basis (steel, cast iron) or on the non-ferrous basis (Brožek 2001b; Brožek 2005). In this case the waste volume reduction, handling facilitation or possibility of following material utilization are the main aims.

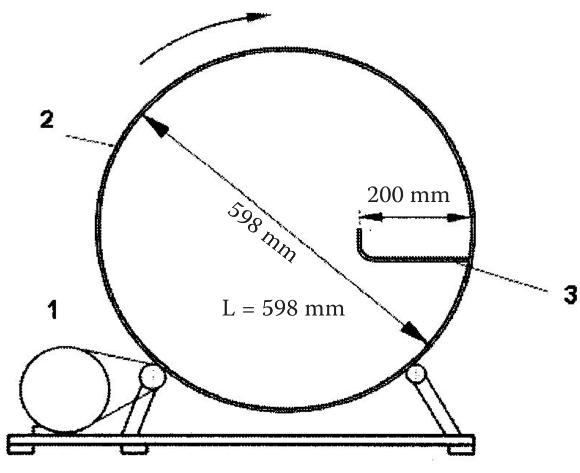


Fig. 1. Principle of the durability drum: 1 – motor, 2 – drum, 3 – baffle

MATERIAL AND METHODS

The important properties of briquettes and pellets are their mechanical properties, which influence their storage time and handling. The mechanical properties of briquettes and pellets determined for combustion are specified in relevant national directives, in the Czech Republic e.g. by the Directive of Ministry of Environment No. 14–2009, which prescribes the requirements on briquettes from wood waste. Analogous directives are valid in other countries, too, e.g. in Germany the standard DIN 51731, in Austria the standard ŐNORM M 7135, in Sweden the standard SS 187120, in Switzerland the standard SN 166000 and in Norway the standards NS 3165, NS 3166 and NS 3167. The Directives and above mentioned standards require the density of briquettes and pellets at least of 900 kg/m^3, or more precisely between 1,000 and 1,400 kg/m^3. The requirements on the briquettes mechanical durability are given in the standard ČSN P CEN/TS 15210-2 (2006), including the description of the test device (Fig. 1). Using this test the briquettes with the length above two times the diameter are cut to a length equivalent to two times the diameter. Smaller particles are separated by the use of the sieve of the specified aperture size. Then the prepared samples are placed in the durability drum and rotated under the given conditions. The briquettes are subjected to controlled shocks against each other and against the walls during the chamber rotation. Afterwards the samples are passed through the sieve again. The mechanical durability is calculated as the ratio of the mass of the pre-sieved briquettes before the drum treatment to the

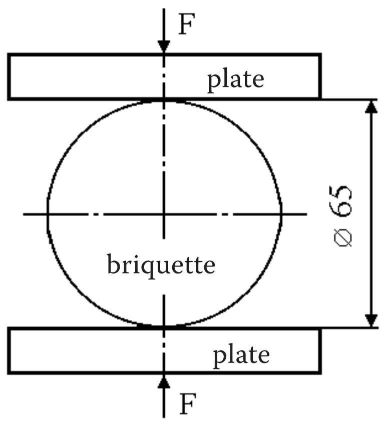


Fig. 2. Principle of the plate-loading test

mass of sieved briquettes after the drum treatment. The requirements on the briquettes strength are not included in any of the above mentioned regulations. But it is very important that briquettes were of adequate cohesiveness in order that at common handling neither crumbling nor falling apart occur (Brožek 2001a; Brožek, Nováková 2009).

The aim of carried out experiments was the evaluation of briquettes quality from the point of view of used materials and fulfillment of required density. Three types of briquettes made from wood waste resulting from logging (pine bark) and arising in woodworking industry (pine sawdust, shavings – mixture about 90% spruce and 10% pine) were tested. The set of tested materials was supplemented with two types of dendromass, namely with birch and poplar chips.

For the briquetting production the briquetting press type BrikStar 50 (Briklis, Malšice, Czech Republic) of the pressure chamber diameter 65 mm was used. From each of the above mentioned materials about 20 kg briquettes were made. One half of this amount was used to the durability test according to ČSN P CSN/TS 15210-2 (2006), the second half was statistically evaluated (Brožek, Nováková 2009). The briquettes were numbered, weighed and their length and diameter were measured. Then the briquettes were plate-loading tested using the universal tensile strength testing machine (Fig. 2). Except for this the gross calorific value [according to ČSN EN 14918 (2010)] and the total moisture [according to ČSN EN 14774-2 (2010)] were determined.

From the measured values the briquettes density was calculated. With regard to the used technology the briquettes were of different length. Therefore the rupture force was recalculated and it is presented as the force per unit (per 1 mm briquette length).

RESULTS AND DISCUSSION

From the test results (Fig. 3, Table 1) it is evident that the briquettes made from five different materials are of very different properties.

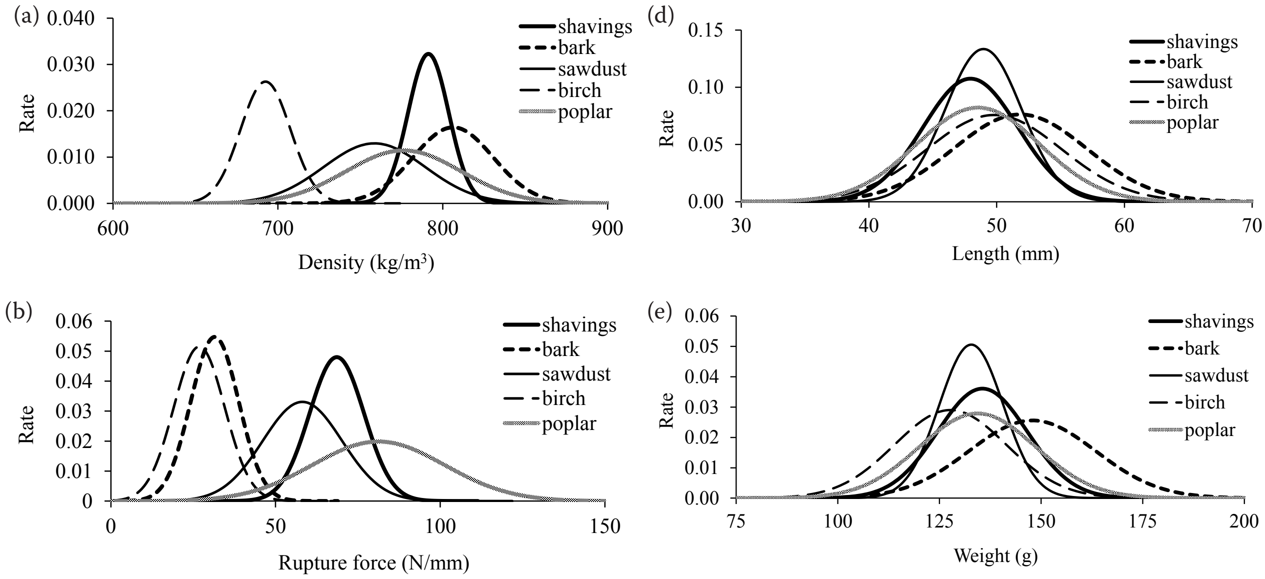
From the point of view of the gross calorific value related to the moisture-free state all materials satisfy (min. 17 MJ/kg^3), as well as of the moisture content (max. 10%). From the point of view of the ash amount (max. 1.5% wt.) three samples met the requirements (shavings, sawdust and birch), two samples failed (bark and poplar).

From the point of view of the mechanical durability [according to ČSN EN 14961-1 (2010)] none of tested samples satisfied the highest grade (DU ≥ 95%). Briquettes made from three materials (shavings, sawdust and poplar chips) satisfied the mean value. Their value was between 90 and 95%. Two remaining samples were of relatively low mechanical durability, namely of DU = 72.8% (bark) and DU = 31.3% (birch chips).

From the point of view of the briquettes density (Fig. 3a) none of five materials fulfilled the demand of the Directive of Ministry of Environment No. 14–2009. The highest density was determined at the briquettes made from pine bark (806 kg/m^3), lower from shavings – mixture of 90% spruce and 10% pine (791 kg/m^3), poplar chips (776 kg/m^3), spruce sawdust (759 kg/m^3) and the lowest at briquettes from birch chips (692 kg/m^3). From the curves form on Fig. 3a the different results (arithmetic mean and standard deviation) are evident. It is confirmed by the calculation results (Table 1).

The results of rupture force tests (Fig. 3b) are interesting, too. The highest rupture force was measured at briquettes from poplar chips (81.2 N/mm), lower at briquettes from shavings (68.6 N/mm) and sawdust (58.2 N/mm); relatively low values were determined at briquettes from bark (31.5 N/mm) and birch chips (26.8 N/mm).

The comparison of the relation between the briquettes density and the rupture force is interesting, too. Generally it is possible to say that the obvious dependence between the density and the rupture force does not exist. Briquettes made from bark were of the highest density (806 kg/m^3), but contemporarily of the second lowest rupture force (31.5 N/mm), comparable with the rupture force (26.8 N/mm)



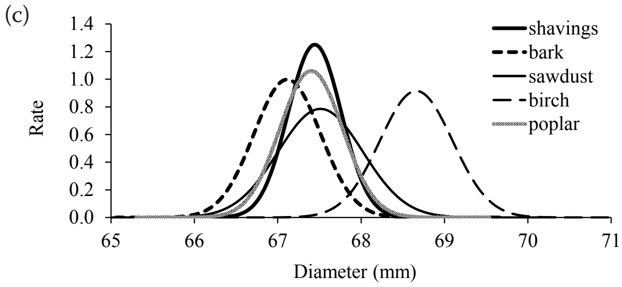


Fig 3. Test results

(a) – density; (b) – rupture force; (c) – diameter; (d) – length; (e) – weight

of the birch chips, which are of the lowest density (692 kg/m^3) from all tested materials.

The matrix diameter for the briquettes production was of 65 mm. As it is evident from the test results all briquettes were of the bigger diameter (Fig. 3c). The diameter of briquettes made from bark (67.11 mm) was the closest to the matrix diameter. On the contrary, the biggest diameter was measured at briquettes from birch chips (68.66 mm). Also from the small set it is possible to trace down the relatively close dependence between the briquettes density and their diameter ($d = -0.013 \times \rho + 77.68$; $R^2 = 0.95$). From this dependence it follows that briquettes of higher density enhance their diameter less than briquettes of lower quality. The briquettes diameter magnification compared with the matrix diameter is in the range from 3.2 to 5.6%.

Relatively even results were determined at the briquettes length (Fig. 3d) and weight (Fig. 3e). But these two parameters are not too interesting for the briquettes quality evaluation. The briquetting press works so that at each piston working stroke the different material amount gets in the press chamber. The material is pushed by a short screw conveyor which is placed in the hopper bottom. Then the briquette weight and length depends on the material

Table 1. Test results

Briquettes material	Gross calorific value (MJ/kg)	Ash amount (%)	Moisture content (%)	Mechanical durability (%)	Density (kg/m^3)	Rupture force (N/mm)	Length (mm)	Diameter (mm)	Weight (g)
Shavings	19.3	0.79	9.1	92.2 ± 0.4	791.3 ± 12.5	68.6 ± 8.4	47.95 ± 3.75	67.44 ± 0.32	135.6 ± 11.2
Bark	18.3	1.72	8.1	72.8 ± 5.2	806.3 ± 24.5	31.5 ± 7.4	51.84 ± 5.28	67.11 ± 0.40	147.9 ± 15.7
Sawdust	18.9	0.29	6.8	91.3 ± 0.8	758.5 ± 31.1	58.2 ± 12.2	48.97 ± 3.02	67.51 ± 0.51	132.8 ± 8.0
Birch	20.1	0.57	6.3	31.3 ± 3.7	692.4 ± 15.3	26.8 ± 7.8	49.81 ± 5.32	68.66 ± 0.44	127.7 ± 13.9
Poplar	19.1	3.61	7.2	94.3 ± 0.9	776.2 ± 35.2	81.2 ± 20.3	48.54 ± 4.90	67.40 ± 0.38	134.4 ± 14.4

amount which gets at the piston working stroke in the press chamber.

CONCLUSION

The paper contains the laboratory test results of briquettes from five different non metallic materials, namely bark (pine), sawdust (spruce), shavings (about 90% spruce and 10% pine), birch chips and poplar chips. For briquetting the briquetting press Briklis type BrikStar 50 of the pressure chamber diameter 65 mm was used. For the evaluation following parameters were determined: gross calorific vale, ash amount, total moisture, mechanical durability, density, rupture force, briquettes length, diameter and weight.

All briquettes fulfilled the demands of relevant directives for combustion heat, total moisture and ash amount. From the point of view of the ash amount (max. 1.5% wt.) meet the three samples (shavings, sawdust and birch), two samples failed (bark and poplar). From the point of view of the mechanical durability the briquettes from shavings, sawdust and poplar chips showed the average properties. The briquettes from bark and birch chips were of the below-average mechanical durability.

From the point of view of the density none of briquettes met the requirements. No doubt it is caused by the too low pressure by use of press of the firm Briklis. The press chamber of this press is from both sides open. From one side it is closed by the preceding briquettes, which are by the just produced briquette pushed out from the press chamber. The pressure intensity depends especially on the pressed material properties, namely on its sliding properties. E.g. the paper is less slippery; therefore the paper briquettes are of a very good quality. The wood waste is more slippery, the back-pressure is low and therefore the briquettes are of a low quality. Therefore the authors of this paper recommended to the producer to increase the briquetting pressure by the easy realizable adaptation of the existing briquetting press design. The increase in the briquetting pressure can be reached by two ways, namely by the pressure chamber diameter reduction or by the pressure chamber lengthening.

These tests were carried out, although none of existing directives prescribes the demands on the briquettes rupture force. On that occasion it was discovered that the rupture force does not depend practically on the briquettes density.

In the following part of the tests the briquettes dimensions (diameter and length) were measured and the briquettes weight was measured. It was discovered that the briquettes diameter depends rather narrowly on the briquettes density.

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