PELLETIZING LIGNOCELLULOSES BIOMASS

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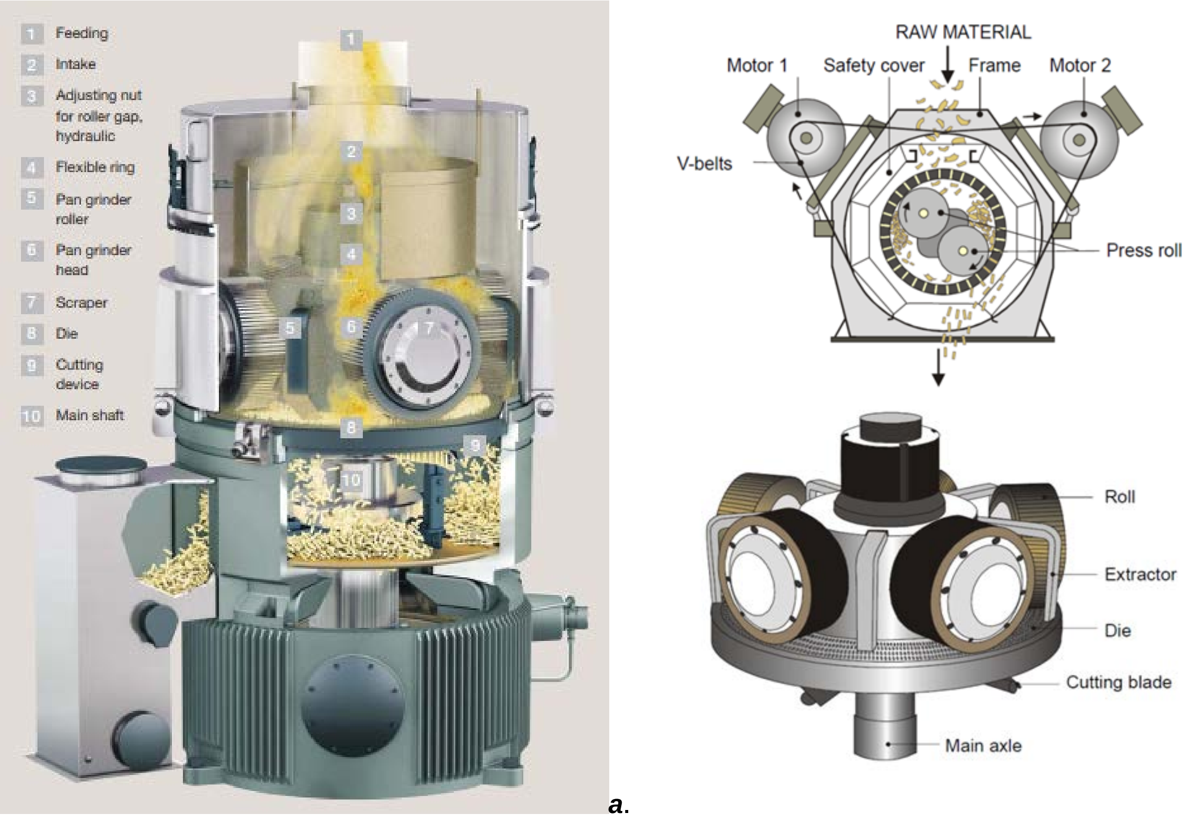
Abstract:
The paper aims to describe the working principle of an experimental press machine for pelletizing of lignocellulosic materials and its use, in order to obtain pellets with superior characteristics. The main stress is put on the pelletizing process, but also on the pellet characteristics. The adoption of experimental variant with a plane matrix was made considering the construction simplicity. The three types of pellets obtained on the installation had got good characteristics, respectively in the case of beech pellets a density of 1039kg/m^3, an ash content of 1.9% and a calorific value of 20.627MJ/kg. The final conclusion of the paper is that a simple experimental press machine with a plane matrix always leads to the production of high quality pellets, with lower costs and investments.

Key words: *press machine; pelletizing; density; ash content; calorific value.*

INTRODUCTION

Continuous depletion of fossil fuel resources (Stelte *et al*. 2012), led to search and discovery of other solid fuels, resulting from lignocellulosic biomass, such as briquettes and pellets. Of these, pellets are high performance renewable fuels, which contribute to the reduction of harmful emissions to the environment. Another advantage of using pellets is that they concentrate raw lignocellulosic biomass, from an average biomass bulk density of about 200kg/m^3 at an average pellet bulk density of 600kg/m^3 (Stelte *et al*. 2011, Stelte *et al*. 2012, Ekman 2015, Samuelsson *et al*. 2009). Pellets are reconstituted engineering materials. They have a homogeneous structure and moisture content, and the moisture content is not changed due to the wrapping in sacks of about 15kg each. All studies show a continuous increase in pellet production, both for the European Union and North America (McKendry 2002, Garcia *et al*. 2018). The target of European Union in the field of emission reduction is that the renewable fuel must to rich 20% from total combustible by 2020 (Calderon *et al*. 2017, Alakangas 2005). The pelletisation is usually done by the extrusion process, namely by forcing the ligno-cellulosic material through some calibrated holes. The holes are executed on a plate matrix, on which the material is ordered (PellCert 2012), and two chuck rolls are pushed on top, pressing the material over the holes (which are provided with truncated holes that help penetrate the material into the channels and compact it). In the second case, the matrix with holes has the shape of a circular crown, inside which it usually presses two rollers, which extrude the ligno-cellulosic material through holes (Fig. 1.).



a. *b*. *c*.

Fig. 1.
Press machine of pelletizing (adaptation from Amandus Kahl (2018) and Selte et al. 2012): a - installation; b - sketch of circular pressing; c - sketch of plane pressing.

The pelletizing was inspired by the briquetting process (with a piston or a screw, at high pressures), as is seen in Fig. 2. Pellets have two dimensions such as: diameter of 6-10mm and length of 5-30mm. Moreover, the European standard limits the length of the pellets to a maximum of 5 times their diameter. After pressing, the pellets are cooled, passed through a sieve to remove debris and loaded into tight polyethylene bags. Making pellets by pressing has a higher productivity than briquetting, because more pieces are produced at a single tact. The pelletizing temperature obtained from the friction between the lignocellulosic material and the moving parts of the press is at least 80-120°C. Temperature of pelletizing always depends on the pressure on the raw material as is seen in Fig. 2b.

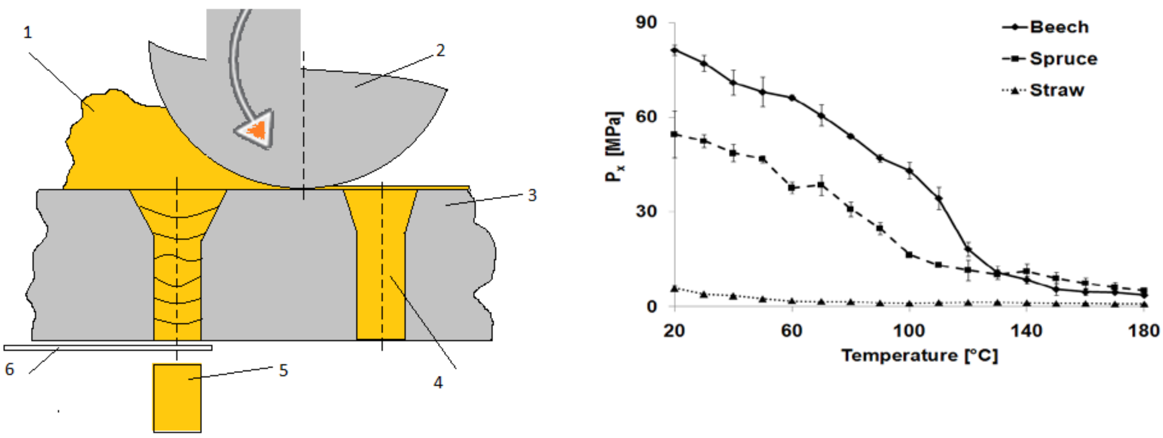


Fig. 2.
Sketch of pelletizing principle (a) and temperature of pelletizing (b) (adaptation from Frodeson et al.): 1-raw material; 2-roller press; 3-matrix (die); 4-holes; 5-pellets; 6-cutter.

OBJECTIVE

The main aim of the paper is to find a simple experimental pelletizing machine on regard to obtain pellets with superior characteristics.

MATERIALS AND METHOD

The experimental installation used for realize pellets was made by Kronpellet Brasov SRL Romania and had a capacity of less than 400kg/hour, and a rotation speed of 120rot/min. It consists organologically of an electric drive motor 1, an electric panel 2 provided with a starter electronic system, a coupling 3, an oil inlet for the reducer 8, a support foot 9 of the entire installation, a pellet exhaust sieve 7, the matrix press 6 and the funnel feeder 5 (Fig. 4, 5, 6, and 7).

Fig. 4.
Installation for pelletizing: 1-motor; 2-electricpanel;3-coupling; 4-oil inlet; 5-feeding funnel; 6-matrix press; 7-outlet with sieve; 8-reducer; 9-chassis.

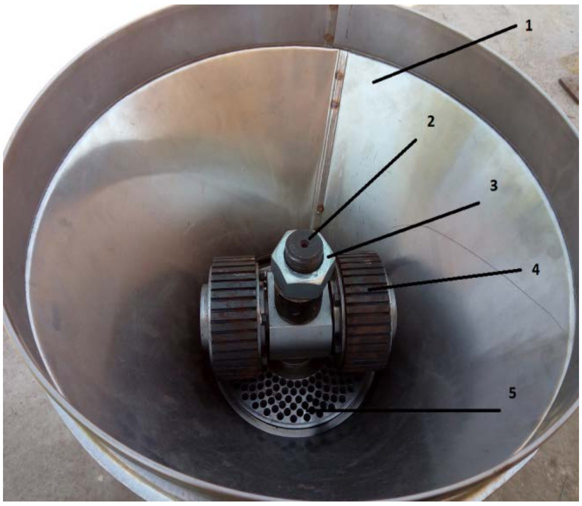


Fig. 5.
Matrix press with feeding funnel: 1-funnel; 2-screw; 3-large nut; 4-roll for pressing; 5-matrix (die).

Fig. 6.
Hardening matrix: 1-keyway; 2-space for drive shaft; 3-threaded hole; 4-shoulder; 5-holes; 6-cleaning area.

Fig. 7.
Group matrix-roles: 1-main screw; 2-roll; 3-roll support; 4-lubrificat; 5-matrix; 6-motor.

With regard to the raw material, three assortments were used, the first two of the spruce and beech wood, respectively, and the third one of the shells of sunflower seeds previously crushed. After they are obtained, the pellets were cooled, conditioned to a moisture content of 10%, at which time they were introduced into polyethylene foil to maintain this moisture content throughout the experimentation period.

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pp. 45-52

a. *b.*

Fig. 8.
Raw material in the stage of pellets (a) and before calcination (b).

Regarding to the characteristics of the pellets, all three types of pellets were used to obtain effective and bulk density, ash content and calorific value. These were the main features of pellet analysis.

For bulk density determination (ASTM D6683 – 14 2014), some vessels with known inside volume and known mass were used in which the pellets were placed to the maximum level. These vessels were vibrating for a better seating of pellets, then were filled once again to the maximum level. The vessels with pellets were weighed, and the bulk density was determined with the following relationship (Eq.1), 10 replicates were performed for each pellet type:

$$\rho_b = \frac{m_s - m_v}{V_v} \ \left[\frac{kg}{m^3}\right] \quad (1)$$

where: ρ_b - bulk density, kg/m^3;
m_s - mass of samples with vessel, in g;
m_v - mass of vessel, in g;
V_v - volume of empty vessel, in cm^3.

The effective density of the pellets was determined for about 20 pieces selected from each type, as a ratio between their mass and volume (EN 323:1993). The pellet mass was obtained by weighing with an electronic balance with an high accuracy of 0.001g, due to their low weight of about 1g. For the determination of the volume, lengths and diameters of each pellet were measured with an electronic caliper (after pellet ends are grinded). Considering that the pellet is in the form of a straight circular cylinder, the final relationship of effective density becomes:

$$\rho_e = \frac{4 \cdot m}{\pi \cdot d^2 \cdot l} \left[\frac{kg}{m^3}\right] \quad (2)$$

where: m - mass of pellet, in g;
d - diameter of pellet, in mm;
l - length of pellet, in mm.

For determining the ash content, fine sawdust was used from each type of material, passing it through a 1x1mm sieve. The experiment used nickel-chromium metallic crucibles, resistant to high temperatures of 650°C. The sawdust sample together with the crucible was dried to the constant mass in a laboratory oven at 105°C for about 2 hours to remove moisture content. Initially it weighed and calibrated crucible with an accuracy of 0.001g, then the crucible was full with sawdust. Then the crucible was placed over a gas flame (Fig. 9a) to burn and remove smoke from the lignocellulosic material to protect the calciner oven.

Fig. 9.
Burning of sample above of a gas flame (a), calcination of sawdust inside of calciner oven (b) and calcined ash on crucible (c).

For the actual test, a calciner furnace (Fig. 9b) with a maximum temperature programmed at 650°C (ASTM D2866 − 11, 2012) was used. The calcination time for a sample of about 1g was 1 hour and half, but the validity of complete calcination was due to the absence of sparks in the sample from oven calciner. At least 10 valid samples for each type of pellet were used. The determination of ash content was made with the next relationship (Eq. 3):

$$AC = \frac{m_{ac} - m_c}{m_{sc} - m_c} \cdot 100\ [\%] \qquad (3)$$

where: m_{ac} - mass of ash with crucible, in g;
m_c - mass of crucible, in g;
m_{sc} - mass of dry sample with crucible, in g.

The calorific value of the pellets was determined using a calorimeter type XRY-1C/China equipped with a calorimetric bomb, with respect of EN 14918:2009 conditions. The whole installation consists of a calorimeter with a bomb, a computer with its own soft, an oxygen cylinder with a pressure regulator and some accessories (Fig. 10).

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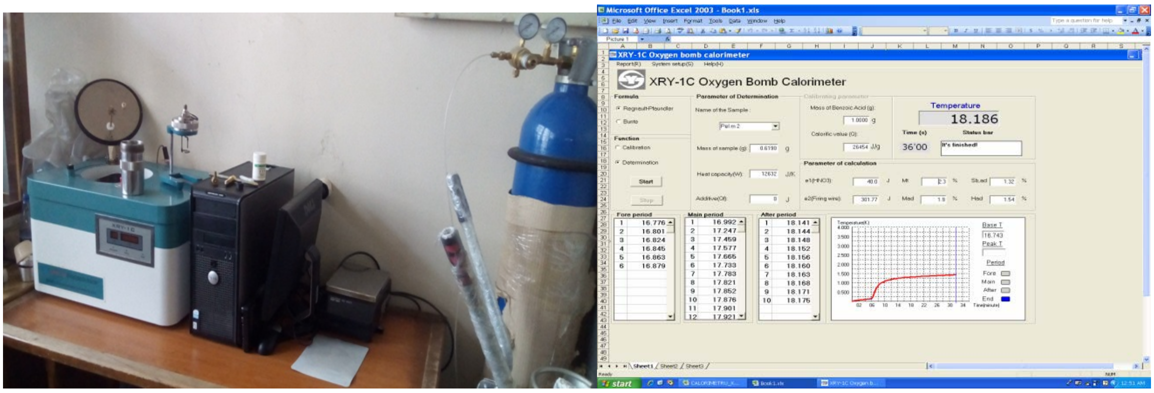


a. b.

Fig. 10.
Installation for determining the calorific value of pellets (a) and test tracking interface (b).

The preparation of the installation for determination has consisted in fixing the nickel wire, cotton wire and pellet in the bomb, tight seal of the bomb, oxygen loading up to 30 bar, insertion of the bomb into the calorimeter, coupling the bomb to the electric wires, closing the lid, coupling the stirrer and inserting the sample data into the computer memory. After the installation was started, the computer software displayed the three distinct periods of the test (fore, main and after), the temperature rise curve and finally the high and low calorific values of the pellets (Fig 10b). The computing relation used by the computer software was the next (Eq. 4):

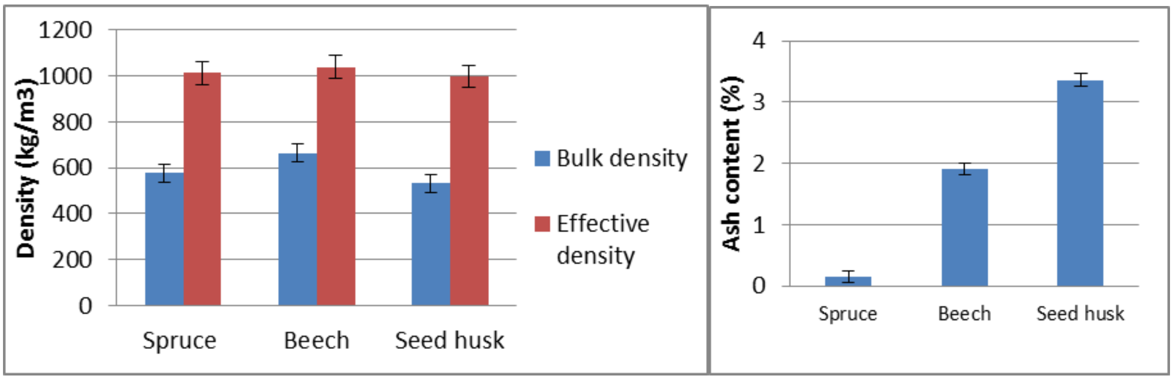
$$CV = \frac{k\cdot(t_f - t_i) - Q_W}{m} \left[\frac{MJ}{kg}\right] \quad (4)$$

where: k- the calorimetric coefficient obtained by the benzoic acid fire, expressed in $MJ/^0C$.

There were used 8 replicas of the same type of pellets.

RESULTS AND DISCUSSION

The pellet temperature at the press outlet has varied between 60-90°C, much lower than that of high-capacity installations (Calderon *et al*. 2017). The measured dimensions of the pellets had a large variation, namely a length between 3.3-36.5mm and a diameter between 6.2-6.67mm (even though the diameter of the holes was 6mm). A pellet diameter relaxation of 3.3-11.1% was observed. Both bulk density (663.3kg/m^3 for beech pellets) and effective density (1039kg/m^3 for beech pellets) (Fig. 11a) fall within the limit values of the Swedish standard according to SS 187120, which provides values at least 600kg/m^3 density in bulk and at least 1000kg/m^3 of effective density. The standard deviation of the values obtained did not exceed ± 5%.



a. ***b.***

Fig. 11.
Density of pellets (a) and their ash content (b).

The values obtained in determining of ash content were different (Fig. 11b), depending on the material used (Rudolfsson *et al*. 2017), the highest value of 3.36% being for the shells of the sunflower seeds. The 1.9% value specificity of the beech wood is slightly above the values found in other scientific papers (Kalian

Morey 2009, Obernberger and Thek G 2004, Huang *et al*. 2017), due to the presence of a large percentage of bark in the material used for pelletizing.

The high (HCV) and low (LCV) calorific value obtained in time of testing is very different related to wood specie, being higher (21.458MJ/kg and 21.308MJ/kg, respectively) for seed husk of sun flower. Values for spruce and beech remains are consistent with other studies (Kocsis and Csanady 2016). All the values obtained fall within the limits imposed by the Swedish standard SS 187120, which stipulates a value more than 16.9MJ/kg (Fig. 12).

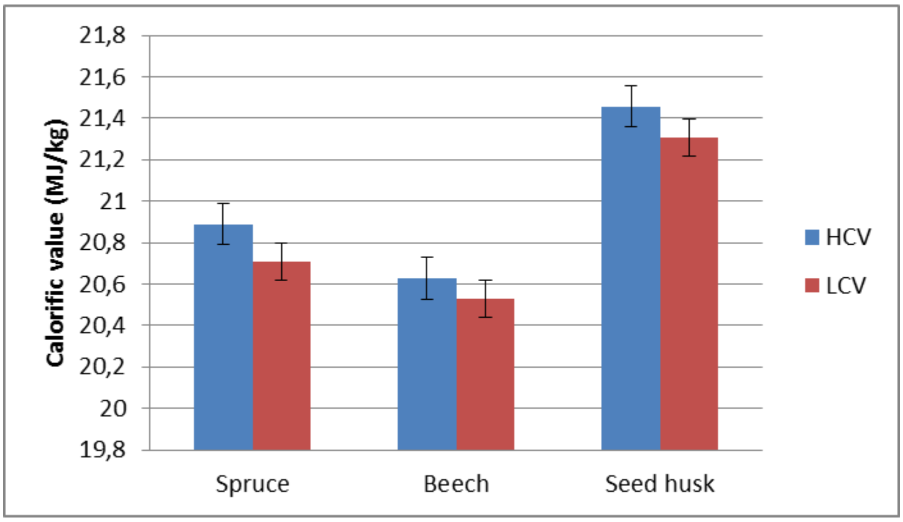


Fig. 12.
Calorific value of three experimental types of pellets.

CONCLUSION

This research highlighted the next conclusions:

- Using many lignocelluloses wastes showed that all pellet characteristics obtained on experimental low-capacity pelletizing machine have got not significant differences.
- The pellet characteristics have corresponded from the point of conditions imposed by European standards in the field.
- The experimental values of pellet density, ash content and calorific value falls within the values found in other papers.
- It has been noticed a very good value of calorific power for seed husk of sun flower and a very bad value of ash content for the same waste;

Finally it can draw as a general conclusion that a simple pelletizing machine, with plane die (matrix) will conduct to realize high-quality pellets.

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