A fine desintegration of plants suitable for composite biofuels production

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ABSTRACT: In case of pressed composite biofuels production the important part of the production process is the input row materials disintegration. In dependence on disintegrated material properties, disintegration device, grinding stage and technological process there is in practice necessary for disintegration of culm materials 0.5–7% and of wooden species even 0.75–10% of total energetical content of material. A wide range of these figures means that in this sphere of raw materials adaptation can be reached relative high savings through correct choice of technological process and device. The authors of the paper have measured energy consumption of fine disintegration of lignocellulose materials in dependence on particles size and moisture. By the realized measurement of different average size of both input and output particles and consequent statistical evaluation was proved the fiducial energy consumption increase at higher stage of disintegration and higher moisture of the input material. All measurements were carried-out for the grinding mill ŠK 300 and the output particles size was limited by the exchange sieves mesh dimension.

Keywords: disintegration; biomass; biofuels; energy consumption

The main part of the pressed biofuels are lignocellulose materials of plant origin. Properties of the input material are given by requirements of a proper device, usually a pressing mechanism. The pressing mechanism for briquettes and pellets production put high demands on the input particles size. Maximum admissible size of particles is in range of decades of mm^3 for briquette pressing mechanisms and in mm^3 for pellet pressing mechanisms.

This size can be reached in practice by mechanical adaptations. The desintegration is a technology, where basic alternations of machinery and materials using, technology and working organization (Šályová 2000) are made. The dimensional adaptations of wood are usually necessary. Advantage of these operations is mainly in simple manipulation and easier determination and description of such adapted raw material. Nevertheless, mechanical adaptation needs higher amount of energy (Souček 2000).

The lignocellulose materials are highly heterogenous with physical properties changing in dependence upon influence of ambient effects. These effects are mainly temperature, humidity, air flow which are factors having impact on dry matter content in material and velocity of its drying or moisturizing (Kafka 1989).

Each lignocellulose material consists of dry matter s and water (total moisture) W_t^r.

$$s + W_t^r = 100\% \qquad (1)$$

Water content in the lignocellulose materials useable as fuel is lower than 50% (Cenek 2001).

To assess other important properties, we present also instantaneous dry matter content in following points of the article for presentation of measured of laboratory found-out values.

The energy consumption of biomass desintegration was investigated in Sweden in 1989. The tested machines was cone-screw chipper Sasmo HP-30 (Finland), involuted single-disc chunker, research prototype (USDA, Forest Service, USA) and double-disc chunker, research prototype (Sweden). Desintegrated matter was Aspen and Red Maple. Moisture content of desintegrated matter was about 30%. The average energy consumption of desintegration was 0.61 kWh/m^3 (Aspen, average output particle length 6.4 mm); 0.92 kWh/m^3 (Aspen, average output particle length 9.5 mm); 0.92 kWh/m^3 (Red Maple, average output particle length 6.4 mm); 1.19 kWh/m^3 (Red Maple, average output particle length 9.5 mm – Danielsson 1990).

Economy and energy balance of desintegration was investigated in the framework of the research activity of South Bohemia Uversity in České Budějovice (Celjak 1999). The investigated process was the poplar chips production. Cost of chipping (poplar chips, moisture 50%) was 152.00 CZK per ton (energy consumption 71.80 kWh/t). Total cost of chips production (plant production, harvesting, chipping, hauling and storaging) was 1,280.60 CZK per ton. The combustion heat of investigated chips was 18.3 MJ/kg and calorific value of final product (poplar chips, moisture 17%) was 14.7 MJ/kg.

The scope of measurements was to determine the course of energy consumption for crushing of chosen

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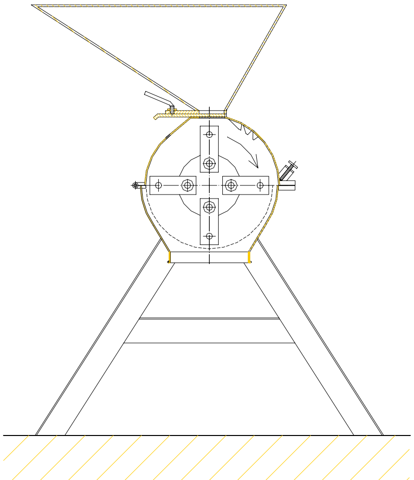

Fig. 1. Schema of grinding mill SK 300 (product of Machine locksmithery Štefan Tuška, Slovakia)

Table 1. Parameters of grinding mill ŠK 300 guaranteed by producer

Height	1,500 mm
Length	1,240 mm
Width	470 mm
Number of hammers	12
Motor input	4 kW
Motor revolution	1,440 min
Grinding mill revolutions	3,600 min
Weight	100 kg
Output	300/500 kg/h

lignocellulose materials suitable for technical-energetical utilization in dependence upon both input and output fraction size. The priority was put on mutual comparison of different materials.

METHODS AND SUBJECT OF MEASURING

Because the absolute value of energy consumption is influenced by properties of the crushing mechanism, only one device for acquisition of all measured values was used.

All measurements was realized by grinding mill SK 300 (Fig. 1). This mill is designed by manufacturer for crushing of corn crops and culm crops.

Consumption of electric power was measured by programmable analysator of electric output and energy PROWATT-3, Chauvin Arnoux. Insertion of material into the grinding mill is manual. Rotor rotating around horizontal axis, mounted perpendicularly to the input hole with hopper is fitted by hammers attached to the rotor by means of pins. Rotor drive provided by V-belt transmission from electric motor. The grinding mill producer provides parameters described in Table 1.

The output fraction size is chosen by the changeable sieve mesh size. For the sieves of diameter 1, 3, 5, 8 and 10 mm. The sieve belting angle is 180º. Grinding mill performance during measuring was 7–30 kg/h depending on sieve mesh diameter and crushed material. For all measurements were determined equal rotor revolutions. Thus the possible mistakes caused by different angular velocity of rotor hammers and transmission efficiency were eliminated.

As perspective agricultural sources of raw materials really useable for production of solid biofuels are

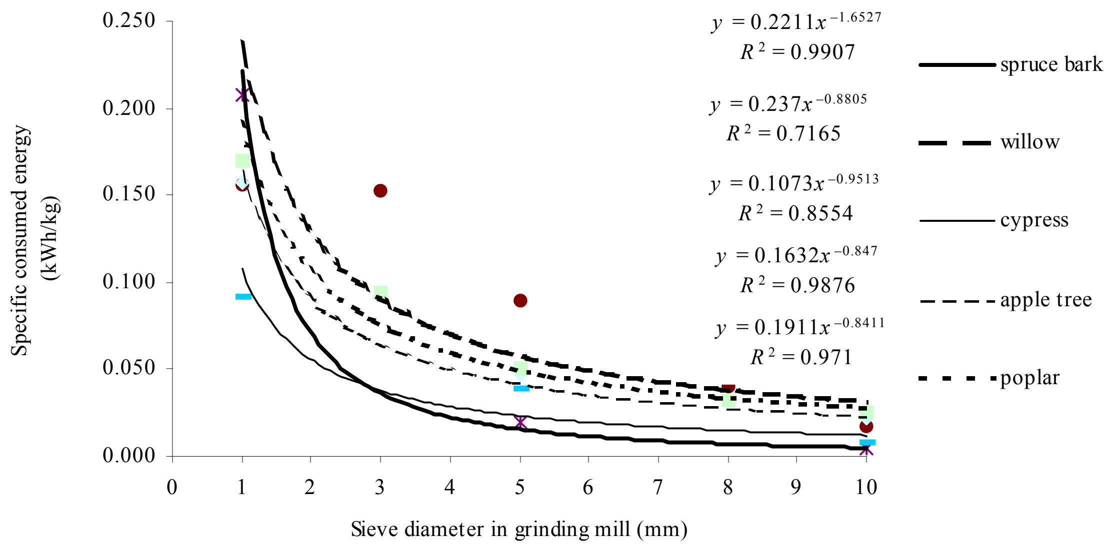

Fig. 2. Specific consumed energy of wood species disintegration

Table 2. Measured materials and their basic parameters

Crushed material	Dry matter s (% wt.)	Heating value Q^r_i (MJ/kg)	Particles size x (mm)
Spruce bark	88.88	14.642	30
Cypress	93.19	16.449	10
Apple tree-cut-out	89.99	16.338	10
Oat straw	86.29	13.688	80
Sorrel	86.91	14.310	30
Rattle grass	91.94	15.224	30
Poplar – chips	89.54	16.081	> 25
Willow – cut-out	88.83	15.620	30
Miscanthus	85.80	15.250	30
Elder-berry	87.78	15.921	30
Knot weed dry	90.82	15.277	30
Knot weed med	80.34	13.231	30

considered raw materials generated particulary in these sectors:

– remains of forestry and wood processing,
– waste and remaining products of crop production,
– purposefully grown crops,
– refuse biomass created within landscape maintenance.

With respect to the practical importance the following materials were chosen.

For the final calculation of energy consumption was counted down the idle input necessary for proper grinding mill drive, thus effect of this factor into final result was removed.

Energy consumption for grinding was related to the dry matter weight in the grinded raw materials.

Desintegration of all raw materials was conducted in two stages. The first stage of disintegration – dimensional preparation of used raw materials was realized by garden grinding mill VIKING GE 115. Energy consumed on the first stage of disintegration has not been included to the proper measuring results. Energy consumption was in the first stage of grinding in interval 3.5–7.3 Wh/kg for individual plants. The only exception is the poplar chips > 25 chipped by mobile board chipping device TOMAHAWK M-P-180 (71 Wh/kg) and consequently graded on sieves by the given fraction size. The second exception is the oat straw which was only chopped by the harvest cutter Claas Jaguar 840 to 80 mm length (17 Wh/kg including harvest from swaths).

Average length of particles after disintegration using individual sieves is presented in Table 3.

All necessary analysis for determination of dry matter, burning heat and screen analysis were carried-out in the

Table 3. Average length of particles after disintegration for individual sieves

Sieve mesh diameter (mm)	Average length of particles after disintegration x (mm)
1	0.660
3	0.896
5	1.260
8	3.220
10	6.662

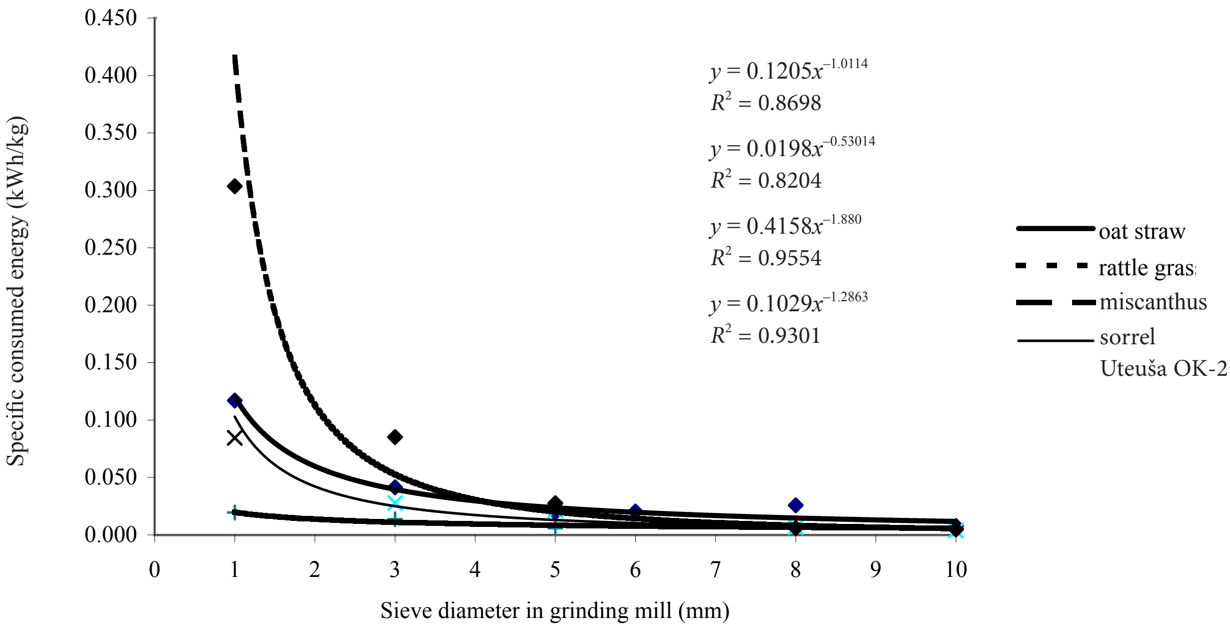

Fig. 3. Specific consumed energy of herbs disintegration

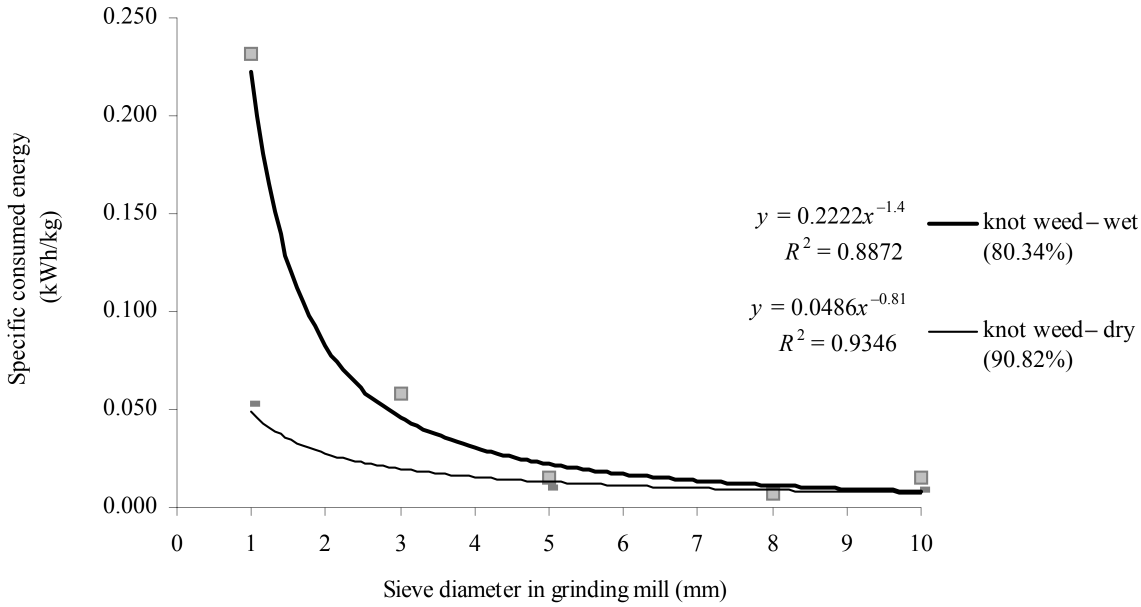

Fig. 4. Specific consumed energy of knot weed (dry) disintegration (90.82% d.m.) and knot weed (wet) (80.34% d.m.)

agro-laboratory of Research Institute of Agricultural Engineering at Prague.

RESULTS AND DISCUSSION

The energy consumption measuring of biomass fine disintegration was carried-out as a part of long-term activity of Research Institute of Agricultural Engineering at Prague focused to research and development of technologies and physical properties of biofuels.

Measured and calculated values are shown in graphs in Figs. 2–5. In accordance with the presumptions the energy consumption is increased by disintegration with reduction of output particles average length (sieve mesh

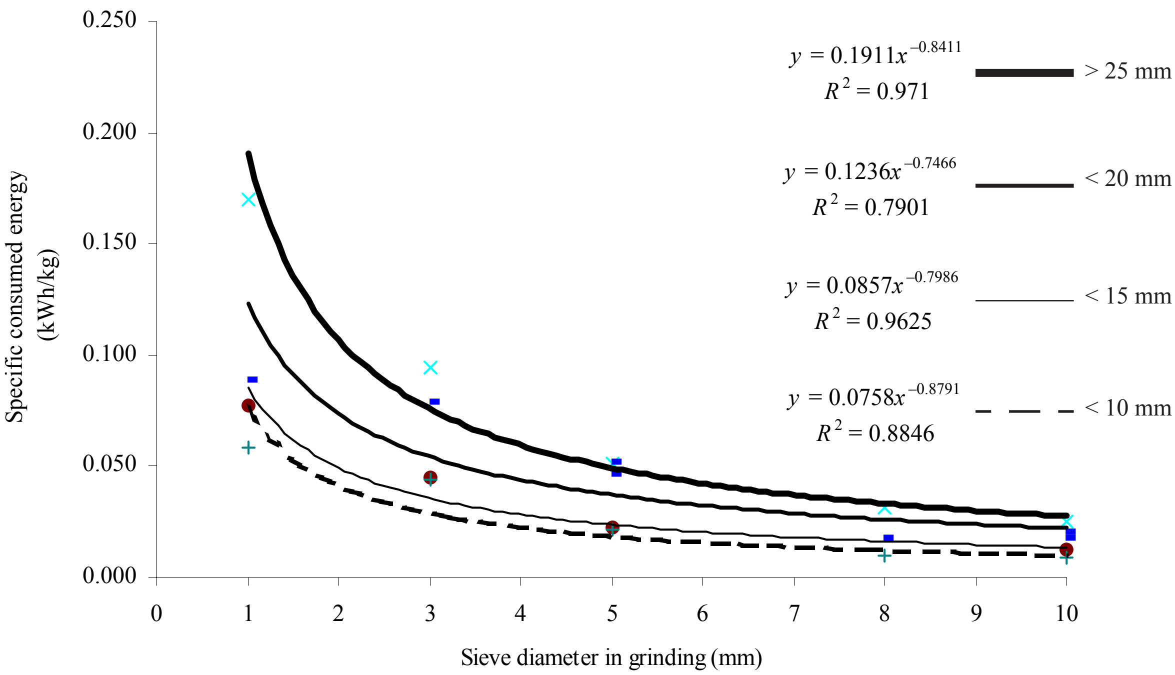

Fig. 5. Specific consumed energy of disintegration of different input fraction of poplar chips (d.m. 89.54%) in dependence on sieve size

diameter), but also with water higher content. When the water content is higher than 12%, then the energy consumption for small mesh diameter is inadequately high.

From Fig. 4 is evident that during grinding by fine sieve at water content decrease from 19.66 to 9.18% the energy consumption of grinding is reduced from 0.232 to 0.053 kWh/kg. For larger sieve diameter (above 5 mm) the energy consumption of disintegration is comparable.

In Fig. 5 is presented energy consumption for different size of input fraction. Individual fractions were acquired by separation of poplar chips by means of sieve separator.

CONCLUSION

By means of practical measurements theoretical presumptions that energy consumption of disintegration increases with reduced size of output particles and growing size of input fraction were confirmed.

- By disintegration to average length of particles 0.66 mm (sieve diameter 1 mm) the energy consumption ranges between 0.9% (rattle grass, d.m. 91.9%) and 13% (miscanthus, d.m. 85.8%) of total energetical content of material.
- By desintegration to average length of particles 6.66 mm (sieve diameter 10 mm) the energy consumption ranges between 0.1% (sorrel, d.m. 86.91%) and 0.5% (apple tree, d.m. 89.99%).
- Resulting course of specific energy dependence on fraction size may be described for every plant in form of individual power function (general function $y = a.x^b$).

References

CELJAK I., 1999. Wood chips production from fast growing woody plants. Farmer, 3/99: 16–18.

CENEK M. et al., 2001. Obnovitelné energie. Praha, FCC Public:

DANIELSSON B.O., 1990. Chunkwood as wood fuel. The IEA Bioenergy Agreement Summary Reports. New York, Elsevier Applied Science:

KAFKA E., 1989. Dřevařská příručka. Praha, SNTL:

SOUČEK J., 2000. Méně tradiční způsoby získávání dřeva jako náhrady běžně používaných surovin. Nový venkov, č. 11: 52–53.

ŠÁLYOVÁ H., 2000. Spracovanie drevnej biomasy pomocou sekačiek. In: Technika a technologie pro nepotravinářské půdy a její udržování v klidu. Sbor. mezinár. veletrhu TECHAGRO, Brno:

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Jemná dezintegrace rostlin vhodných pro výrobu kompozitních biopaliv

ABSTRAKT: Při výrobě lisovaných kompozitních biopaliv je důležitou složkou výrobního procesu dezintegrace vstupních surovin. V závislosti na vlastnostech dezintegrovaného materiálu, dezintegračním zařízení, stupni rozmělnění a technologickém postupu se v praxi jen na dezintegraci spotřebuje u stébelnatých materiálů 0,5–7 % a u dřevin dokonce 0,75–10 % celkového energetického obsahu v materiálu. Široké rozpětí těchto čísel znamená, že v této oblasti úpravy surovin lze správnou volbou technologického postupu a zařízení dosáhnout poměrně velikých úspor. Autoři příspěvku měřili velikost spotřebované energie při jemné dezintegraci lignocelulózových materiálů v závislosti na velikosti částic a vlhkosti. Provedeným měřením při různých průměrných velikostech vstupních a výstupních částic a následným statistickým vyhodnocením byl prokázán předpokládaný nárůst energetické spotřeby při vyšším stupni dezintegrace a vyšší vlhkosti vstupního materiálu. Všechna měření byla provedena na šrotovníku SK 300 a velikost výstupních částic byla dána velikostí otvorů používaných výměnných sít.

Klíčová slova: dezintegrace; biomasa; biopaliva; energetická spotřeba

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