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Česká zemědělská univerzita v Praze
Fakulta tropického zemědělství

Bachelor Thesis

Analysis of Briquetting Press Working Parameters

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ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

Katedra udržitelných technologií

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

Radek Novotný

Trvale udržitelný rozvoj tropů a subtropů

Název práce

Analysis of Briquetting Press Working Parameters

Název anglicky

Analysis of Briquetting Press Working Parameters

Cíle práce

The main objective of this Thesis is analyses of parameters of briquetting press. For meeting the above main objective it is necessary to prepare research schedule and methods of analyses of main briquetting parameters.

The following specific objectivess will be met:
-Gathering biomass with different structures and composed of various organic materials and use it for briquette production and during the briquetting proces register the measured data as needed for press parameters assessment.
-Monitoring the briquetting process and
-Analyzing energy consumption during briquetting.

Metodika

Materials:

Biomass from energy crops and bio-waste (wood residues, sawdust)will be used for briquetting. These materials will be got from Czech University of Life Sciences Prague (Technical Faculty and Faculty of Forest and Wood Sciences).

-Energy crops selected such as: Miscanthus sinensis, Miscanthus giganteus, hemp (Cannabis sativa)

-Bio-wastes to be used: wooden material from trimming trees, such as Sea Buckthorn (Hippophae rhamnoides), pine sawdust.

Methodology in sequence of steps:

1) Studies of relevant references – articles and books on biomass energy use and solid biofuel production.

2) Selected types of biomass collecting and preparing operations for briquetting (fragmenting biomass: either chopping or grinding)

3)preparing briquetting press for experiments (inbuilding tensors and connecting elektricity measuring devices)

Doporučený rozsah práce

25-40, včetně obrazové přílohy

Klíčová slova

briquetting press, briquette, measuring press working parameters

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Doporučené zdroje informací

Andert D., Sladký V., Abraham Z. 2006. Energetické využití pevné biomasy. Praha : Výzkumný ústav zemědělské techniky.

Havrland B., Hutla P., Adamovský D. 2010. Experimental biomass dryer. Institute of Tropics and Subtropics. Prague.

Stupavský V., Holý T. 2010. Brikety z biomasy – dřevěné, rostlinné, směsné brikety. Biom.cz. [Online] 01 01, 2010. [Cited: 02 14, 2015.] http://biom.cz/cz/odborne-clanky/brikety-z-biomasy-drevene-rostlinne-smesne-brikety.

Předběžný termín obhajoby

2015/06 (červen)

Vedoucí práce

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Děkan

V Praze dne 15. 04. 2015

Declaration

I hereby declare that the present Bachelor Thesis “Analysis of Briquetting Press Working Parameters” is my own work and effort. Where all the information sources and literature derived from the published and unpublished references of other authors has been acknowledged in the text and a list of references given.

Prague Apr 17st 2015 ....

Radek Novotný

Acknowledgements

I express my sincerest gratitude to my supervisor, **Prof. Ing. Bohumil Havrland, CSc**., who supported me throughout my thesis with his patience and knowledge and I also thank sincerely my coordinator **Ing. Tatiana Ivanova Ph.D.** for her help and time and finally to my friend **Bc. Tomáš Nergl** for help.

Abstrakt

Neobnovitelné zdroje energie se podílí největším procentem na výrobě energie, vzhledem k jejich vyčerpatelnosti a obnovitelnosti je nutné hledání obnovitelných zdrojů energie jako pevná bio-paliva, vodní energie, solární energie a geotermální energie.

Bakalářská práce se zabývá studiem parametrů briketovacích lisů. Cílem měření bylo zjištění spotřeby elektrické energie v kWh a vliv vstupních materiálů a vlhkosti materiálů na spotřebu energie. Bylo porovnáno několik materiálů a jeich vliv na spotřebu energie. Vyrobené brikety byly o průměru 50 mm a 65 mm. Součástí je též teoretická část, kde je informováno o biomase a samotném briketování.

Klíčová slova: brikety, biomasa, briketovací lisy, spotřeba energie, vstupní materiál

Abstract

Fossil fuels participate on energy production in largest percentage. Fossil fuels are non-renewable energy sources and therefore it is necessary to use renewable energy sources like solid fuels, water energy, wind energy, solar energy and geothermal energy.

The Bachelor Thesis deals with the studies of briquetting press parameters. The Thesis deals with measurement of consumption electric energy in kWh and impacts of input material and moisture content to energy consumption. Several materials were compared and the effect on energy consumption was measured. Briquettes were made with a diameter of 50 mm and 65 mm. The Bachelor Thesis also includes the theoretical part, where information about biomass and briquetting process are presented.

Key word: briquettes, biomass, briquetting presses, energy consumption, input material

Table of Content

List of Tables and Figures

1 Introduction

In present world there is problem with fossil fuels. It is a global problem and problem which depends on various factors such as word wide population growth, the rapid decline in fossil fuel reserves and others. Fossil fuels could not be restored in short time and it is necessary to solve it.

Renewable energy sources are solution of scarcity of fossil fuels. One solution is producing energy from briquettes or pellets combustion. Briquetting and pelletizing technology is one of the renewable technology. The main ingredient in the briquettes or pellets is biomass. Nowadays there is a lot of biological waste from agriculture and industry. It is possible to use waste biomass for briquetting or pelletizing and produce energy from it. Renewable energy is important for sustainable development and it can helps to reduce CO_2. (Havrland, a další, 2013)

Briquettes and pellets are produced by pressing equipment. Briquetting or pelletizing have a number of positive properties, one of them is high density. Briquettes and pellets have high density and their combusting take a long time (about 180 – 240 minutes, but it depends which material is used). Briquetting increases density and caloric value of raw material. (Muntean, et al., 2012)

For briquetting is important to use materials with low moisture content. For drying is possible to use dryer. Dryers and their operations are expensive. Modern method improving the drying technology and change the efficiency of the dryer (Havrland, et al., 2010).

This Thesis is focused on studies of briquetting technologies. The main object deals with study of briquetting parameters. Briquetting parameters as energy consumption, briquetting pressure, density and structure of material. The goal is to calculate how much electricity is needed for briquetting presses in kWh. Today, the most popular types of briquetting presses are extruders (screw press – body of press looks like screw) and piston presses (hydraulic and mechanical).

2 Literature review

2.1 Biomass

One of the alternative ways of replacing fossil fuels is use of biomass. Biomass is all organic matter in the natural form, which is produced by photosynthesis and transformation of solar energy in plants such as trees, herbs, grasses, algae and seaweed. (Andert, et al., 2006). Biomass forms 2/3 of production of renewable energy in Europe. This biomass is made from nearly 80% of wood and residues form wood extraction. The briquettes and pellets from another type of biomass represent only 0.2%. Production from other types of biomass is increasing, because briquetting and pelletizing have many advantages (Murphy, et al., 2013). Biomass is used, because it is CO_2 neutral and it is a good way to decrease the greenhouse effect. The importance of biochemical process in the formation of biomass is that during the growth of biomass, CO_2 is consumed and is replaced by O_2.

Using biomass as source of energy includes the entire set of possible technological ways. There are many ways how to process biomass. For example biogas production, fuels (biodiesel and bio-ethanol), waste heat (eg. from composting), but the simple and most common way is combustion of biomass. The product of combustion is thermal energy. This thermal energy is used for heating or for power generation.

Fig. 1 shows diagram of cycle of dendromass. The energy from biomass has a form of thermal energy. When the biomass is combusted it creates carbon dioxide. This carbon dioxide could be re-captured by plants and the whole cycle repeats.

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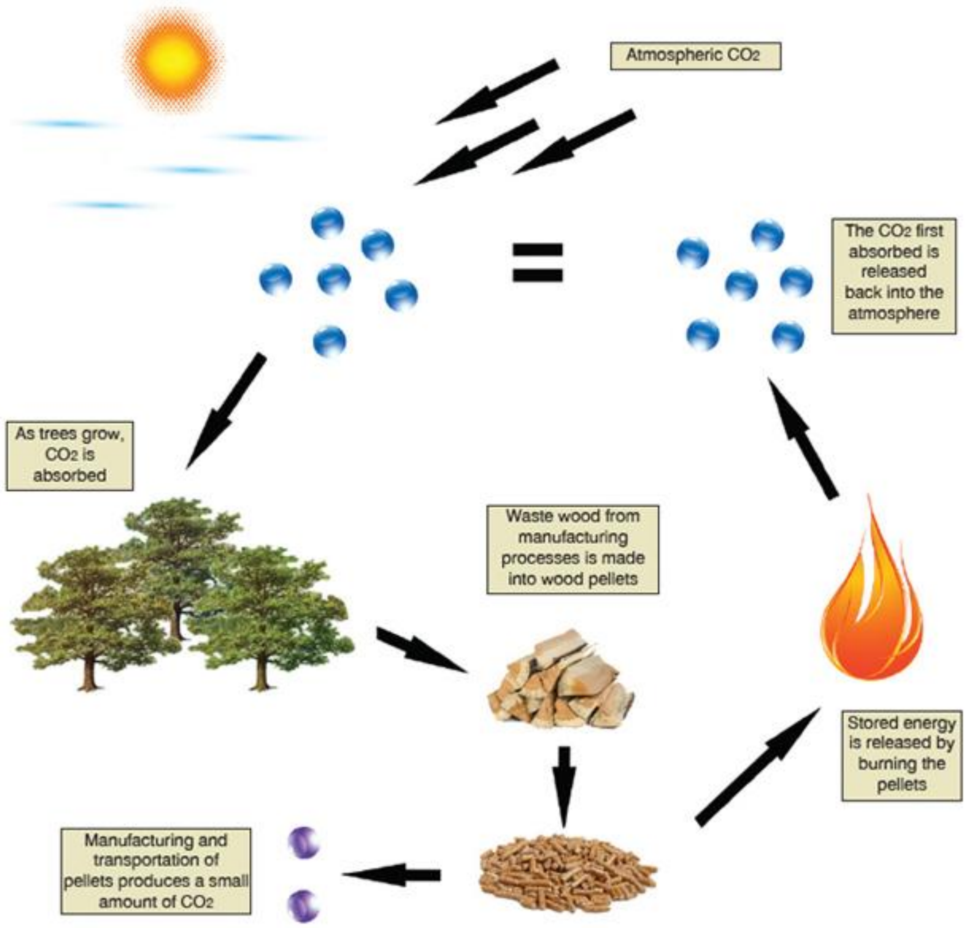

Fig. 1 The cycle of dendromass

Source: Perďochová, (2010)

2.1.1 Distribution of biomass

According to Bechník, (2009) biomass could be classified into several categories

- **Fytomass** – mass from plant production
- **Dendromass** – wood, residues from wood cutting
- **Purposely grown biomass** – fast growing trees or grass
- **Waste biomass**
    - From plant production – straw, residues from cleaning grains, etc.
    - From livestock production – manure, etc.
    - From extraction and processing of wood – sawdust, shaving, wood chips, etc.
- **Biodegradable waste**
    - Municipal waste - food scraps, paper packaging
    - Industrial waste - waste from the paper manufacture, sugar, flour, etc.
    - Sewage from the sewer

2.1.2 Biomass processing

According to Motlík, (2002) the biomass processing could be classified into several categories:

- **Mechanical processes**
  - Cutting
  - Crushing
  - Chipping
  - Briquetting and pelletizing
  - Oil production
- **Thermal processes**
  - Combustion
  - Gasification
- **Chemical processes**
  - Esterification – special type of esterification by refluxing a carboxylic acid and an alcohol in the presence of an acid catalyst.
- **Microbiological processes**
  - Alcoholic fermentation – bio-ethanol production
  - Anaerobic digestion – biogas production
  - Composting – possible use of thermal energy

2.1.3 Energy crops

Cultivation of energy crops for biomass production are essential to biomass production. Plantations with fast growing trees are useful. Less known are energy herbs. It is possible to use these crops for briquetting, pelletizing or bio-gas production. Energy crops are crops which are grown especially for energy application (Laurent, et al., 2015).

Compared with other biomass resources, energy crops can grow on marginal land (sand, industrial waste land). Energy crops have potential advantages for advanced bio-fuel feedstock (Guan, et al., 2010).

Crops for bio-fuel production can have negative effect on food security. The shift in agricultural production from food crops to energy crops can increase food prices (Wijnen, et al., 2015). Cultivation of energy crops can have negative effect on biodiversity. Another problem is with N_2O. Erisman, et al. (2009) indicate that first generation of energy crops will result in increasing N_2O emission from fertiliser use (Erisman, et al., 2009).

Energy crops are categorized as:

Energy herbs- Herbs are non-wooden plants. High productive annual energy crops are: corn, sorghum, sweet sorghum, miscanthus, hemp and some others (Laurent, et al., 2015).

Energy trees- Fast-growing trees cultivated in plantation way. The main goal is to produce biomass with high yield production per hectare. Europe use willows, poplars or alders, but in subtropical and tropical areas are used: acacia, eucalyptuses, subtropical pine and some others (Laurent, et al., 2015).

2.2 Solid bio-fuels

2.2.1 Pellets parameter and types

Pellets are most often manufactured in diameter about 6 mm and length between5 to 40 mm (Stupavský, 2010). Pellets are made from wooden residues like sawdust and wooden shavings.

Pellets are produced by pressing raw dry material without binders or adhesives. Pellets are pressed by pressing machine and this process is called pelletizing. Pellets have high energy density, heat value and excellent transporting and handling properties (Stupavský, 2010).

Calorific value: 16 – 18 MJ/kg

Weight/ volume: up to 850 kg/ m^3

Humidity: maximal 10% (Stupavský, 2010)

Pellets are made from biomass and bio-waste, pellets are produced mostly from wood.

- **Wooden pellets** – Wooden pellets are made without tree bark
- **Pellets from bio-waste**

2.2.2 Briquettes

Briquettes are made of wooden or plant residues by strong compression, this process is called briquetting. From briquetting rise a new type of solid bio-fuels. This fuel quality is ranking between brown and black coal. Briquettes have excellent properties in terms of transporting and handling. Fuels from biomass are used in heater for solid fuels like brown or black coal (Stupavský and Holý2010).

Briquettes are produced by pressing raw dry material. Material is pressed in special briquetting machine without additional mixtures, binders or adhesives. Briquettes are transported either in bags with weight about 10 kg or on pallets with weight up to 1000kg (Stupavský and Holý 2010).

Briquettes have bigger size than pellets; therefore briquettes are not so suitable for automatic combustion, although briquettes have different benefits (Hrázný and Král, 1999):

- Burning of briquettes is slower and more uniformed.
- The functional parts in briquetting press have lower wear and tear.
- Briquetting is cheaper than pelletizing and less demanding on the input material.
- Lower investment demands and energy input.
- Calorific value of briquettes is almost similar to brown coal.
- Ash content is insignificant with no toxicity and without heavy metals.

Briquettes have also disadvantages (Hrázný and Král., 1999):

- Price. Costs of purchasing briquetting lines and energy inputs are expensive.
- Needs of new material throughout the whole year.
- The low quality of source material.

2.2.3 Briquettes in power plants

World is using energy from coal-fired power plants, for example in China is more than 70% energy from coal-fired power plants. In this case renewable energy from biomass briquettes is important. Briquettes can save energy and reduce CO_2 emission (Liu, et al., 2014).

For biomass briquettes combustion is possible to use the same furnace as for black coal. The differences between black coal and briquettes are in gross calorific value. For black coal it is 18, 7 MJ/kg and for biomass briquettes 12, 2 MJ/kg. Briquettes have lower contain of carbon and sulphur than black coal (Liu, et al., 2014).

2.2.4 Briquettes types and parameters

According to Andert, et al., (2010) the briquettes are possible to separate to several groups:

- **Wooden briquettes**
- **Briquettes form leaves**
- **Straw briquettes**
- **Coal briquettes** – Black or brown coal
- **Metal briquettes** – Iron, copper, brass, aluminium, etc.
- **Paper briquettes** –Industry waste or paper from sorted waste (Andert, et al., 2006)

Calorific value: 12 – 18 MJ/kg

Ash content: 0, 5 – 1%

Weight/ volume: up to 1200 kg/ m^3

Humidity: maximal 10% (Stupavský and Holý. 2010)

2.3 Parameters of solid bio-fuels

2.3.1 Water content

Briquettes or pellets with high level of water content have worse combustion properties. When the material is burning, it leads to releasing of large amount of water vapour. This vapour cools the heater element and it causes worse combustion condition (Jevič, et al., 2008).

2.3.2 Ash content

By ash content is possible to show the formation of sediments in combustion chamber and the character of the ash. (Havrland, et al., 2013) Further it is possible to determine elements in the ash. The most important is info, what is the contents of heavy metals and other elements are contained in the ash. Metals and other elements can get into bio-fuels from chemicals (contamination of As, B, Cl, Cr, Cu, Fe, P, Zn), colours (contamination of Cd, Pb, Ti), used tools or machines (contamination of Fe, Cr, Ni), additives (e.g. limestone – contamination of Ca, kaolin – contamination of Si, Al) (Kotlánová, 2009).

2.3.3 Calorific value

Calorific value is necessary for combustion and market value of the product. Calorific value is lower than in black and brown coal or natural gas. (Demirbas, 1999) The calorific value is defined as the amount of heat released in combustion (burn quantity unit of fuel). Combustion products are CO_2 and H_2O and the products are cooled to a standard temperature (298K) corresponding to 0°C. (Kers, et al., 2010).

2.3.4 Mechanical properties

Mechanical properties are significant for storage and combustion. They are considered as quality parameters. Density and mechanical strength is necessary for properties of final briquette. These properties depend on the used material, structure of briquette, water content and compaction pressure (Plíštil, et al., 2005). For density is specific value $\rho > 700$ kgm^{-3}. For the wooden briquettes are in Czech Republic regulations for briquettes requirements in the Decree 357/2000. This decree is specifying fuel quality from the point of view of atmosphere protection, but do not present demands for mechanical properties. Briquette mechanical strength is characterized by the force necessary to destruction (Brožek, 2001).

Strength of briquettes is attained by material which is used. It means that material inside the pressing chamber works as counter pressure and briquettes are compressed by higher pressure (Brožek, 2001).

2.4 Briquetting parameters

Parameters of the briquetting process are required for final properties of briquettes. Parameters are possible to divide into three groups:

- Material parameters
- Technological parameters
- Structural parameters (Šooš and Křižan 2005)

2.4.1 Material parameters

Material parameters are properties of the material: moisture content, fraction largeness, chemical composition of material, binders and etc. (Matúš and Křižan, 2010)

2.4.1.1 Material moisture

Natural material for briquetting may absorb water from the surrounding microclimate. The content of moisture is necessary for briquettes production, because when the moisture content will be high briquettes may crack or crumble. The traditional method of removing moisture is to use dryers. Dryers request the data equilibrium of moisture content of the concerned biomass (Singh, 2004).

Moisture has to be as low as possible, generally in the range 10 – 15%. High moisture content will pose problems. Huge moisture content can lead to reduction of the combustion temperature (Chen, et al., 2009). Briquettes with high moisture content may cause mold or presence of bacteria and this has negative impact, during combustion, on the environment or even on human health (Jevič, et al., 2008).

It is possible to distinguish critical and optimal humidity value in production of solid bio-fuels. The best mechanical properties of solid bio-fuels have optimal moisture value in the range 4 - 10%. The critical value is in the range 10 - 15% and this value could destroy the resulting product (Ivanova, 2012).

The excess of moisture can be removed by using special dryers and the moisture content may be influenced, to a certain extent, by appropriate harvest time (Rehman, et al., 2012). Moisture content of final briquette is determined by laboratory dryer. The sample has to be weighed before inserting into the dryer. The sample is removed and weighed again. The own calculation is the difference of the two weights.

2.4.1.2 Particle size

The maximum allowable particle size for briquetting is in tens of mm, for pelletizing in units of mm (Souček and Maloun, 2003). An important component of the technological process is disintegration, which has the function of creating smaller particles. Particle size can be divided into rough disintegration (the output particle size is in centimetres) and into fine size (the output particle size is in millimetres) (Slavík ml., et al., 2006).

For the quality of briquettes is necessary to improve the material input size. Briquettes from crushed waste material have lower quality, than briquettes from sawdust. Briquettes with smaller fraction are more compacted. The crushed wood should form only certain part of raw material and the rest should be in form of sawdust and wooden shavings (Muntean, et al., 2012).

2.4.1.3 Binders

Binders are used for improving mechanical properties of briquettes or pellets. As binders is possible to use cellulose, hemicellulose[1], lignin, crude protein, starch or crude fat. As a binder can be considered even water. Water acts as film type binder. Between the particles are binding forces. These forces can act through two binding mechanisms: 1) bonding without a solid bridge, and 2) bonding with a solid bridge between particles (Kaliyan and Morey, 2009). Solid bridge helps to bond the particles. Solid bridges can be developed by diffusion of molecules from one particle size to another. These properties need high pressure and temperature (Oladeji and Enweremadu, 2012).

[1] Hemicellulose = neutral detergent fiber (NDF) – acid detergent fiber (ADF)

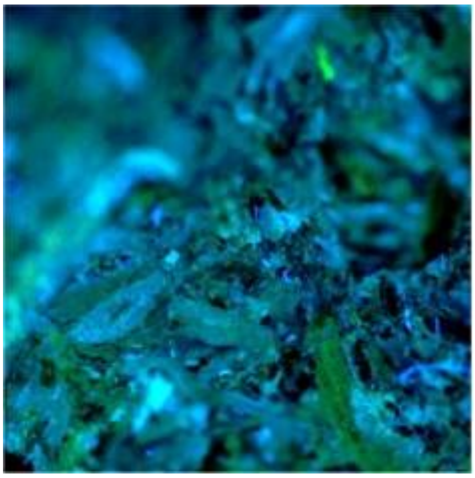

Fig. 2 Scan from electron microscopy (magnification at 600×) and UV - Auto - Fluorescence (magnification at 145×). The green or yellow-green fluorescence represents protein compounds. The brilliant blue or bluish-white fluorescence represents lignin. Briquettes were prepared with pressure 150 MPa and the material is corn stover.

Source: Kaliyan et al., (2009)

2.4.1.4 The influence of material briquetting

For briquetting is necessary to know, which material is used and structure of the material. In briquetting process are differences between materials like paper and wood, but there are also differences among deciduous and coniferous trees (Křižan and Matúš, 2009).

Material from different type of wood has typical density. The density affects the mechanical and physical properties. Input material with higher density, will predict better briquette compaction. Wood density is influenced by moisture content, width of annual circles, proportion of the summer wood and age of the tree (Křižan, et al., 2009).

Type of material is necessary for pressure in briquetting chamber, paper scart is less slippery than wooden waste and it means that paper briquettes have better quality. Wooden waste is more slippery and in this case it means the pressure in the chamber is low, thus briquettes have lower quality, than paper briquettes (Brožek, et al., 2012).

2.4.2 Technological parameters

Technological parameters are pressing temperature, compacting pressure, holding time, pressing speed and pressing way. These parameters are possible to be achieved through the compaction according to compacting machine possibilities.

Križan et al. (2010) designed an experiment, which deals with dependencies between technological and material parameters. Functional dependence is expressed by the equation,

$$\rho = f(p, T,\ w_r, L)\ \ (kg \times dm^{-3})$$

Where: ρ - briquettes density ($kg.dm^{-3}$), T - pressing temperature (ºC), w_r - relative material moisture, p - axial compacting pressure (MPa), L - fraction (mm) (Križan, et al., 2010).

2.4.2.1 Pressing temperature

Pressing temperature belongs with compacting pressure in briquetting process, it has the effects on quality of final briquettes. Pressing temperature is significant for lignin excretion from cellular structure. Lignin is released under temperature and this temperature has to be reached in briquetting process (Križan, et al., 2009).

Pressing temperature has positive influence on briquette density. Chou, et al. (2009) made a research about briquettes from rice straw and rice bran. Experiment showed the importance of pressing temperature on the final briquette. Research shows that the briquettes made at temperature more than 90 °C have higher density than briquettes made at room temperature. Briquettes which are prepared at higher temperature are more compacted (Chou, et al., 2009).

2.4.2.2 Compacting pressure

Compacting pressure has influence on the strength of final briquettes. The quality of briquettes is increasing with increasing pressure in briquetting chamber (Križan, et al., 2009). Compacting pressure depends on type of briquetting press. Compacting pressure can be higher, which is related to higher power consumption.

Compacting pressure can be lower, but the pressing temperature has to be higher. That means, when the temperature is higher, final briquettes will have similar quality as high compressed briquettes (Kers, et al., 2010).

2.4.2.3 Holding time

Holding time is connected with compacting pressure. Li (2000) made a research about effect of pressure and holding time. In his study was used hydraulic press with maximal pressure 138 MPa and different holding times ranging between 0 to 60 sec. Experiment shows that holding pressure was more effected at lower pressure than at high pressure. From this study follows that compacting pressure is more necessary than holding time. Holding time at high pressure is negligible. (Li, 2000)

2.4.3 Structural parameters of briquetting press

Properties of briquetting chamber are indicated by structural parameters. The successful pressing of high quality briquettes has to fulfil all briquetting parameters (pressing temperature, material moisture, compacting pressure and fraction largeness). Achieving better quality of briquettes is possible to be improve by changing of some structural parameters. Major structural parameters are (Križan, et al., 2010):

- diameter of pressing chamber
- length of pressing chamber
- conicalness of pressing chamber
- friction coefficient between chamber and pressing tool
- length of cooling canal

Geometry of pressing chamber is important for briquettes compaction, but analyses about description of compacting process and briquetting press parameters are not widely spread. The diameter of pressing chamber has a significant effect on the properties of stamping and wear of working parts (Križan, et al., 2010).

2.4.3.1 Briquetting chamber

Briquetting presses have different pressures in briquetting chamber. Higher compaction pressure causes higher density of briquettes. On **Fig. 3** are explained pressures and length of compacted briquette in closed pressing chamber. Križan, et al. (2010) published the list about testing the impact of length of compacted briquette H.

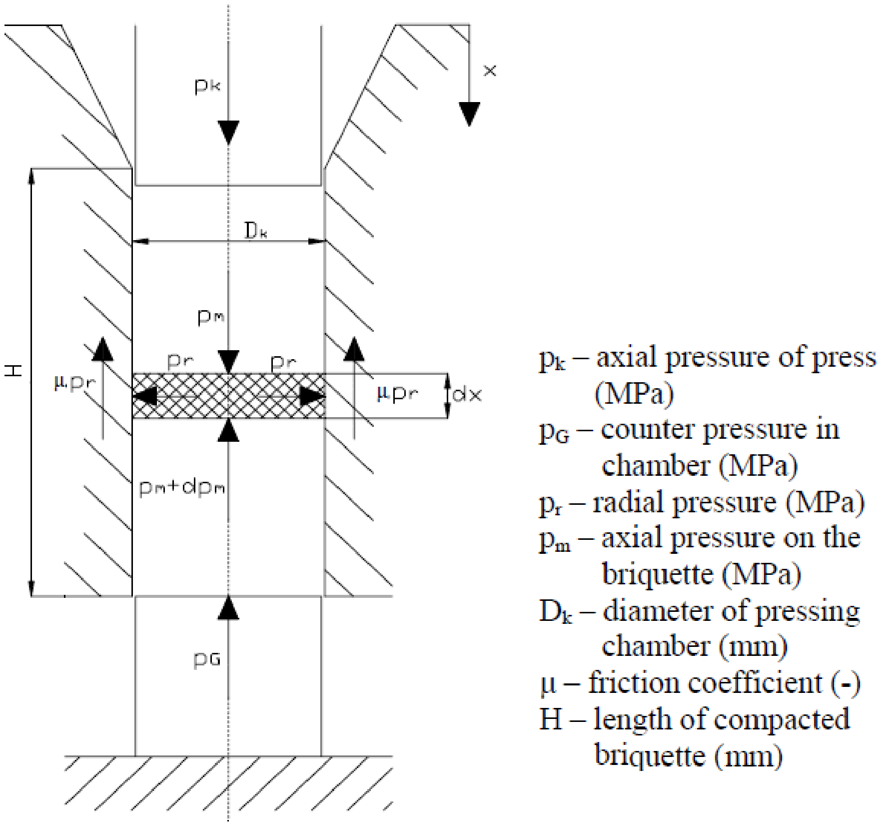

Fig. 3 Pressing condition in closed pressing chamber.

Source: Križan, et al.,(2010)

Maximal compacting pressure p_k depends on pressing chamber length, shape and material slippery. Equation shows relation between axial pressure p_k and counter pressure in chamber p_g. Friction coefficient and length of pressing chamber provides counter pressure at compacting. This model could calculate the optimal length of pressing chamber. (Križan, et al., 2010).

$$p_G = p_k \times e^{\frac{4 \times \lambda \times \mu \times H}{D}} \ (MPa)$$

2.4.3.2 Conicalness of the briquetting chamber

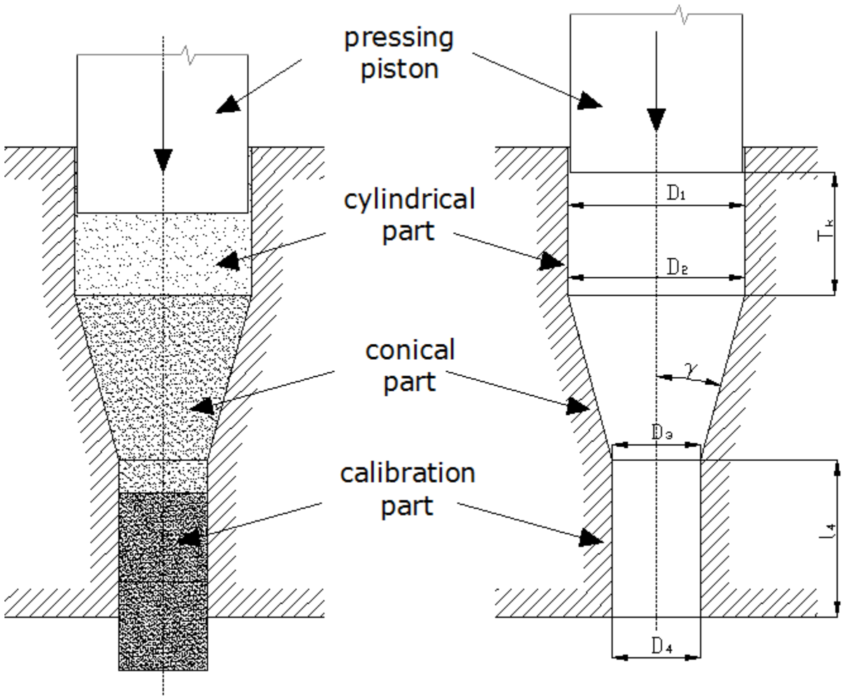

Fig. 4 Main parts of a conical pressing chamber.

Source: Križan, et al., (2010)

This parameter can help with final briquette density and reduce power consumption. Conditions in the briquetting chamber are very complicated. Briquetting chamber has normally cylindrical shape, but it starts to be replacing by conical pressing chamber. Simple scheme with part of conical pressing chamber is shown on **Fig. 4**. The conical part which is used for material compressing by shape of briquetting chamber.

2.5 Presses used for briquettes production

Briquetting is executed by briquetting presses. Briquetting is a most popular and widely spread technology of material compacting. Briquetting technology uses mechanical and chemical properties of materials to prepare biomass into compact briquette. Briquetting is high pressure compacting process. (Križan, 2009) Biomass for briquetting is better than paper, metal or industry waste, because biomass contain lignin – which is a natural binder. (Kers, et al., 2010)

2.5.1 Screw press and piston press technologies

Briquetting presses could be divided into three categories according to principal of their function. Presses are: Mechanical piston, Hydraulic piston, Screw presses

	Piston press	Screw extruder
Optimum moisture content of raw material	10-15%	8-9%
Output from the machine	in strokes	continuous
Density of briquette	1 000 – 1 200 kg/m^3	1 000 – 1 400 kg/m^3
Combustion performance of briquettes	not so good	very good
Homogeneity of briquettes	non-homogeneous	homogeneous

Table 1 comparison between screw and piston press

Source: Andert, et al., (2006)

Mechanical presses (piston) - This type of press is working on the principle of a crank mechanism with large flywheel. The piston presses are characterized by the highest pressure in a briquetting chamber. Performance of this type of presses is about one tone per hour. Briquettes have cylindrical or hexagonal shape (Andert, et al., 2006).

Hydraulic presses (piston) – Hydraulic presses are working with less pressure in the compression chamber. This press could produce less briquettes per hour than mechanical presses. The performance of these presses is between 0.05 and 0.5 ton per hour. Hydraulic presses are suitable for pressing herbs, sawdust or mixtures. Briquettes from this type of presses have lower cohesion. (Andert, et al., 2006).

Screw presses – These presses work with turning screw press in compression chamber. Performance is around 0.5 ton per hour. Briquettes coherence is very good because the pressure and material friction on the screw heats the lignin which acts as binder. Briquettes from these presses have stiff lignin on the surface which is like wax. This wax is protecting the briquette from moisture. (Andert, et al., 2006)

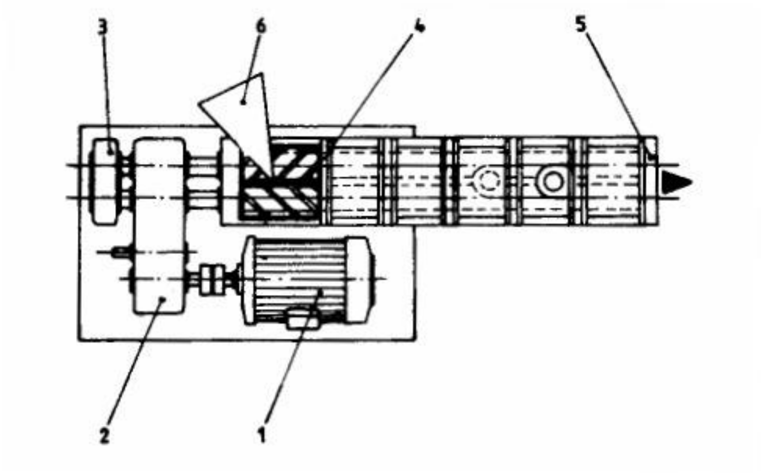

Fig. 5 Diagram shows the twin screw press for briquetting straw. 1. Electric motor 2. Gears 3. Main bearing 4. Screw press 5. Matrices output calibration.

Source: Sladký (1992)

2.5.2 Briquetting process

The operations of the piston press and the crew press are similar, but crew press technology was developed later and the process could be changed. The first point in briquetting process is biomass and preparation biomass for latest briquetting. Crushing can be omitted, because some raw material do not need to by crushed (wood sawdust). (Grover, et al., 1996)

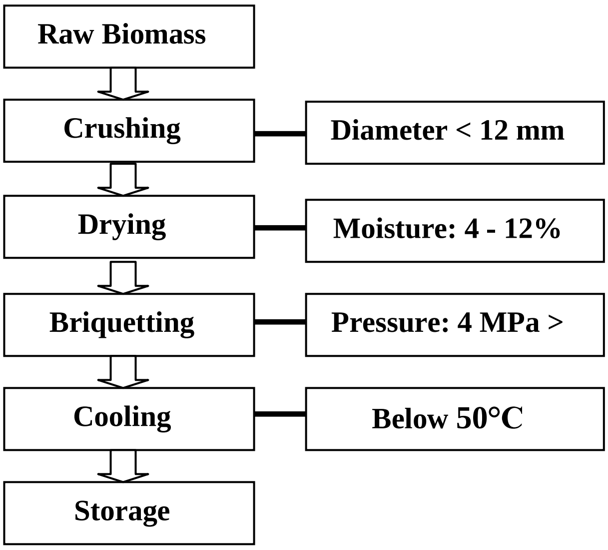

Fig. 6 Briquetting process.

Source: Author, (2015)

2.6 Power consumption in the briquetting process

The power consumption is specific parameter, because power consumption is related with economic factor. Mechanical (piston), hydraulic (piston) and screw press have different energy consumption. Another factor is structure and type of the material. Piston presses have specific energy consumption between 44 to 70 $kWht^{-1}$. Different is screw press (extruder), which consume about 83 – 132 $kWht^{-1}$ and up to 180 $kWht^{-1}$ (Ivanova, et al., 2013). Energy consumption is more than 10kW higher than in piston presses (depends on the model).

Table 2 Comparative characteristics of briquetting presses.

Press Mark	C.F Nielsen BP – 3200	Briklis Brikstar 400	EB – 350	Briklis Brikstar 50	SBM - 15
Type of press	Piston mechanical	Piston hydraulic	Screw extruder	Piston hydraulic	Screw extruder
Performance, kg·h-1	400 – 600	360 – 420	350 – 400	50	100 – 150
Power intake, kW	22	28	49. 57	5.4	18
Specific energy consumption $kWht^{-1}$	44	70	132.18	108	180

Source: Ivanova, et al., (2013)

To create the fuel briquette a lot of energy needed. **Fig.7** shows the two types of power consumption process. The process (A) has just one input of energy for collecting and transporting, and then biomass is converted into energy by the burning process (burning of raw material). But the process (B) has two energy inputs. First one is the same, but the second one is densification process. Densification process involves drying, shredding, briquetting. This process needs costly equipment and energy sources (Sakkampang and Wongwuttanasatian, 2014).

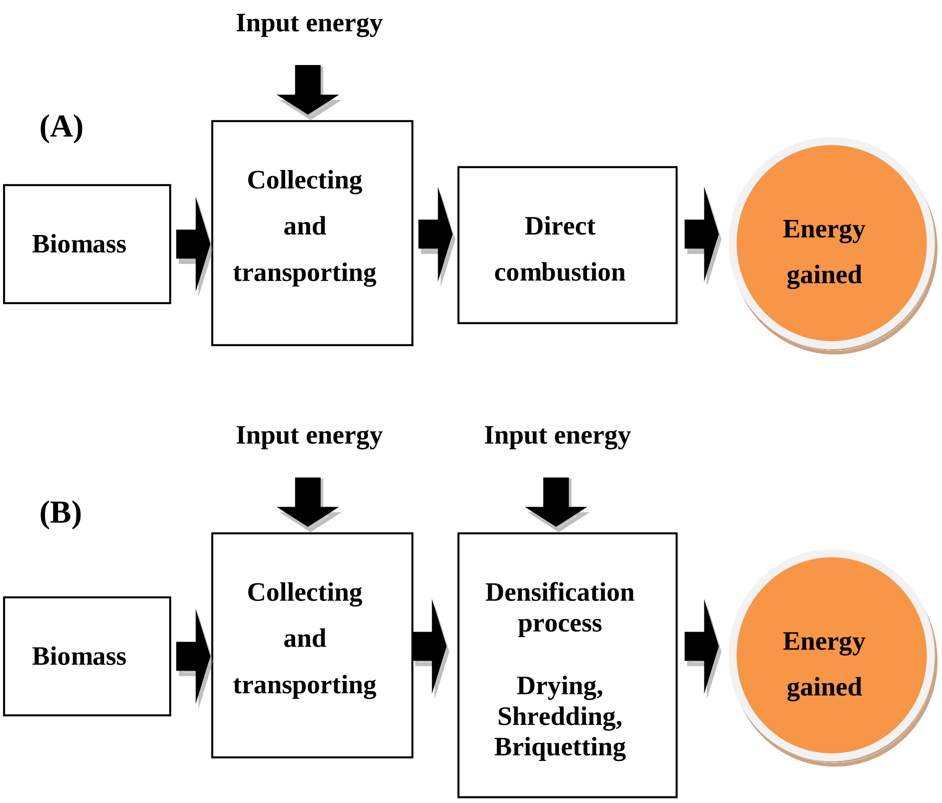

Fig. 8 Conversion of biomass to energy diagram.

Source: Sakkampang, et al., (2014)

3 Aims of the Thesis

The main objective of this Thesis is to analyse briquetting press parameters. In order to obtain the main aim the following specific objectives are set:

- Collection of biomass with different structure and use of this biomass for briquettes production and data collecting

- Monitoring of briquetting process and analysis of electric energy consumption during the briquetting.

4 Material and Methodology

4.1 Material

In practical part was used for briquetting biomass from energy crops (Miscanthus, industrial hemp) and bio-waste (wood residues, sawdust). Materials were provided by Faculty of Tropical AgriSciences and Technical faculty. Materials are from Czech University of Life Science Prague.

4.1.1 Input material

Two types of material were used in this Thesis - energy crops and wooden material. Miscanthus (*Mischanthus giganteus L.)* and industrial hemp (*Cannabis sativa L.*) were selected as energy crops, because of their different raw structure. Miscanthus has rough structure, whereas the structure of industrial hemp is more fibrous (industrial hemp is textile herb). Sea buckthorn (*Hippophae rhamnoides*) and pine sawdust were selected as wooden material. Sea buckthorn is in form of woodchips, but the structure can be contaminated by leaves or other bio-waste. Sawdust is a mixture of pine (approximately 90%) and spruce (ca. 10%). Sawdust was selected due to its lignin contain.

4.2 Methodology of literature review

The main background for elaboration of literature review were articles from scientific databases ScienceDirect and Scopus regarding to briquetting. Articles were searched by key words: briquetting presses, briquettes, power consumption, input material and biomass. Scientific articles from Czech and international sources were used in Thesis. Bibliography is listed at the end of the Thesis in the References. Literature review contains information about biomass, briquettes and briquetting parameters.

4.3 Methodology of practical part

4.3.1 Material crushing

For material disintegration was used the crusher type Green Energy 9FQ40-5610 with engine input 5.5 kW. Crusher produce 500 - 800 kg per hour. Biomass materials were crushed into two fractions: 8 mm and 12 mm.

4.3.2 Moisture content

Determination of moisture content was processed according to the applicable standard CSN EN 14774-1: method of drying in drier. The Drier UFE 500 - MEMMERT was used for measurement. Materials were divided into two samples of wet material and were weighed in beakers with different masses. Samples were dried for eight hours and temperature was 105 ° C. After drying, samples were removed and weighed again. The moisture content in percentage was defined by using equation:

$$\omega = \frac{(m_w - m_d)}{m_w} \times 100\ [\%]$$

$\boldsymbol{\omega}$–moisture content (%)

$\boldsymbol{m_w}$–wet material weight (g)

$\boldsymbol{m_d}$–dry material weight (g)

Weight of material has to be calculated without beaker. Difference between the weight of beaker with material (wet and dry) and the weight of the empty beaker is calculated.

4.3.3 Briquetting

Briquetting was accomplished on two types of briquetting presses. Briquetting presses are from Briklis Company (Briklis, Malešice, Czech Republic). **Brikstar CS25** with power input 4.4 kW, briquette diameter 50 mm and the hopper 0.7 m^3. **Brikstar 30 - 12** with power input 4.4 kW, briquette diameter 65 mm and the hopper 1m^3 (Briklis, 2011). Other technical specifications are similar.

Table. 3 Technical parameter of briquetting presses **Brikstar CS25** and **Brikstar 30 - 12.**

Press type	**Brikstar CS25**	**Brikstar 30 - 12**
Energy output	20 - 40 kg/h	20 - 40 kg/h
Diameter	50 mm	65 mm
Power consumption	4,4 kW	4,4 kW
Input material moisture	8-15 hm%	8-15 hm%
Briquettes density	900 – 1100 kg/m3	900 – 1100 kg/m3
Operation pressure	180 bar (18MPa)	180 bar (18MPa)
Operation temperature	60 °C	60 °C
Control voltage	400 V	400 V
Device power supply	24 V	24 V
Noise level	77 dB	77 dB
Running time of the press	1 inning - limited by oils temperature	1 inning - limited by oils temperature

Source: Briklis, (2015)

4.3.4 Determining of energy consumption

Energy consumption was measured at the Czech University of Life Science (Prague, Suchdol) and Research Institute of Agricultural Engineering (Prague, Ruzyně). In Engineering Research Institute the biomass was briquetted in Brikstar 30 - 12 (diameter 65 mm), In Czech University of Life Science was used Brikstar CS25 (diameter 50 mm).

Determining of power consumption is implemented by electrometer (16A, 380V). The electrometer was collecting data in kWh. Measurement of electric energy was performed in order to determine electric energy consumption. Two types of measurements of power consumption were made with two types of briquetting presses.

The first measurement was conducted on Brikstar 30 - 12 (diameter 65 mm). The power consumption was deducted from electrometer (in kWh) after 60 minutes, the time is necessary for the measurement accuracy. Time could not be less than 30 minutes, when it is less the measurement is erroneous. Before own measuring the material was weighed for later calculation.

The second measurement was made with two different times; times were 40 minutes and 60 minutes. These measurements were conducted on Brikstar CS25 (diameter 50 mm) and Brikstar 30 - 12 (diameter 65mm). In measurement, which was implemented at time 40 minutes, were made four readings each 10 minutes and for time 60 minutes were made six readings each 10 minutes. These measurements were more accurate.

5 Results and Discussion

Briquettes were made from various materials. Presses from Briklis Company in Malešice were used for briquetting. The test estimates the power consumption in briquetting process.

5.1 Results

5.1.1 Power consumption

Table 4 Effect of material moisture and type of material for power consumption.

Material	Moisture (%)	Briquette diameter (mm)	Power consumption (kWh)
Cannabis sativa L.	8.82	65	1.9
Miscanthus x giganteus L.	9.91	65	2
Hippophae rhamnoides L.	14.50	65	1.1

Source: Author (2015)

Table 4 show three types of materials and their influence on power consumption. Sea buckthorn (*Hippophae rhamnoides L.)* has raw structure as wooden chips, but power consumption is lower, compared to other materials which can be caused by material moisture (14.50%). Miscanthus (*Miscanthus x giganteus L.)* has highest power consumption (2kWh) with moisture (9.91%).

The samples of industrial hemp (*Cannabis sativa L.*) and Miscanthus (*Miscanthus x giganteus L.)* have almost similar moisture content (industrial hemp 8.82 and Miscanthus 9.91) and power consumption (industrial hemp 1.9 kWh and Miscanthus 2 kWh). This measurement proved that the moisture content have influence on power consumption.

Company Briklis (Malešice) has stated in the technical data section that the engine has performance 4.4 kW for briquetting press Brikstar 30 - 12 with diameter 65mm. This engine has theoretical power consumption 4.4 kWh, but measurement showed that the power consumption is not more than 2 kWh.

M. Kolarikova (2014) and her team calculated the average power consumption for industrial hemp on briquetting press Brikstar 50 - 12 (power input 5,4 kW). The average power consumption was 1.94 kWh (Kolarikova, et al., 2014), different presses for briquettes production were used and the power consumptions were similar (1.94 kWh and 1.9 kWh). Power input of Brikstar 50 - 12 is higher than in presses which were used in this Thesis. This comparison shows that the power consumption depends on type of material.

According to the result of Mani S. et al,. (2005) moisture content has influence on power consumption. Briquettes were made from corn stover with different moisture content (5, 10, 15 %). As briquetting press was selected the piston press (pressure 15MPa). Corn stover with moisture content 15% had lowest power consumption (3.9 kWh). In this Thesis the sea buckthorn had lowest power consumption (1.1 kWh), but the moisture content was 14.50%. (Mani, et al., 2006).

Table 5 Miscanthus (*Miscanthus x giganteus L.)* and moisture content 9.91%, the reading every 10 minutes. (Time is 60 minutes)

Time (minutes)	Diameter 50mm	Diameter 65 mm
10	0,5	0,4
20	0,5	0,3
30	0,4	0,4
40	0,4	0,3
50	0,4	0,4
60	0,4	0,3
Total	**2,6**	**2,1**

Source: Author, (2015)

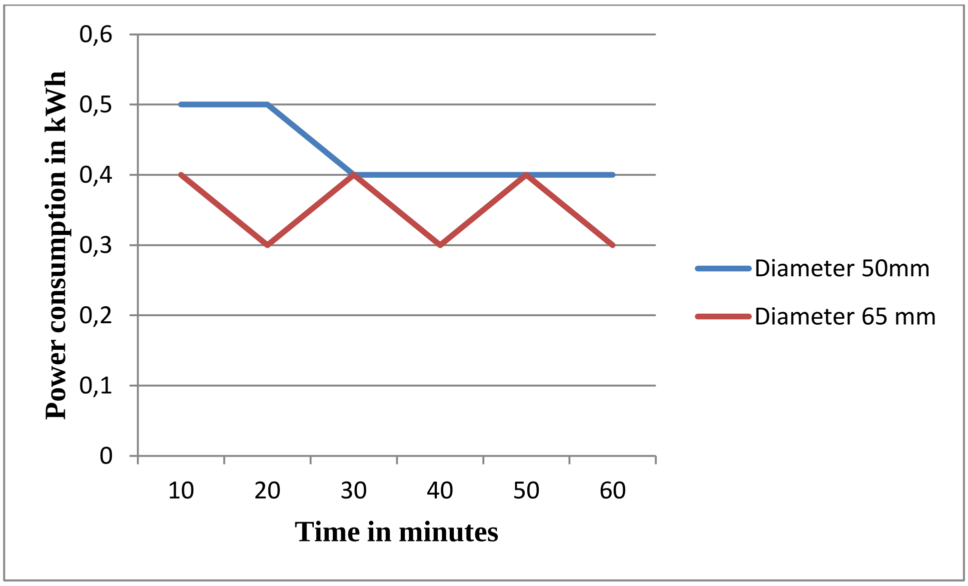

Fig. 9 Comparison of energy consumption for material Miscanthus (*Miscanthus x giganteus L.)* with diameter 50 mm and 65 mm.

Source: Author, (2015)

Table 5 and **Fig.8** shows comparison between two diameters 50 mm and 65 mm. This experiment tried to detect the differences between the presses Brikstar CS25 with diameter 50 mm and Brikstar 30 - 12 with diameter 65 mm. Experiment showed, that briquetting with diameter 65 has lower power consumption, than diameter 50 mm. The difference of this two diameters is 0.5 kWh which is minor difference, but in this measurement was used just 28.7 kg of raw material for diameter 65 mm and 31kg for diameter 50 mm. Material weight can improve the accuracy of measurement.

R.N. Singh (2006) made the experiment with production of 35 mm and 60 mm briquettes. Scientific paper contains the comparison between diameter 35 mm and 60mm and their power consumption. Briquettes were made from groundnut shell. Power consumption per tonne of briquettes 35 mm was 67 kWh and for 60 mm briquettes it was 56 kWh. R.N. Singh (2006) stated that power consumption was increasing due to reduction in production rate with 60 mm briquettes.

Table 6 Pine wood sawdust and moisture content 10.35%, the reading every 10 minutes. (Time is 40 minutes)

Time (minutes)	Diameter 50mm	Diameter 65 mm
10	0,4	0,5
20	0,4	0,4
30	0,4	0,5
40	0,5	0,4
Total	**1,7**	**1,8**

Source: Author (2015)

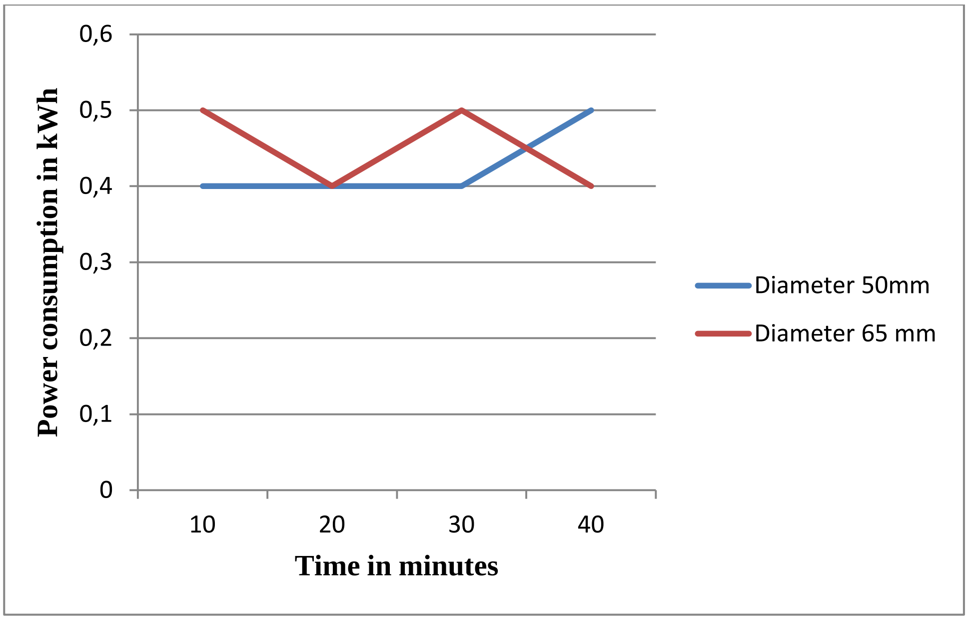

Fig. 10 Comparison of energy consumption for material pine sawdust with diameter 50 mm and 65 mm.

Source: Author (2015)

Table 6 and **Fig. 9** show comparison between two diameters 50 mm and 65 mm. As material was used wood sawdust - mixture of pine (approximately 90%) and spruce ((ca.) 10%) with moisture content 10.35%. Measurement was performed for 40 minutes with readings every 10 minutes. For wood sawdust were made just four readings, because of lack of material. Experiment of power consumption did not indicate the significant difference between diameters 50 mm and 65 mm. Wood sawdust has almost similar power consumption in both measurements.

Muntean A. (2012) and his team made an experiment with particle size of input material. The material which has small particles are joined and pressed better, but they also face to various types of deformation. Wood sawdust is soft material and deforms easily than others wooden materials. Wooden material can also secrete the lignin under the pressure temperature. (Muntean, et al., 2012)

6 Conclusion

Nowadays the renewable energy sources are used more than before, because the fossil fuel will be depleted in few years. Briquetting technology is one of the ways to replace the fossil fuels. Briquetting technology has a lot of advantages, one of them is more efficient combustion of briquettes. The other advantages are storability, transporting and manipulation with final briquettes. The main goal of briquetting is to prepare fuel with higher density and higher gross calorific value than raw material.

The aim of literature review was to inform about briquetting process, materials which are used, briquetting technologies and briquetting parameters.

The research was focused on power consumption in briquetting process. Overall, five types of raw material was used for briquetting. As materials were used pine sawdust, hemp (*Cannabis sativa L.)*, Miscanthus (*Miscanthus x giganteus L.)* and sea buckthorn (*Hippophae rhamnoides L.*). Those materials were used for power consumption measuring. Materials pine sawdust and Miscanthus were measured on two types of briquetting presses (diameter 50 mm and 65 mm), this measurement was focused on differences between these types of briquetting presses. The rest of materials were produced with diameter 65 mm.

Sea buckthorn (*Hippophae rhamnoides L.*) had the lowest power consumption (1.1 kWh, diameter 65 mm). It is caused by moisture content, moisture content of sea buckthorn was 14.50 %. Vice versa, higher power consumption had pine sawdust (2,7 kWh, diameter 65 mm), but the measurement was implemented at time 40 minutes. Overall, every material had almost the same power consumption. It can be caused by small amount of material or inaccuracy of electrometer (one decimal place on display). Recommendation for next experiments is to use more material for briquetting and measure over a longer time.

7 References

Andert David, Sladký Václav, Abraham Zdeněk. 2006. Energetické využití pevné biomasy. Praha : Výzkumný ústav zemědělské techniky: 59-63

Bechník B. 2009. Biomasa - definice a členění. tzbinfo. Available at http://www.tzb-info.cz/5641-biomasa-definice-a-cleneni: Accessed 21-02-2015.

Briklis. 2011. Briketovací lis BrikStar CS 25, 50. [Cited: 03 05, 2015.] http://www.briklis.cz/briketovaci-lis/cs/#product-tabs=obecne_informace: Accessed 03-05-2015.

Brožek M. 2001. Briketování nekovového odpadu. Sborník z mezinárodní konference XIV Diamatech. 2001: 84-87.

Brožek M, Nováková A, Kolářová M. 2012. Quality evaluation of briquettes made from wood waste. Res. Agr. Eng. 58: 30-35.

Demirbas A. 1999. Physical properties of briquettes from waste paper and wheat straw mixtures. Energy Conversion & Management 1: 437 - 445.

Erisman JW, Grinsven H, Leip A, Mosier A, Bleeker A. 2009. Nitrogen and biofuels; an overview of the current state of knowledge. Springer Science+Business Media 86: 211-223.

Grover D, Grover, Mishra K,. 1996. Biomass briquetting: technology and practices. Food and Agrciculte Organization of the United nations 46.

Guan Y, Ma Y, Zhang, K. 2010. Co-pyrolysis behaviors of energy grass and lignite. Energy Conversion and Management 51: 1060-1064.

Havrland B, Hutla P, Adamovský D. 2010. Experimental biomass dryer. Institute of Tropics and Subtropics 43: 19-28.

Havrland B, Ivanova T, Lapczynska K, Kolarikova M. 2013. Comparative analysis of bio-raw materials and biofuels. Engineering dor rural development 25: 541-544.

Hrázný J, Král P. 1999. Využití dřevních a jiných lignocelulozových odpadů. Brno: Mendelova zemědělská a lesnická univerzita 93.

Chen Ln, Xing Li, Han L. 2009. Renewable energy from agro-residues in China: Solid biofuels and biomass briquetting technology. Renewable and Sustainable Energy Reviews 13: 224-232

Chou Ch, Lin S, Lu W. 2009. Preparation and characterization of solid biomass fuel made from rice straw and rice bran. Fuel Processing Technology 90: 980-987.

Ivanova, T. 2012. Research of Energy Plants Processing to Solid Biofuels. Dissertation thesis. Praha: Czech university of life sciences Prague, 142p.

Ivanova, T, Muntean A, Havrland B, Pobedinsky V. 2013. Theoretical modelling of the briquetting process with different pressing equipment. Agronomy Research 11: 47-52.

Jevič P, Hutla, P, Šedivá Z. 2008. Udržitelná výroba a řízeni jakosti tuhých paliv na bázi agrárních bioproduktů: Faktory ovlivňující kvalitu tuhých biopaliv a potenciál biomasy a biopaliv. Metodická příručka Mze ČR, 42-53.

Kaliyan N, Morey R, V. 2009. Natural binders and solid bridge type binding mechanisms in briquettes and pellets made from corn stover and switchgrass. Bioresource Technology: 101: 23-26.

Kers J, Kulu P, Aruniit A, Laurmaa V, Križan P. 2010. Determination of physical, mechanical and burning characteristics of polymeric waste material briquettes. Estonian Journal of Engineering 16: 307–316.

Kolarikova M, Ivanova, T, Havrland B, Amonov K. 2014. Evaluation of sustainability aspect – energy balance of briquettes made of hemp biomass cultivated in Moldova. Agronomy Research 2: 519-523.

Kotláková, A. 2009. Testování biomasy a výrobků z biomasy (pelet a briket) určených ke spalování. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/testovani-biomasy-a-vyrobku-z-biomasy-pelet-a-briket-urcenych-ke-spalovani: Accessed 2015-02-23

Križan P. 2009. Wood waste compacting process and conception of presses construction. Dissertation Thesis. Bratislava : FME STU: 56p.

Križan P, Šooš Ľ, Matúš M, Svátek M, Vukelic D. 2009. Evaluation of measured data from research of parameters impact on final briquettes density. 9th Internation Conference.

Križan P, Šooš Ľ, Matúš M. 2010. Optimalisation of briquetting machine pressing chamber geometry. Machine design.

Křižan P, Matúš M. 2009. Vplyv niektorých druhov drevných materiálov pri briketovaní a peletovaní. Sborník příspěvků ze semináře „Energie z biomasy X“.

Laurent A, Pelzer E, Loyce C, Makowski D. 2015. Ranking yields of energy crops: A meta-analysis using direct and indirect comparisons. Renewable and Sustainable Energy Reviews. 2015: 46: 41-50.

Li Y. 2000. High-pressure densification of wood residues to from an upgraded fuel. Biomass and Bioenergy 19: 177-186.

Liu Yi, Wang X, Xiong Y, Tan H, Niu Y, 2014. Study of briquetted biomass co-firing mode in power plants. Applied Thermal Engineering 63: 266-271.

Matúš M, Křižan, P. 2009. Konštrukčné faktory v procese zhutňovania biomasy. Sborník příspěvků ze semináře „Energie z biomasy X“.

Mani S, Tabil, GL, Sokhansan S. 2006. Specific energy requirement for compacting corn stover. Bioresource Technology 97: 1420–1426.

Motlík, J. 2002. Biomasa pro energii (2) Technologie. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/biomasa-pro-energii-2-technologie: Accessed 2015-03-12

Muntean, A, Ivanova T, Havrland B, Pobedinsky V. 2012. Comparative analysis of methods for fuel biobriquettes production. Egineering for rural development: 496 - 499.

Murphy F, Devlin G, McDonnell, K. 2013. Miscanthus production and processing in Ireland: An analysis of energy requirements and environmental impacts. Renewable and Sustainable Energy Reviews 23: 412-420.

Oladeji JT, Enweremadu C. 2012. The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes. International Journal of Energy Engineering 2: 22-27.

Perďochová M. 2010. Vliv samozahřívání pevného paliva z biomasy na kvalitu paliva a bezpečnost jeho skladování. Bachelor Thesis, p47.

Plíštil, D, Brožek M, Malaťák J, Roy A, Hutla P. 2005. Mechanical characteristics of standard fuel briquettes on biomass basis.

Rehman, M, Rashid N, Saif A, Mahmood T, Han J. 2012. Potential of bioenergy production from industrial hemp (Cannabis sativa):Pakistan perspective. Renewable and Sustainable Energy Reviews 18: 154-164.

Sakkampang C, Wongwuttanasatian T. 2014. Study of ratio of energy consumption and gained energy during briquetting process for glycerin-biomass briquette fuel. Fuel 115: 186-189.

Singh RN. 2004. Equilibrium moisture content of biomass briquettes. Biomass and Bioenergy 26: 251-253.

Singh RN, Bhoi PR, Patel SR. 2006. Modification of commercial briquetting machine to produce 35 mm diameter briquettes suitable for gasification and combustion. Renewable Energy 32: 474-479.

Sladký V. 1992. Využití fytomasy k vytápení zemedelských objektu. Studijní informace ÚVTIZ 1.

Slavík ml. J, Hutla P, Kára J. 2006. Vliv složení směsi na vlastnosti topných pelet. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/vliv-slozeni-smesi-na-vlastnosti-topnych-pelet: Accessed 2015-02-20.

Souček J, Maloun, J. 2003. Využití kladívkového drtiče při výrobě pevných biopaliv. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/vyuziti-kladivkoveho-drtice-pri-vyrobe-pevnych-biopaliv. Accessed 2015-02-20.

Stupavský V, Holý T. 2010. Brikety z biomasy - dřevěné, rostlinné, směsné brikety. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/brikety-z-biomasy-drevene-rostlinne-smesne-brikety. Accessed 2015-02-14.

Stupavský V. 2010. Pelety z biomasy - dřevěné, rostlinné, kůrové pelety. Biom.cz. Available at http://biom.cz/cz/odborne-clanky/pelety-z-biomasy-drevene-rostlinne-kurove-pelety. Accessed 2015-02-14.

Šooš L, Križan P. 2005. Analyze of forces interaction in pressing chamber of briquetting machine. Proocedings of the 11. International Conference TOP 11: 299-306.

Wijnen J, Ivens W, Kroeze C, Löhr A. 2015. Coastal eutrophication in Europe caused by production of energy crops. Science of The Total Environment 511: 101-111.

8 Annex

Figure 1. Technical parameters of briquetting press Brikstar CS25

Figure 2. Electrometer

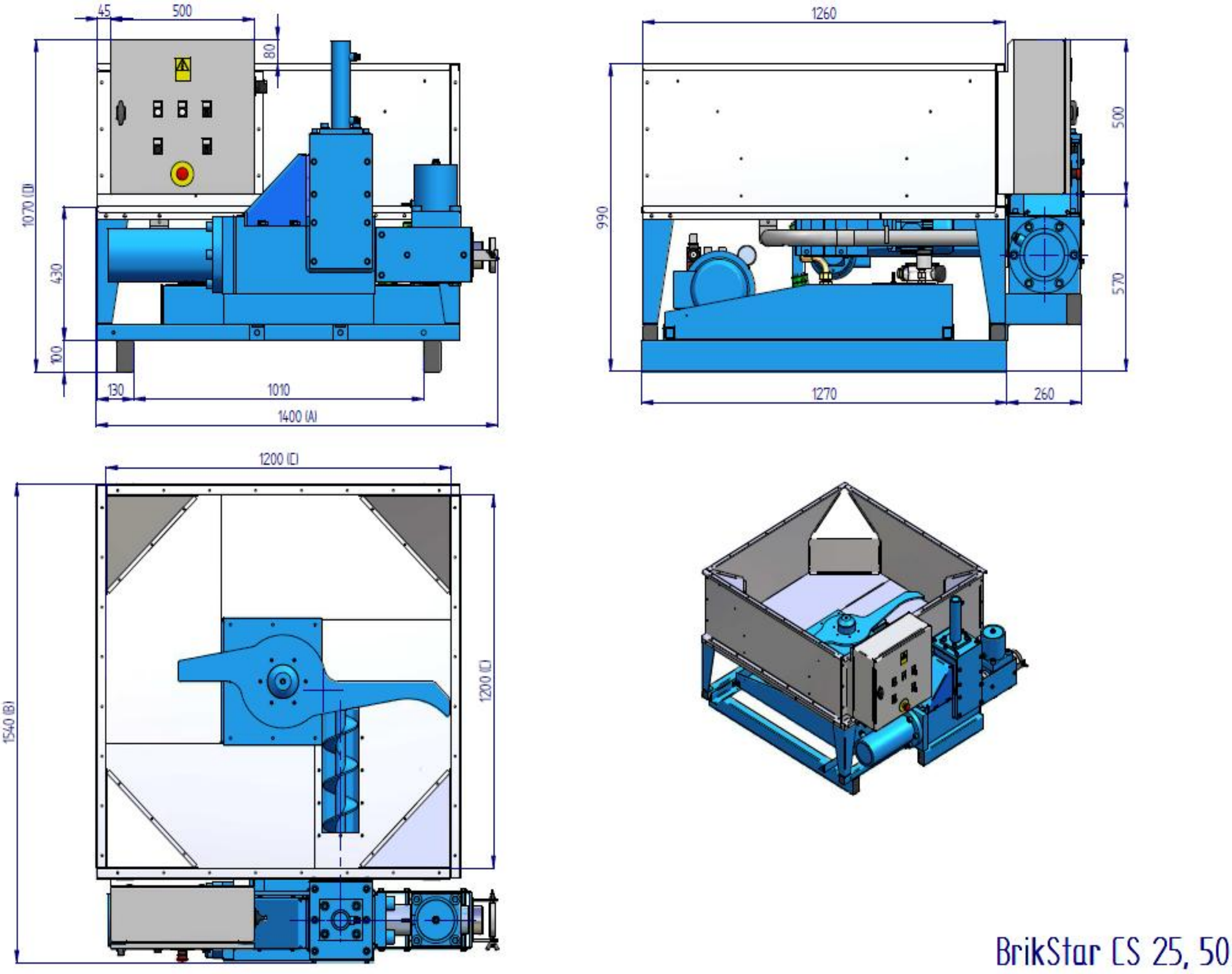

Figure 1. Technical parameters of briquetting press Brikstar CS25

Source: Briklis (2011).

Figure 2. Electrometer

Source: Author, (2015).