Heating briquettes from energy crops

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ABSTRACT: The aim of this research is to find and to evaluate energy crops with respect to their compactibility. It resulted in an evaluation of mechanical properties of seven crop species and in findings concerning mechanical parameters that exert influence on the compacting process. The evaluated mechanical properties cover the briquette density and the force required to break the briquettes. Following energy crops were studied: *Sorghum vulgare, Phalaroides arundinacea, Crambe abyssinica, Fectusa pragensia, Camelina sativa, Miscanthus sinensis, Carthamus tinctorius*. Before compression these crops were disintegrated in a grinder. The fraction size was given by the sieve mesh size – viz. a circular cross section of a 15 mm diameter. All crops had an unchanged moisture content during the measurement and a uniform output diameter of the briquette of about 65 mm. The crops showed following moisture contents in the experiments: *Sorghum vulgare* = 10.95%, *Phalaroides arundinacea* = 11.40%, *Crambe abyssinica* = 15.97%, *Fectusa pragensia* = 10.66%, *Camelina sativa* = 15.37%, *Miscanthus sinensis* = 9.97%, *Carthamus tinctorius* = 15.54%.

Keywords: phytomass; energy crops; briquetting; mechanical properties; fissure test

Biomass is a general concept of organic matter in the original natural form growing on the basis of photosynthesis – collecting and transforming solar energy in plants – like trees, herbs, crops, grasses, algae and seaweed. With respect to processing and energy utilization we distinguish dendromass and haulm phytomass (SLADKÝ et al. 2002). Phytogenic fuels have served the human kind as heat resource for many thousand years and only since the last 250 years they were gradually substituted by fossile fuels with higher heating values which are practically better applicable. The global annual phytomass increase surpasses ten times the current energy consumption of the human society but the harder conditions of obtaining it and the great diversity of their species, of their characteristics and heating values, and of their forms obstruct their wider and immediate utilization. Nowadays phytomass fuels share in covering energy consumption by about 25 to 30% on a global scale, by about 5% on West European scale, and by about 15% in Austria and Scandinavia (SLADKÝ 2002). The literature dealing with fibre compression and with porous materials in general (BLAHOVEC, ŘEZNÍČEK 1980) very often refers to the dependence between pressure and volumetric weight of the material. Mechanical properties of phytomass are basic assumptions to find out characteristics of processes of pressing briquettes. From the point of mechanical properties straw presents a rather complicated, very porous and inhomogenous material. The course of phytomass shaping or pressing is mostly impacted by its compressibility (OSOBOV 1970). Compacting phytomass into the form of briquettes (wafers) is one of the basic types of pressing. Briquettes are compressed by high pressure into the shape of full cylinder or prism or in a body with a central alleviating hole with an external diameter larger than 40 mm but lesser than 100 mm, and with specific volumetric mass of about 1,000 kg/m^3 (SLADKÝ et al. 2002). Briquettes are produced when pressing material of suitable granularity in a briquetting (wafering) press (SIMANOV 1995). The pressing into a compact shape facilitates the handling of phytomass as compared to its loose, bulk form. Furthermore, briquetted phytomass is suitable for subsequent technical operations like storing, hauling and burning (PLÍŠTIL 2003a,b). Briquetting can considerably reduce the volume of produced waste which otherwise would present difficulties to be processed. Briquetting results in briquettes having lesser volume than the original material thus offering a produce with higher density (BARTOŠ 2000). A rational utilization of renewable energy resources increases and becomes one of the basic conditions of a sustainable development of agriculture and society. An important area is offered by the utilization of residual biomass. In the agriculture it is above all presented by the by-products of the plant production (ABRAHAM, MUŽÍK 2003).

METHODS

Phytomass is treated by a disintegrator into a finer fraction which falls through sieve mesh of circular cross section of about 15 mm. It concerns following plants: *Sorghum vulgare, Phalaroides arundinacea, Crambe*

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Table 1. Mathematic expression – dependence of briquette density on compacting pressure

Briquette material	Regression equation	Determination coefficient
Sorghum vulgare	$\rho = 17.514\, p_D + 260.02$	$R^2 = 0.9838$
Phalaroides arundinacea	$\rho = 13.542\, p_D + 210.86$	$R^2 = 0.9684$
Crambe abyssinica	$\rho = 37.529\, p_D - 64.153$	$R^2 = 0.8487$
Fectusa pragensia	$\rho = 39.211\, p_D - 998.25$	$R^2 = 0.9829$
Camelina sativa	$\rho = 13.722\, p_D + 187.61$	$R^2 = 0.9352$
Miscanthus sinensis	$\rho = 18.723\, p_D + 198.65$	$R^2 = 0.9238$
Carthamus tinctorius	$\rho = 15.063\, p_D + 315.53$	$R^2 = 0.9542$

Table 2. Mathematic expression – dependence of failure force on compacting pressure

Briquette material	Regression equation	Determination coefficient
Sorghum vulgare	$F = 4.0610\, p_D - 81.557$	$R^2 = 0.9161$
Phalaroides arundinacea	$F = 3.6051\, p_D - 100.25$	$R^2 = 0.8833$
Crambe abyssinica	$F = 0.1933\, p_D - 1.1602$	$R^2 = 0.9998$
Fectusa pragensia	$F = 7.6104\, p_D - 313.32$	$R^2 = 0.9142$
Camelina sativa	$F = 7.1674\, p_D - 260.02$	$R^2 = 0.9426$
Miscanthus sinensis	$F = 10.525\, p_D - 279.78$	$R^2 = 0.9365$
Carthamus tinctorius	$F = 5.3708\, p_D - 107.71$	$R^2 = 0.9187$

abyssinica, Fectusa pragensia, Camelina sativa, Miscanthus sinensis, Carthamus tinctorius. Subsequently the phytomass is compressed into briquettes of a diameter of about 65 mm. Pressing is performed by a briquetting press HLS 50 of Briklis Ltd. The basic parameter for phytomass pressing is moisture. If the moisture content exceeds the limit of 20% then the phytomass in pressing chamber cannot be compacted to the demanded dimension and the briquette disintegrates. Maximum recommended moisture content is up to 15% (PLÍŠTIL 2003a,b). The crops showed following moisture contents in the experiments: *Sorghum vulgare* = 10.95%, *Phalaroides arundinacea* = 11.40%, *Crambe abyssinica* = 15.97%, *Fectusa pragensia* = 10.66%, *Camelina sativa* = 15.37%, *Miscanthus sinensis* = 9.97%, *Carthamus tinctorius* = 15.54%.

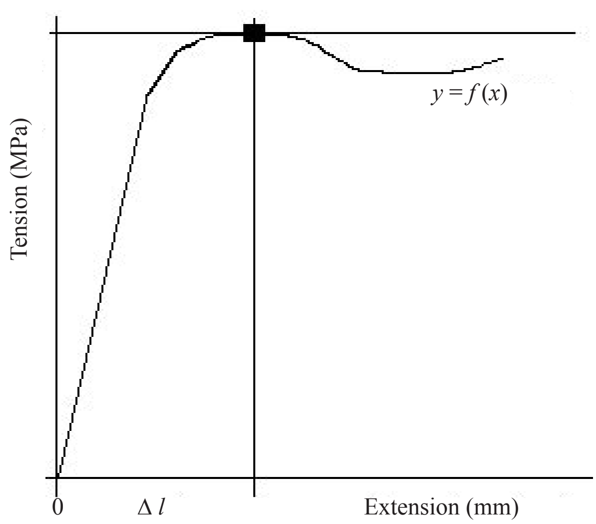

Fig. 1. Graphic progression during fissure testing

The compacting pressures of the briquetting press are chosen in dependence of the input of the pressed material. The compacting pressure amount depends of the material we press and its moisture that does not change within the measurement time. The output diameter of the briquette is 65 mm. The pressing piston has a 140 mm diameter. For certain materials that are not compacted during achievable pressing we must use higher compacting pressures. If the briquette from phytomass is more compacted the necessary breaking force will be higher. The more separated phytomass enters the pressing chamber the longer will be the briquettes and the resistance which increases in narrow parts of pressing matrices pressure will raise the compacting.

The testing of mechanical fissure is carried out according to methods described in research handout (BROŽEK 2001) on universal shredder machinery ZDM 5t (Fig. 1).

The line, that is parallel to axis – specific elongation, intersects the curve of the graphic presentation of the fissure testing. It indicates in which specific elongation Δ1 reaches to the failure of the compacted briquette. During fissure testing the testing body is pressed in one direction between two parallel plates to the condition when it reaches to the briquette crushing.

RESULTS

The graphic values for individual species of energy herbs are moving only in illustrated areas. These areas depend on types of pressed matter and their moisture. The graphic illustration of the dependence of briquette density on compacting pressure is displayed in Fig. 2. The graphic illustration of the de-

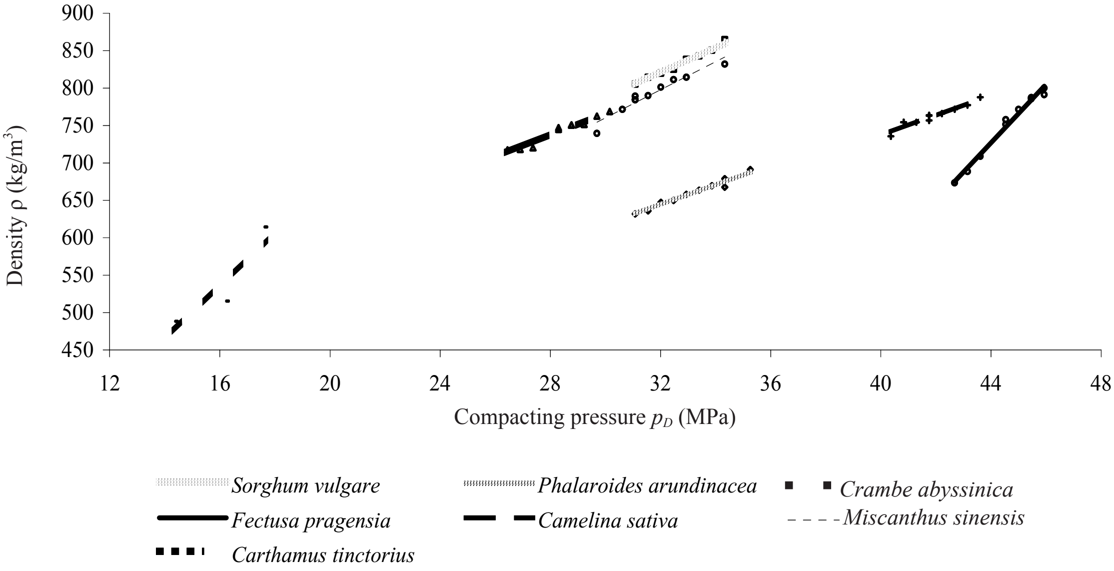

Fig. 2. Dependence of briquette density on compacting pressure

pendence of the failure force on compacting pressure is displayed in Fig. 3.

DISCUSSION

In comparison with the literature (BARTOŠ 2000) where the author measured pressing of briquettes in laboratory (Material and Engineering Technology, CUA) conditions we can judge that he did not reach the same quality of compression of phytomass during pressing with the same compacting pressure. This was reached when utilizing of higher pressures which of course increased pressing costs unnecessarily. Pressed phytomass in real press has better mechanical parameters than pressed phytomass in laboratory conditions. In laboratories are only found dependencies of mechanical parameters without taking respect of difficulty and effectivity of such research. Therefore it is better to devote efforts to measurement on real briquetting presses that have already better developed pressing chambers and are thanks to the research constructed for phytomass pressing.

From the graph results that energy crop – *Crambe abyssinica* was compressed with more effort because it was pressed with seeds which contain oil. During pressing oil was released and prevented briquette cohesion. If these seeds are removed from the given crop we can target to prevent influence of oil on pressing and pressed briquettes will have better mechanical parameters.

Measurement of phytomass resulted in following mechanical values: *Sorghum vulgare*: density 810–870 kg/m^3, failure force 45–59 N. *Miscanthus sinensis*: density 750–850 kg/m^3, failure force 32–82 N. *Fectusa pragensia*: density 680–810 kg/m^3, failure force 11–38 N.

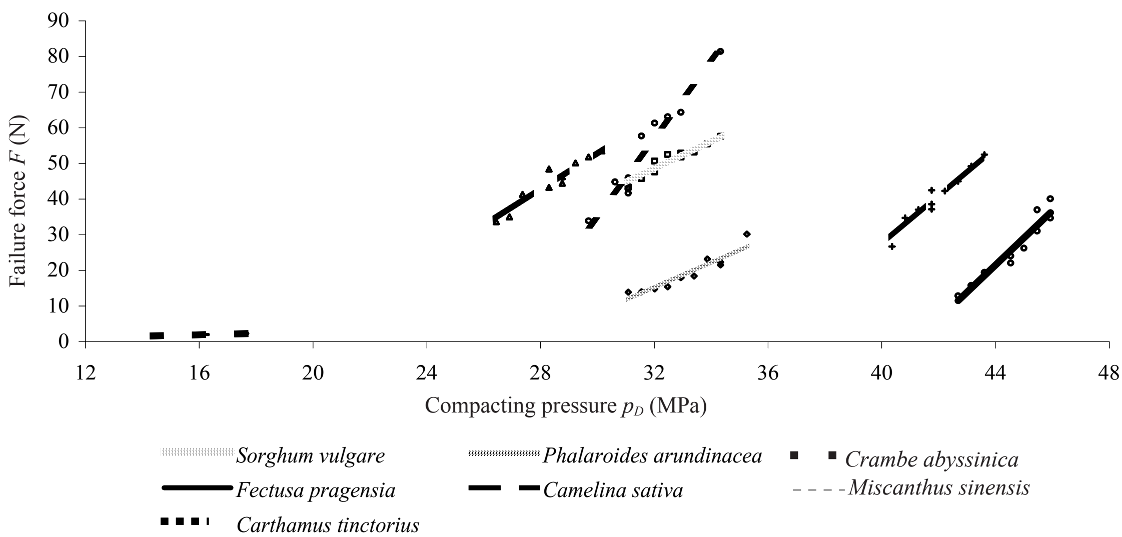

Fig. 3. Dependence of the failure force on compacting pressure

Camelina sativa: density 740–800 kg/m^3, failure force 30–50 N. *Carthamus tinctorius*: density 710–770 kg/m^3, failure force 35–55 N. *Phalaroides arundinacea*: density 630–660 kg/m^3, failure force 11–28 N. *Crambe abyssinica*: density 470–580 kg/m^3, failure force 2–5 N.

CONCLUSION

Measurement of heating briquettes pressed from energy crops resulted in finding that the best pressing crops are: *Sorghum vulgare* and *Miscanthus sinensis*. These energy crops are the best compressible ones have high specific density require heavy force for breaking their integrity.

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Topné brikety z energetických rostlin

ABSTRAKT: Cílem práce je zjištění a vyhodnocení, které energetické rostliny se nejlépe lisují a které se lisují obtížněji. Následuje vyhodnocení mechanických vlastností sedmi druhů energetických rostlin a zjištění mechanických parametrů, které mají vliv na lisování. Mezi vyhodnocené mechanické vlastnosti patří hustota briket a síla, která je potřebná na jejich porušení. Zkoumané energetické rostliny jsou: *Sorghum vulgare, Phalaroides arundinacea, Crambe abyssinica, Fectusa pragensia, Camelina sativa, Miscanthus sinensis, Carthamus tinctorius*. Tyto rostliny jsou před lisováním dezintegrovány na šrotovníku. Velikost frakce je udána velikostí ok síta, kruhového průřezu o průměru 15 mm. Všechny rostliny mají během lisování neměnnou vlhkost a jednotný průměr výstupních briket o průměru 65 mm. Vlhkosti jsou: *Sorghum vulgare* = 10,95 %, *Phalaroides arundinacea* = 11,40 %, *Crambe abyssinica* = 15,97 %, *Fectusa pragensia* = 10,66 %, *Camelina sativa* = 15,37 %, *Miscanthus sinensis* = 9,97 %, *Carthamus tinctorius* = 15,54 %.

Klíčová slova: fytomasa; energetické rostliny; briketování; mechanické vlastnosti; zkouška na rozštěp

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