INFLUENCE OF STORAGE ON BRIQUETTES MECHANICAL PROPERTIES

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The effects of the storage place, placing manner, and storage time on mechanical properties of briquettes made from birch chips were laboratorily tested. A unique methodology developed by the present author enabling a relatively easy assessment of mechanical properties of the briquettes is described. The briquettes properties were evaluated by their density and rupture force determination. From the test results it follows that if the briquettes are stored in a well closed plastic bag, neither the place nor the storage time influence significantly their life time. When stored in a net plastic bag, the briquettes get seriously damaged, namely depending on their storage place and storage time.

renewable energy sources; briquetting; properties of briquettes; mechanical durability

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INTRODUCTION

The reserves of non-renewable energetic sources are gradually getting exhausted and their price permanently increases. Therefore in recent decades the renewable energy sources like wind energy, water energy, sunshine energy, and biomass energy have been a topic of interest. In the Czech Republic, conditions for possible use of biomass are perspective. Biomass is an organic material of animal or vegetable origin. In principle, it can be obtained from growing it for a concrete purpose or from biological waste. The next biomass exploitation depends mainly on its properties. One of the possibilities is combustion. For this purpose, the biomass is compacted into a suitable size and form, e.g. of pellets or briquettes (Basore, 1929; Sheridan, Berte, 1959; Plíštil et al., 2004; Nováková, Brožek, 2008; Kolářová, 2011; Brožek, 2011, 2013a; Brožek et al., 2012). In practice, the briquetting technology is often used for the metallic materials volume reduction, e.g. for chips resulting from machining (Brožek, 2002, 2005, 2009; Brožek, Nováková, 2010).

The briquettes mechanical properties are very important (Lunguleasa, 2010; Kakitis et al., 2011; Sellin et al., 2013; Zvicevicius_et al., 2013; Brožek, 2013b; Brožek, Nováková, 2013). They influence expressively e.g. the storage ability. It was experimentally proved by the present author (Brožek, Nováková, 2011; Brožek, 2013a) that the mechanical properties of the briquettes worsen with time. The decrease depends above all on the storage conditions and storage time. The adequate mechanical properties level is influenced also e.g. by the producer's handling, by the process of packing and sale, and by the way of incineration carried out by the final user.

MATERIAL AND METHODS

The briquettes from biomass determined for combustion must meet a wide range of requirements ordered by relevant national directives. In the Czech Republic, the demands on briquettes mechanical properties are specified in the Directive of the Ministry of the Environment of the Czech Republic No. 14/2009. The briquettes minimum density of 900 $kg \cdot m^{-3}$ is demanded, while strength demands are neglected. However, for operational reasons the adequate compactness is very important for common handling without crumbling or disintegration.

The assessment of the briquettes mechanical properties change at their long-term storage under suitable, less suitable, and unsuitable conditions was the subject of testing (Brožek, Nováková, 2011; Brožek, 2013a).

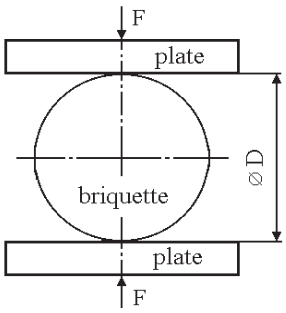


Fig. 1 Principle of the rupture test

The tested briquettes were made from birch chips. The briquettes were manufactured using the briquetting press BrikStar 50 (pressure chamber diameter of 65 mm) (BRIKLIS, spol. s r. o., Malšice, Czech Republic) with constant adjustment of all briquetting parameters. All briquettes were made at the briquetting parameters constant adjustment. Before the briquetting, the material was examined for the moisture content (6.3% according to ČSN EN 14774-2, 2010), ash amount (0.6% according to ČSN EN 14775, 2010), and gross calorific value (20.1 MJ kg^{-1} according to ČSN EN 14918, 2010).

The suitability of different storage spaces for the briquettes long-term deposition was the first factor observed. The briquettes were divided into three groups and deposited the in following storage spaces:

- Storage space A – a closed heated room, storage in a plastic bag and in a plastic net bag,
- Storage space B – a closed unheated room, storage in a plastic bag and in a plastic net bag,
- Storage space C – an unheated, from one side open shelter, storage in a plastic bag and in a plastic net bag.

The time of the briquettes storage was the second factor observed. At predetermined intervals (6 and 12 months), 100 pieces of briquettes were always taken from each storage space (A–C) for testing. The first part, i.e. the first 100 pieces of briquettes, was tested immediately after their production. The measured values were used as the reference data at the final evaluation.

After sampling the briquettes were numbered, weighed, and their length and diameter measured. Then the individual briquettes were loaded by pressure using the universal tensile strength testing machine (Fig. 1) and the rupture force was determined. The testing load rate was 15 mm min^{-1} (Brožek, Nováková, 2011; Brožek et al., 2012).

From the measured values the briquettes density was calculated. With regard to the production technology, the briquettes were of different length. Therefore their rupture force was recalculated and presented as the force per 1 mm of the briquette length.

RESULTS AND DISCUSSION

All the measured values were statistically evaluated (Table 1) and given in Figs. 2–7. Figs. 2–4 present the distribution of the briquettes density, Figs. 5–7 present the normal distribution of the rupture force in dependence on the storage time and storage space. On the *y*-axis the f(x) values are presented according to the following equation:

$$f(x) = \frac{1}{\sigma.\sqrt{2.\pi}}.e^{-\frac{(x-\mu)^2}{2.\sigma^2}}$$

where:
μ = arithmetic mean
σ = standard deviation

Figs. 2–7 reveal that the starting density of the tested briquettes was only of 666.1 kg m^{-3}, which is under the lower limit demanded by the Directive of Ministry of the Environment of the Czech Republic No. 14/2009. Considering the fact that briquettes of the same density are commonly marketed, the tests were realized.

Table 1 Test results

Sample	Density kg/m^3	Rupture force per 1 mm briquette length N/mm
Without exposure	666.1 ± 30.0	21.8 ± 6.6
Storage space A, exposure 6 months, plastic net bag	568.1 ± 42.3	11.1 ± 4.5
Storage space A, exposure 6 months, plastic bag	619.6 ± 33.7	15.2 ± 5.9
Storage space A, exposure 12 months, plastic net bag	522.4 ± 36.6	4.6 ± 2.5
Storage space A, exposure 12 months, plastic bag	618.9 ± 35.7	14.6 ± 5.3
Storage space B, exposure 6 months, plastic net bag	414.1 ± 36.8	1.7 ± 1.4
Storage space B, exposure 6 months, plastic bag	623.7 ± 31.5	15.9 ± 5.9
Storage space B, exposure 12 months, plastic net bag	410.2 ± 38.9	1.9 ± 1.4
Storage space B, exposure 12 months, plastic bag	606.8 ± 47.8	13.8 ± 6.0
Storage space C, exposure 6 months, plastic net bag	387.1 ± 66.2	0.6 ± 0.7
Storage space C, exposure 6 months, plastic bag	621.7 ± 47.5	16.0 ± 6.4
Storage space C, exposure 12 months, plastic net bag	407.1 ± 31.4	0.5 ± 1.1
Storage space C, exposure 12 months, plastic bag	613.5 ± 55.4	14.2 ± 6.8

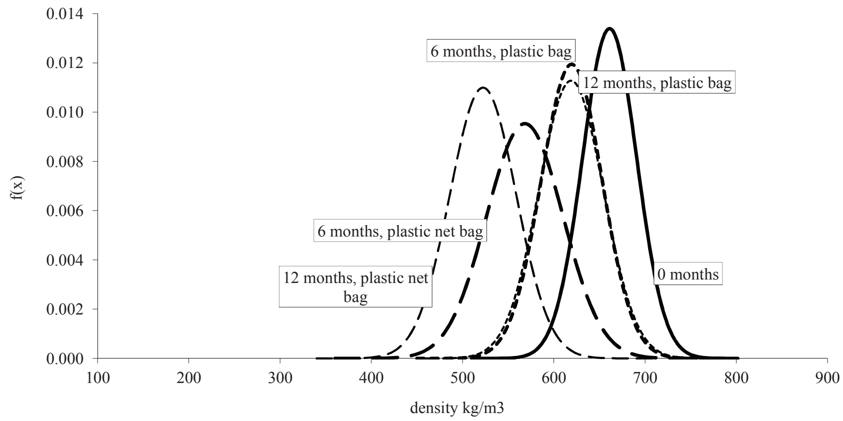


Fig. 2 Relationship between the briquettes density and the storage time, storage space A

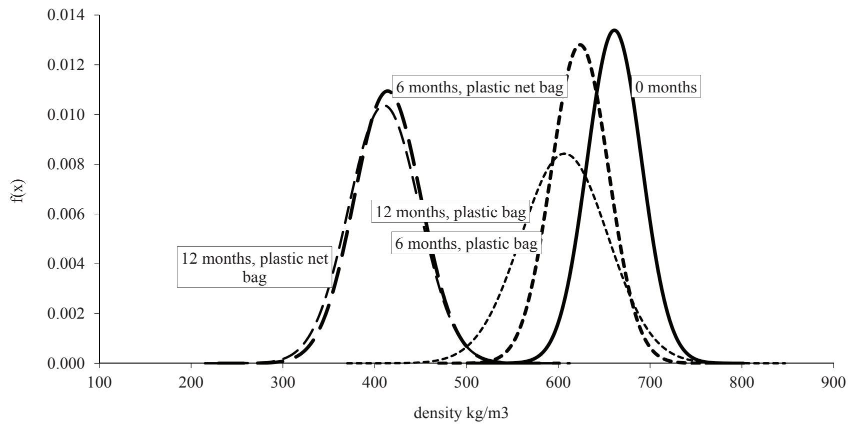


Fig. 3 Relationship between the briquettes density and the storage time, storage space B

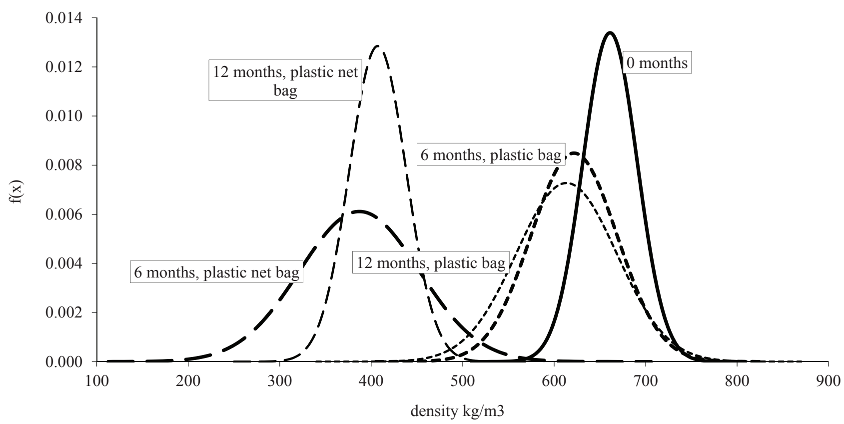


Fig. 4 Relationship between the briquettes density and the storage time, storage space C

By the carried out tests it was decidedly proved that at the briquettes stored in the well closed plastic bag, neither the storage space (A, B, C) nor the storage time (6 months, 12 months) significantly influenced their quality. After the storage time of 6 months, the density decrease was no more than 7.0%, after the storage time of 12 months it was no more than 8.9%. The rupture force decrease was more substantial. After the storage time of 6 months, the rupture force decrease was (in dependence on the storage space A, B, C) 26.6–30.3%. After the storage time of 12 months, the rupture force increase was 33.0–34.6%. Nevertheless, it must be accentuated that all briquettes were compact and usable.

However, the briquettes properties changed fundamentally at their storage in the plastic net bag. In accordance with the assumption, the minimal briquettes disturbance occurred at their storage in the closed heated room (space A). After 6 months, the briquettes density decrease made 14.7%, after 12 months 21.6%. At the storage in the closed unheated room (space B), the density decrease after 6 months was of 37.8%, after 12 months of 38.4%. At the briquettes storage in the unheated, from one side open shelter (space C), the density decrease after 6 months made 41.9%, after 12 months 38.9%.

Substantial were the changes in the briquettes rupture force. Although the monitoring of this parameter

Fig. 5 Relationship between the rupture force and the storage time, storage space A

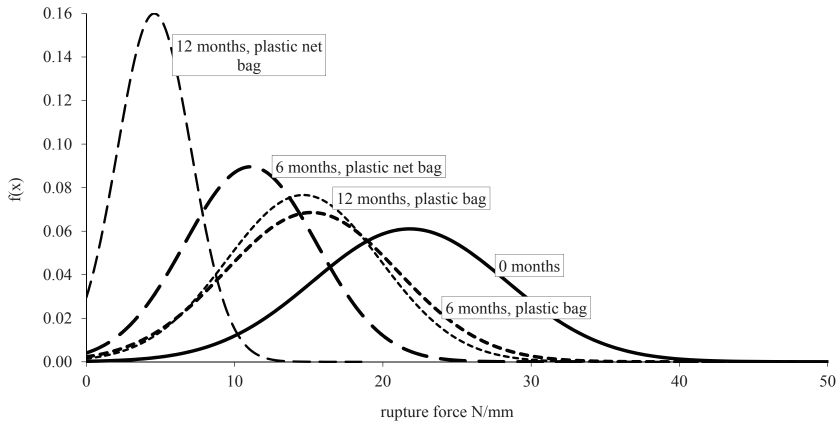


Fig. 6 Relationship between the rupture force and the storage time, storage space B

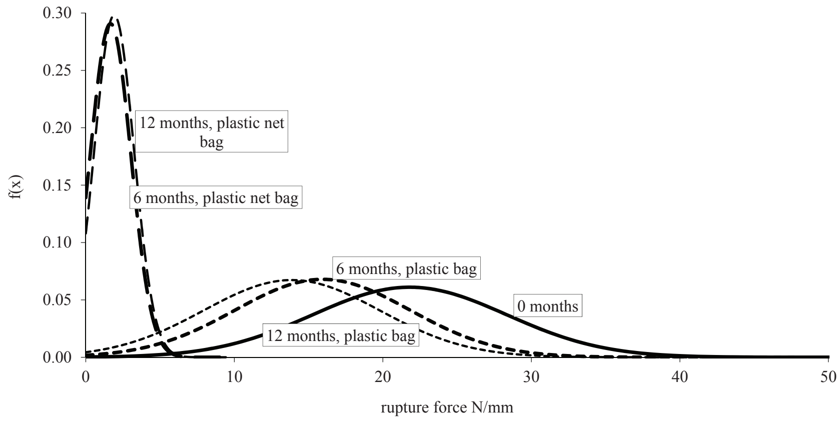
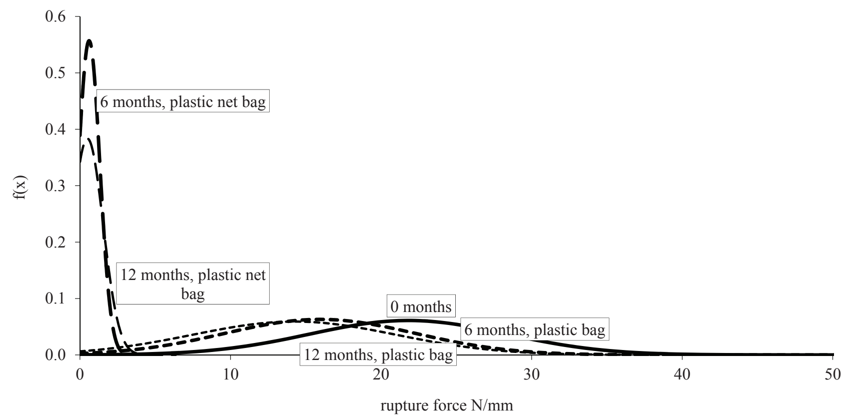


Fig. 7 Relationship between the rupture force and the storage time, storage space C



is not ordered by the Direction of the Ministry of the Environment of the Czech Republic No. 14/2009, the results are interesting. At the briquettes storage in the plastic net bag, space A, the rupture force decrease after 6 months made 49.1%, after 12 months 78.9%. At the briquettes storage in space B, the rupture force after 6 months decreased by 92.3%, after 12 months by 91.3% (as the difference between the rupture forces values was only slight, the lower value after 12 months was neglected). At the storage in space C, the briquettes rupture force after 6 months decreased by 97.2%, after 12 months by 97.7%. At this unsuitable storage the spontaneous disintegration occurred at 60% of the briquettes as early as after 12 months.

From the test results it follows that the briquettes durability is not substantially influenced by the storage time, but primarily by the storage space and manner. According to the producer's recommendation, dry and heated rooms can be considered as suitable spaces. On the contrary, unheated spaces are totally unsuitable, regardless of their structure. Briquettes should always be stored in leak-proof, closed, plastic containers.

CONCLUSION

Three factors influencing the briquettes mechanical properties at the long-time storage were studied: the briquettes storage space, storage manner, and storage time. Density and rupture force were criterions for the briquettes evaluation. A unique methodology developed by the present author enabling a relatively easy assessment of the briquettes mechanical properties was presented.

The carried out tests decidedly proved that the briquettes durability is most influenced by the storage space. Briquettes stored in a well closed plastic bag in the suitable (A), less suitable (B), and unsuitable (C) space changed their properties only little. On the contrary, properties of the briquettes stored in a plastic net bag changed very considerably as early as after 6 months, regardless of their storage space. At the unsuitable briquettes storage (space C), a spontaneous disintegration occurred in 60% of briquettes already after 12 months.

It can be concluded that briquettes should always be stored in leak-proof, well closed plastic containers.

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