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THE BRIQUETTES PROPERTIES FROM SEED SUNFLOWER HUSK AND WOOD LARCH SHAVINGS

VERONICA DRĂGUȘANU (JAPALELA), AUREL LUNGULEASA, COSMIN SPÎRCHEZ
TRANSILVANIA UNIVERSITY OF BRAȘOV
ROMANIA

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ABSTRACT

The paper aims to use the residue of sunflower seed hulls to obtain organic briquettes and to improve their properties by using larch shavings obtained in the process of solid wood planning. The physical-mechanical properties of briquettes made on a hydraulic machine, calorific value, ash content and volatile content were evaluated. The obtain results highlighted the briquettes obtained from larch waste, but also the acceptable characteristics of the briquettes obtained from sunflower seed husks. The main conclusions of this study is that briquettes obtained from unprocessed sunflower seed husks are acceptable in terms of physical-mechanical and calorific characteristics, even if they do not reach the level of briquettes obtained from larch shavings.

KEYWORDS: Breaking strength, briquette, density, larch shavings, sunflower seed husk.

INTRODUCTION

Nowadays, energy resources are constantly decreasing and solid fuels such as wood briquettes are becoming increasingly sought after on the energy market. Lignocellulosic briquettes have a clean combustion in thermal power plants, and the price is much lower than of coals. Vegetable briquettes are all the more sought after as they are obtained from residues obtained from food processing. The sunflower (*Helianthus annuus*) is an annual plant of the Asteraceae family, originating from America. It is one of the most cultivated plants for its oil-rich seeds, from which sunflower oil is extracted. The residues obtained from the manufacture of sunflower oil are enormous is quantity, of the order of dozens of wagons per year, and their higher use is made in the field of lignocellulosic composites, pellets and briquettes and even by direct combustion. It is much better to use briquettes than to use the lignocellulosic residues directly, in order to capitalize the advantages given by the briquetting/pelletizing process, meaning the concentration of a large amount of energy in a small volume of briquettes. Also, the existence of a kit for automatic feeding of briquettes/pellets with an independence of 12-24 hours makes it possible to automate the loading of the thermal power plant and facilities this activity.

Rosa et al. (2019) analyzed the chemical composition of sunflower seed hulls, obtaining at moisture content of 6.7%, as protein (nitrogen x 5.3) 18.2%, ash content of 3.8% and raw fiber of 11.3%. Oil factories have a current capacity of 400 t/24 hours which results about 100 tons of peeled seeds, meaning a ratio of 1:4. Worldwide in 2007 there were 31 million tons of sunflower seed production. Popescu et al. (2013) analyzed the use of residues from the manufacture of sunflower oil to obtain bioethanol. This biomass is also presented as a renewable and sustainable and very little capitalized. Zygarlicke and Folkedahl (2003) made a chemical analysis (proximate and ultimate analysis) of sunflower seed hulls with wood chips and fossil coal. In terms of a proximate analysis, the following were found: the moisture content was 11.4% for sunflower hulls, 5.2% for wood chips and 20% for coal, volatile matter was 72.21% foe sunflower hulls, 78.54% for wood chips and 37.71% for coal, fixed carbon of 13.53% sunflower hulls, 15.71% for wood chips and 37.25% for coal, and the ash content was 2.85% for sunflower hulls, 0.55% for wood chips and 5.14% for coal. In terms of an ultimate analysis, the following were identified: the hydrogen content was 7% for sunflower seed hulls, 46.46% for wood chips and 53.37% for fossil coal, the oxygen content was 41.89% was for sunflower seed hulls, 46.34% for wood chips and 34.72% for fossil coal from Brazil, and the calorific value was 18035.8 $kJ \cdot kg^{-1}$ for sunflower seed hulls, 18059.05 $kJ \cdot kg^{-1}$ for wood chips and 21689.93 $kJ \cdot kg^{-1}$ for fossil coals from Brazil. Spîrchez et al. (2018) analyzed the manufacturing flow of sunflower oil and found that there were two types of manufacturing residues, namely food from which halvah and fatty acids can be obtained, and another in the form of sunflower seed hulls that can be used in the composites and briquettes/pellets industry. Plíštil et al. (2005) obtained briquettes from several straws and crops using a hydraulic briquetting machine. The method of breaking the briquettes by compression was used to quantify the strength, as a ratio between the maximum breaking force and their diameter. By using pressures of maximum 20 MPa of the briquetting press, the densities below 850 $kg \cdot m^{-3}$ and breaking strength below 70 $N \cdot mm^{-1}$ were obtained. Brožek et al. (2012) evaluated the quality of lignocellulosic briquettes obtained from various wood and vegetable residues having as criteria the dimensions, moisture content, density, breaking strength, ash content, mechanical durability and calorific value.

Determining the strength of briquettes is a complicated problem because it isn't possible to quantify exactly what its breaking surface is. In general, there were several models in choosing the breaking surface is. In general, there were several models in choosing the breaking surface, respectively of linearity considering the diameter of the briquette (Plíštil et al. 2005), by quantifying the average surface remaining after flat pressing, by the flat surface left after pressing in the cage (Lunguleasa 2010) and by the central flat surface of the briquette determined by the diameter and length of the briquette (Spîrchez et al. 2018, Spîrchez et al. 2019), as seen in Fig. 1.

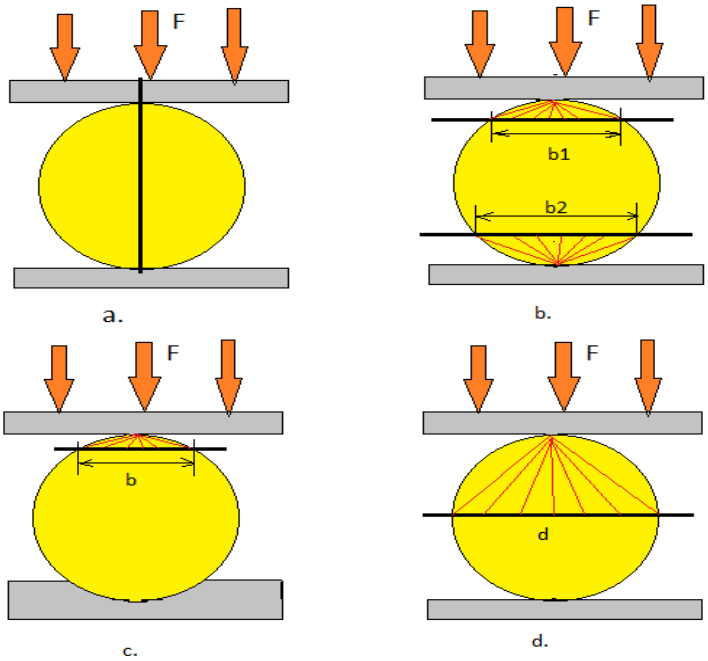

Fig. 1: Ways of quantifying the briquette breaking plane: a- linear; b-with two pressing surfaces; c-with a flat surface by arrangement in the cage; d-through the central of the briquette.

The conclusions on the bibliographic study can be quantified in terms of the briquettes themselves but also of the briquetting presses. Briquettes can be obtained from all categories of lignocellulosic residues with better or less good characteristics. The briquettes obtained from vegetable residue are less qualitative than those obtained from wood residue. Difficulties are also encountered in briquetting with hydraulic presses in which briquettes with a lower density and lower strength are obtained than when using industrial presses with helical conveyor or crank gear mechanism.

The paper aims to make good quality briquettes from sunflower seed hulls and larch shavings, made on a hydraulic briquetting machine Gold Mark type (Brașov, Romania), in order to compare their quality.

MATERIAL AND METHODS

The raw material used in the paper consisted of two parts: from the sunflower hulls obtained from an oil factory, taking over the residues of the hulls obtained from this technology and that obtained from the planning of larch wood. The larch (*Larix decidua*) shavings was also processed by crushing in a mill with laboratory hammers, working with its natural and unchanged state, but also with it in a shredded state to determine the content of calcined ash. The husk of the sunflower seeds was also crushed, in order to use them to obtain briquettes, but also to determine the ash content. For the raw material, the bulk density and their granulometry were determined. The bulk density was determined using constant volume conical recipients (to determine the volume) and a Kern type analytical scale (Germany) to determine the mass. Considering the volume of the cone trunk, the bulk density calculation formula was as follows:

$$\rho_b = \frac{3 \cdot m}{\pi \cdot h \cdot \left(R^2 + r^2 + Rr\right)} \cdot 10^6 \ [\mathrm{kg \cdot m^{-3}}] \qquad (1)$$

where: m - mass of the sample from the taper recipient, (g); h - height of the taper recipient, (mm); R - radius of the taper recipient, (mm); r-small radius of the taper recipient, (mm).

From each type of residues, lignocellulosic briquettes were made on a pneumatic briquetting machine Gold Star type (Brașov, Romania), provided with two pistons and a silo of about 1.5 m^3. The briquettes obtained were cleaned of fibres and were prepared to determine the physical-mechanical properties. In order to determine the density of the briquettes, their volume was considered as a straight circular cylinder, the calculation relation being the following:

$$\rho_b = \frac{3 \cdot m}{\pi \cdot d^2 \cdot l} \cdot 10^6 \ [\mathrm{kg \cdot m^{-3}}] \qquad (2)$$

where: ρ_b - density of briquettes, ($kg \cdot m^{-3}$); m - mass of briquettes, (g); d-diameter of the briquettes, (mm); l - length of briquettes, (mm).

The breaking strength by compression of the briquettes considered the stress distribution during the breaking as well as the shape of the briquette after breaking, using the model from Fig.1d, with the following relationship:

$$\sigma_c = \frac{F}{d \cdot l} \left[\frac{N}{mm^2}\right] \qquad (3)$$

where: F - maximum breaking force, (N); d - diameter of the briquette, (mm); l - briquette length, (mm).

The calorific value of larch briquettes and sunflower hulls was determined experimentally with an XRY-1C type calorimeter bomb, produced by Shanghai Changji Geological Instrument Co. (China) on pieces of briquettes with a mass of 0.6-0.8 g. The testing included 3 distinct stages: preparations of the installation and the wood material, the actual test and taking over the results with their statistical interpretation. The results were expressed by the high and low calorific value, in $kJ \cdot kg^{-1}$. The installation software used the following calculation relationship to determine the higher calorific value of the analyzed lignocellulosic material:

$$HCV = \frac{K \cdot (T_f - T_i)}{m} - Q_{wc} [kJ/kg] \qquad (4)$$

where: HCV - high calorific value, ($kJ \cdot kg^{-1}$); K - calorimetric coefficient, (kJ/ºC); T_f - final temperature of the calorimetric installation, (ºC); T_i - initial temperature of the calorimetric installation, (ºC); m - mass of the test piece, (kg); Q_{wc} - the amount of additional heat due to the burning of nickel wire and cotton wire, ($kJ \cdot kg^{-1}$).

The ash content obtained on the base of ASTM E1755-01: 2003 was determined on shredded material sorted with a 0.4 x 0.4 mm sieve, overtaking the fraction that passed through this sieve. The idea of using such a small material is given by the duration of calcination of the lignocellulosic material. The material that is subjected to this test is dry, because the moisture content greatly influences the final result. Because the test is performed by means of a crucible, the final relation of obtaining the ash content was:

$$A_c = \frac{(m_{ac} - m_c)}{(m_{sc} - m_c)} \cdot 100\ [\%] \tag{5}$$

where: A_c - ash content, (%); m_{ac} - ash mass with crucible, m_c-mass of crucible, (g); m_{sc} - mass of oven dry sample with crucible, (g).

As the weighed values were very low, it was necessary to use an analytical balance with 3 decimal units. In order to protect the calcification oven (not to deposit soot on the interior walls) it was necessary to burn the crucible with lignocellulosic sample on a flame with butane gas, until it no longer smokes, which is why the black ash content was determined, with a similar relationship with Eq. 5.

The volatile content was determined based on the EN 15148 (2009) standard, using an electric oven with the possibility of reaching a temperature of 900 ± 10ºC and 1.5 h by a crucible with a silica lid, which doesn't allow the oxidation of the lignocellulosic material inside. The calculation relation didn't take into account the moisture content of the lignocellulosic material, because the material was dried at 105ºC, up to 0% moisture content.

$$V_c = \frac{m_v}{m_s - m_{cl}} \cdot 100\ [\%] \tag{6}$$

where: m_v - mass of substances lost during heat treatment, (g); m_s - mass of dry sample with crucible and lid, (g); m_{cl} - mass of empty crucible with lid, (g).

Statistically, the Minitab 18 program (Minitab LLC, State College, Pennsylvania, USA) was used, with the calculation of the survey average for a confidence interval of 95%. Also, where was necessary the Excel Microsoft was used, in addition with some common statistical parameters of trend and spread such as arithmetic mean and standard deviation that were also used.

RESULTS AND DISCUSSION

Regarding the characteristics of the larch shavings, its bulk density (determined with relation 1) was 118.5 kg·m^{-3}. If we consider that at 10% moisture content, the density of solid larch wood is 600 kg·m^{-3} (Wood handbook 2020), it can be started that the shavings used has a degree of looseness of 4.56. The granulometry of the larch shavings, determined on

5 independent samples is presented in Fig. 2. A good distribution of values is observed, and the polynomial equation of 2nd degree best approximates the Gaussian distribution of values.

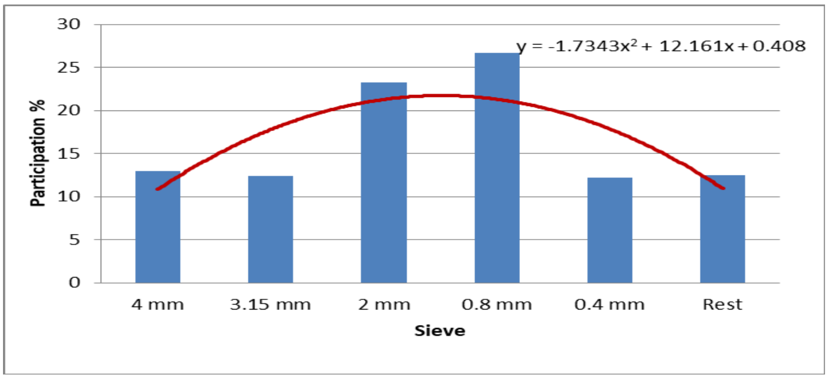

Fig. 2: Grading of larch shavings

The average dimensions of the 30 specimens made of larch shavings were: the diameter of 40.8 ± 0.1 mm and the length of 30.3 ± 5.3 mm. Regarding the diameter of the briquettes, in the conditions in which the diameter of the extrusion channel of 40 mm is known, the degree of expansion of the briquette diameter after pressing of only 2% can be determined, a very good value, which shows the very good compaction of the larch carving. The average density of these briquettes was 1024.8 ± 147.3 kg·m^{-3}, a very good value, above the requirements required by European standards in the field ÖNORM M7135 (2000), (Fig. 3).

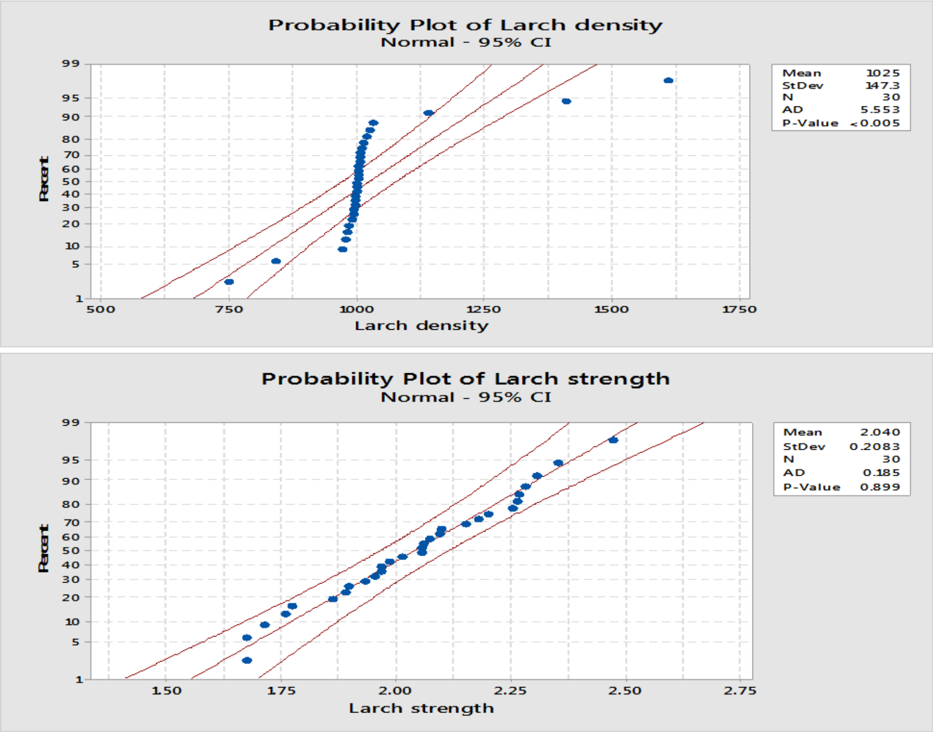

Fig. 3: Probability plot of density and strength of briquettes obtained from larch shavings.

The breaking strength of larch briquettes, calculated with relation to Eq. 3 was 2.04 ± 0.2 N·mm^{-2}, also a very good value, comparable to that found by another research in the field (Spirchez et al 2019) . The calorific value of the larch briquettes was 19375 kJ·kg^{-1} (HCV) and 18906 kJ·kg^{-1} (LCV). The ash content of larch briquettes was 0.4% the current value of softwood species (WHW 2020, Krajnic 2015) and within the norms of the European standard ÖNORM M7135, 2000, which provides a value of less than 6% (Fig. 4).

Regarding the husk of the sunflower seeds, they had a bulk density, determined with the relation (1), of 207 ± 19 kg·m^{-3} in raw state and of 301 ± 26 kg·m^{-3} in ground state (the sort that passed through the sieve of 0.4 x 0.4 mm). The dimensions of the briquettes obtained with the Gold Mark press were the following: the average diameter 40.8 ± 0.5 mm and the length of 44 ± 5 mm. The degree of return of the briquettes after leaving the briquetting press was as in the case of briquettes made from larch shavings of 2%.

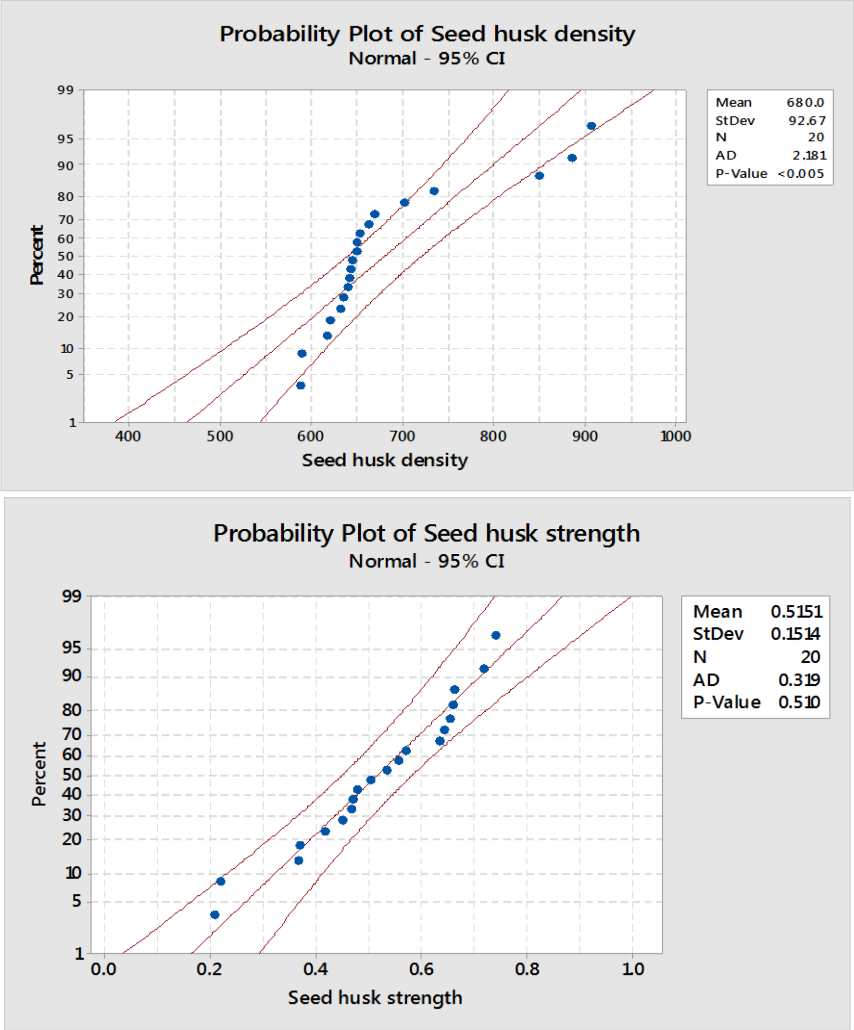

Fig. 4: Probability plot of seed husk density and strength.

The effective density of briquettes obtained directly from non-ground hulls was 680 ± 7.3 kg·m^{-3}, and that of briquettes obtained from ground hulls was 854 ± 73.7 kg·m^{-3}. The big difference between the two densities is given by the fact that the small chips fit better in the briquette structure, thus decreasing the free spaces in the briquette. The breaking strength of the briquettes was 0.51 N·mm^{-2} for those obtained from large seed hulls and 0.09 N·mm^{-2} for those obtained from ground hulls. There is a big difference between the two resistances, which isn't proportional to the density, which leads to the finding that the resistance of the briquettes depends on the size of the lignocellulosic particles (with the increase of the particle size the resistance will increase). This finding is also specific to the composite materials industry, the OSB boards type with long chip having higher resistance to the classic wood chipboards. Therefore, it can be concluded that it isn't necessary to grind the sunflower seed hulls, but on the contrary if we leave them in their natural state, we will obtain briquettes with higher properties.

Because a large difference was observed in the strengths of the two types briquettes (from larch shavings and sunflower seed hulls), a mixture of chips was obtained experimentally in different percentages of seed hulls, respectively 25, 50 and 75%. The results were inconclusive, the resistance of the briquettes obtained experimentally not only didn't improve but decreased in all cases. For example, in the case of briquettes with 50% larch shavings and 50% sunflower seed hulls, the resistance of the briquettes was 0.21 N·mm^{-2}, less than half that of the briquettes with 100% sunflower seed hulls. Therefore, it can be concluded that the mixture of sunflower seed hulls and larch carving is compatible and that other solutions must be found to improve seed hulls. Therefore, it can be concluded that the mixture of sunflower seed hulls and larch carving is incompatible and that other solutions must be found to improve the resistance of the briquettes in the sunflower seed husk.

In order to observe the influence of the briquetting press on the physical-mechanical properties of the briquettes obtained from the sunflower seed hulls, some briquettes made on an industrial screw press were taken, which had an average density of 921.8 ± 27.6 kg·m^{-3} and an average resistance of 0.46 ± 0.07 N·mm^{-2}, as seen in Fig. 5.

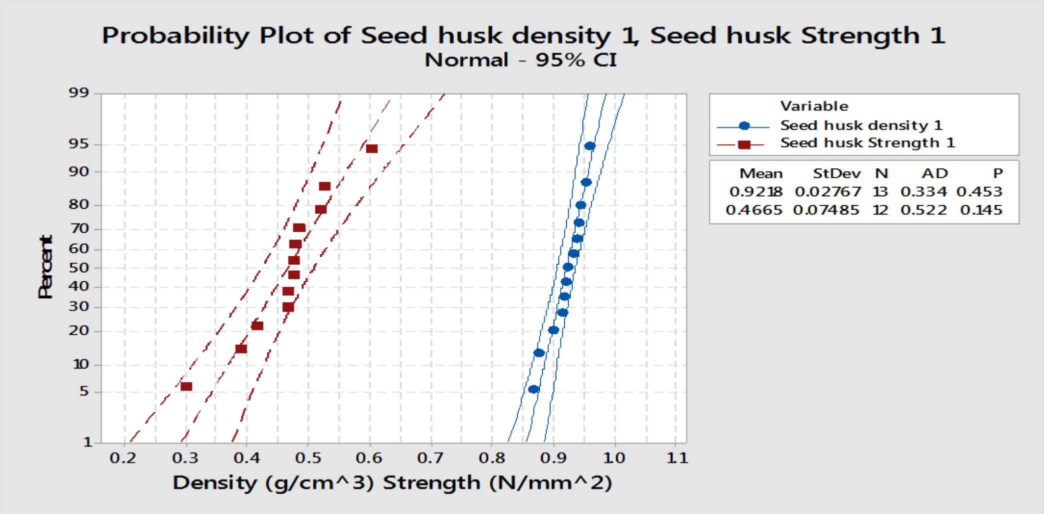

Fig. 5: Probability plot of seed husk density (g·cm^{-3}) and strength (N·mm^{-2}).

It is observed that although the density of briquettes increased greatly from 680 kg·m^{-3} on the hydraulic press to 921.8 kg·m^{-3} on the screw press (an increase of 35.4%), the strength of breaking by compression decreased from 0.51 N·mm^{-2} at 0.46 N·mm^{-2} (a decrease of 9.8%).

It can also be concluded that the breaking strength of briquettes obtained from sunflower seed hulls is much lower than that of briquettes obtained from larch carving, respectively about 4 times.

The high calorific value of the briquettes obtained from the sunflower seed hulls was of 19265 kJ·kg^{-1}, while the lower calorific power as average value obtained was 18655 kJ·kg^{-1}. There values were in concordance with those obtained from larch shavings or other wood residues (Verna et al. 2019). The ash content of sunflower seed hulls was 30.72% for black ash and 2.34% for calcined ash (Fig. 6). Ash content as calcined one wasn't too much as other vegetable residues (Brožek at al. 2012).

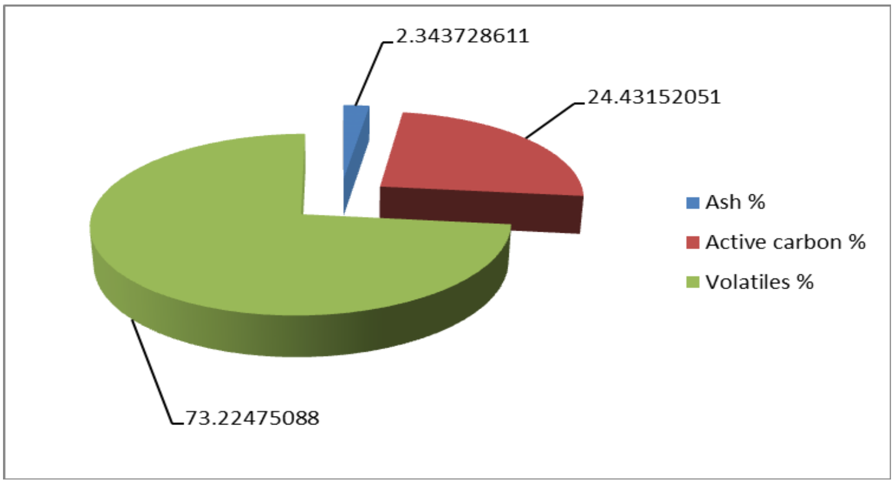

Fig. 6: The values of ash content, active carbon, and volatile for sunflower seed husk

A general conclusion of the paper can be that the larch shavings are very well compressible and briquettes with good mechanical properties from it are obtained, and the sunflower seed husk has weaker strength, even if the densities are acceptable. That is why it is recommended to use small bags to pack the briquettes, of maximum 8-10 kg, so that the briquettes don't crumble during transport on storage at the beneficiary.

CONCLUSIONS

The main conclusions obtained from the research carried out in this paper can be summarized as follows: *(1)* Both larch shavings and sunflower seed husk can be used in their natural state, without additional processing, to obtain briquettes with good physical and mechanical characteristics; *(2)* The briquettes obtained from larch shavings, had a density of 1024.8 kg·m^{-3} and a high calorific value of 19375 kJ·kg^{-1}; *(3)* Even if they have lower mechanical strengths, the briquettes obtained from sunflower seed husk are calorically efficient with calorific value of 19265 kJ·kg^{-1}, close to wood briquettes; *(4)* The ash content of 2.34% falls within the limits of briquettes obtained from plant resources and wood waste; *(5)* Through the experiments in this paper it can be started that the briquettes from the sunflower seed hulls become a viable alternative to the wood briquettes.

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VERONICA DRĂGUȘANU (JAPALELA), AUREL LUNGULEASA, COSMIN SPÎRCHEZ*
TRANSILVANIA UNIVERSITY OF BRAȘOV
DEPARTMENT OF WOOD PROCESSING AND DESIGN OF WOODEN PRODUCTS
29 EROILOR BLVD, 500036
BRAȘOV
ROMANIA
*Corresponding author: spirchez.cosmin@gmail.com