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COMPARISON BETWEEN SPRUCE AND BEECH BRIQUETTES (AS RENEWABLE SOURCE OF COMBUSTIBLE IN ROMANIA) FROM THE PERSPECTIVE OF PHYSICAL, MECHANICAL AND ENERGETIC PROPERTIES

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Abstract
This paper compares briquettes made of spruce with those made of beech from the perspective of physical, mechanical and energetic features, for the purpose of making the appropriate selection from the market. The main properties being studied are briquettes' density, as a physical feature, resistance to perpendicular compression, as a mechanical feature necessary to determine chips' compression degree and their compression status, and the calorific value as an energetic feature. The research findings show that coniferous tree briquettes are denser and more resistant, but have a lower calorific value. It was also determined that briquettes compression is directly dependent on their density and consequently, briquettes' energy density remains the only property able to collectively characterise the quality of briquettes.

Key words: *briquettes; spruce; beech; caloric density; compression strength.*

INTRODUCTION

Romania is a country with a high biomass energy potential, of almost 8,000 toe/year (tonnes of oil equivalent), i.e. 19% out of the total consumption of primary resources in the 2000 year, with the following categories of combustibles: forestry and firewood residues, wood wastes (sawdust, wood rests), agricultural waste (cereal straws, corn stems), biogas (Lica 2012, Lunguleasa 2013).

Ligneous biomass is one of the oldest known combustible materials. It represents a renewable combustible material as a result of two different main causes: the wood is the result of photosynthesis and annual raise, and wood rests are inherent products in wood processing industry. The heat resulted from biomass consumption has various uses, as follows: 50% out of the heat produced based on biomass come from the forest residues combustion, 50% out of the heat produced from biomass has agricultural origins (Fraunhofer 2012). Out of the total amount of thermal energy produced based on biomass, 10% is found in wood processing industry. In Western European countries, the use of biomass as primary energy source may become profitable both for biomass producers, and for biomass consumers (Gavrilescu 2008, Altuncu 2011, Berkesy 2013). Ligneous biomass consists of the total amount of wood rests obtained from wood cultivation and exploitation process, as well as from the wood processing industry, such as timber, veneer, plywood factories (Demirbas 2001, Koike 2012, Syed 2014, Zanuncio 2014).

The advantages of using biomass for suppliers are: smaller storing spaces for the wood rests resulted from the manufacturing process and lower environmental impact (Jenol 2014). In case of biomass consumers, the advantages of using biomass are: shorter time of production in case of this type of combustible as compared to conventional combustibles (oil, natural gas, coal), and also lower environmental impact (Wilkins 2003, Van Dam J 2008, Fengmin 2011).

Wood biomass combustion is a non-ecological process, but indispensable for human activity, due to the thermal use it produces. The use of wood biomass as bio-combustible material is based on its good properties, such as low price and its renewable feature (Prasertan 2006, Bridgwater 2012, Morrin 2014).

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Certain specialists (Fraunhofer 2012) consider that Romania has a high biomass energy potential, estimated to 7,594 thousand toe/year (tonnes of oil equivalent), i.e. 19% from the total consumption of primary resources in 2010, divided in the follwoing categories of combustibles: forestry and firewood residues (1,175 thousand toe), wood waste (487 thousand toe), cereal waste (4,779 thousand toe), biogas (588 thousand toe), urban domestic waste and residues (544 thousand toe).

In order to locally differentiate the biomass potential, there were defined the following eight regions of Romania: Region 1 (Danube Delta-biosphere reservation), Region 2 (Dobrogea), Region 3 (Moldova), Region 4 (Carpathian Mountains), Region 5 (Transylvanian Plateau), Region 6 (Western Plain), Region 7 (Sub Carpathians), Region 8 (Southern Plain).

Biomass energy potential for renewable energies of the eight regions of Romania (Fraunhofer Institute) is presented in Table 1.

Table 1

Biomass energy potential for renewable energies of the eight regions of Romania (Fraunhofer Institute 2012)

Region	**Forest biomass thousand t/year TJ**	**Wood waste thousand t/year TJ**	**Agricultural biomass thousand t/year TJ**	**Biogas thousand t/year TJ**	**Urban waste thousand t/year TJ**	**Total TJ**
1	-	-	-	-	-	-
2	54 451	19 269	844 13,422	71 1,472	182 910	29,897
3	166 1,728	58 802	2,332 37,071	118 2,462	474 2,370	81,357
4	1,873 19,552	583 8,049	1,101 17506	59 1231	328 1640	65,415
5	835 8,721	252 3,482	815 12,956	141 2,954	548 2,740	43,757
6	347 3,622	116 1,603	1,557 24,761	212 4,432	365 1,825	60,906
7	1,248 13,034	388 5,366	2,569 40,849	177 3,693	1,314 6,570	110,198
8	204 2,133	62 861	3,419 54,370	400 8,371	1,350 6,750	126,639
Total	4,727 49,241	1,478 20,432	12,637 200,935	1,178 24,620	4,561 22,805	518,439

The spruce and the beech are two representative tree species for the Centre Region of Romania.

OBJECTIVE

The main objective of the present research is to compare beech briquettes against spruce briquettes, in order to evaluate wich are better to be used for combustion.

MATERIAL, METHOD, EQUIPMENT

In order to determine the density (at 10% moisture content), the classic method of determining masses and volumes was used. The samples, over 20 pieces of each type, were taken from the test rods. In order to obtain a clear lenght the rod ends were cut perpendicular to their longer axis. We chose the cylinder shaped briquettes because only this type allows the use of method for determining the perpendicular compression, and the volume is easy to find, as the volume of a right circular cylinder. The briquettes were weighted using an electronic TP KERN EW 1500-24 balance with a precision of 0.1 g. The briquettes' average diameter was also determined, as the arithmetic mean in three points (the two ends and the middle) of two perpendicular diameters. Density was calculated by the following formula:

$$\rho = \frac{4m}{\pi D_m^2 l} \text{ [g/cm}^3\text{]} \quad (1)$$

where:
m is briquette's mass, in g;
D_m is briquette's average diameter, in mm;
l is test rod length, in mm.

In order to find the resistance to compression, the previous samples (from the density analysis) were used on a universal testing machine, manufactured by Fritz Heckert, having the following technical specifications: 50 Hz frequency, 220 V power supply voltage, 3.3 KVA electrical power, mechanically and electronically drive. Thefeed speed was 4 mm/min at the work scale of 0 - 400 kgf in order to determine the maximum compression force, until the start of briquettes desintegration (Fig. 1). The method to determine the resistance to compression of spruce briquettes (Lunguleasa et al. 2010) is statically destructive and it was computed as a ratio between the maximum force and the area of compression (the product between test rod length and crush width), the resistance being measured in N/mm^2. The reason for determining the resistance to compression is also to find the maximum weight at wich briquettes remain intact in their package, when stacked.

Fig. 1.
Compression strength determination

The calorific value represents the amount of heat resulted when a combustibles mass unit is burnt (DIN 51900-1). Two caloric value determinations were performed for briquettes: superior calorific value (when water vapours condense, releasing vaporization heat) and inferior calorific value (when a part of heat is lost for water's evaporation). Inferior calorific value is the difference between the superior calorific value and the amount of heat released for the evaporation of water from the combustion gases. The equipment used to determine the spruce briquette's caloric value is the XRY-1C bomb calorimetric (Fig. 2).

Fig. 2.
XRY-1C bomb calorimeter

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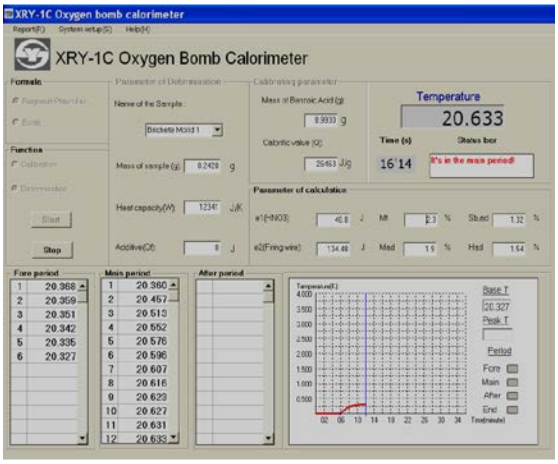
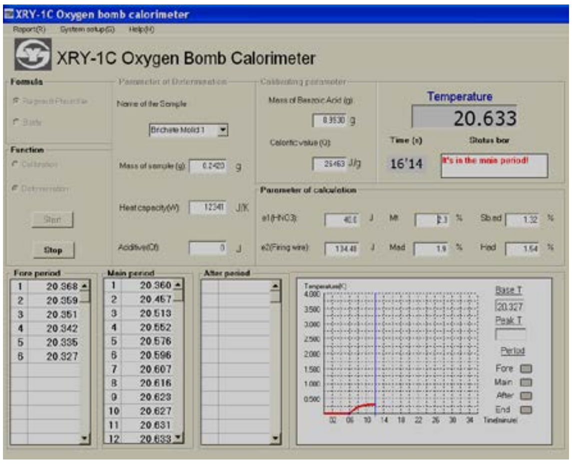
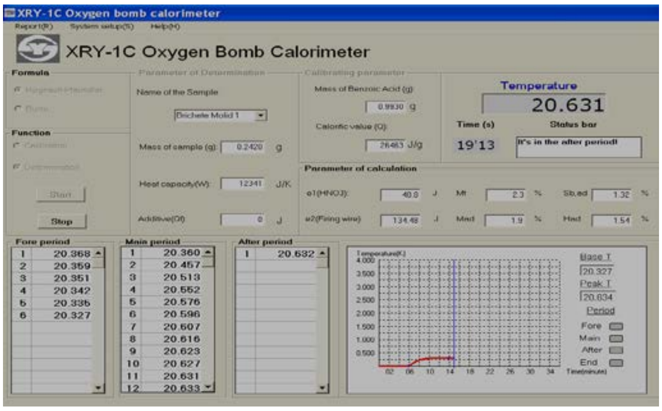
Finding the calorific value involves three stages: initial stage, main stage and final stage. The initial stage consists of the determination of water temperature variation inside the calorimetric container as a result of the heat exchange with the exterior before combustion. At the end of the initial stage, the combustion of samples extracted from the briquettes starts. In the main stage we may notice a controlled increase in temperature of the thermal agent in calorimeter. When the temperature gets stable, the next stage is started. In the final stage, the temperature will be constant or it will slightly decrease, until the procedure ends and the computer shows "end" (Fig. 3).



a.



b.



c.

Fig. 3
The stages of calorific value determination process
a.-initial stage; b.-main stage; c.-final stage

The superior caloric value is found based on the following formula:

$$Q_s = \frac{K \cdot (t_f - t_i)}{m} - q_s \text{ [kJ/kg]} \tag{2}$$

where:
K is the calorimetric factor, defined in kJ/°C;
t_f is temperature's final value, in °C;
t_i is temperature's initial value, in °C;
q_s is heat consumed for burning of nickeline glow wire and the cotton wire, for starting the combustion, in kJ/kg;
m is combustible sample mass, in kg.

RESULTS AND DISCUSSION

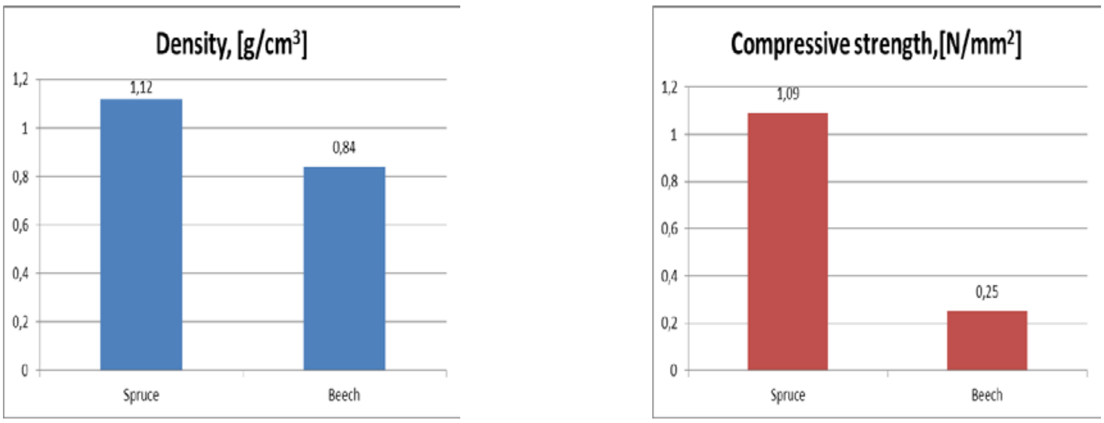
Based on the values measured on spruce and beech briquettes batches, there were drawn up Excel tables which were statistically processed, being obtained the values in Table 2.

Table 2

The physical and mechanical characteristics of spruce and beech briquettes

Spruce	**Beech**
Density (g/cm^3)	**Density (g/cm^3)**
Mean = 1,129966	Mean = 0,846763
Median= 1,125965	Median= 0,858395
Standard Deviation = 0,085859	Standard Deviation = 0,071767
Sample Variance = 0,007372	Sample Variance = 0,00515
Kurtosis = 0,611772	Kurtosis = -0,47904
Skewness = -0,38477	Skewness = 0,406164
Minimum = 0,899317	Minimum = 0,74358
Maximum = 1,330112	Maximum = 1,013537
Sum = 45,19862	Sum = 16,93527
Compressive strength (N/mm^2)	**Compressive strength (N/mm^2)**
Mean = 1,090035	Mean = 0,256806
Median= 1,05371	Median= 0,262342
Standard Deviation = 0,357667	Standard Deviation = 0,093343
Sample Variance = 0,127926	Sample Variance = 0,008713
Kurtosis = - 0,32489	Kurtosis = 0,57404
Skewness = 0,56895	Skewness = 0,480676
Minimum = 0,515187	Minimum = 0,104861
Maximum = 1,862723	Maximum = 0,496808
Sum = 43,60138	Sum = 5,13612

It may be noticed that the spruce is more compressible, and spruce briquettes are denser and have a better compression (Fig. 4).



a. ***b.***

Fig. 4.

a.-Briquettes density b.-Briquettes compression

The briquette's compression is closely related to and dependent on their density, this being the reason why their values were included in the same graph. We may note density's influence on spruce and beech briquettes' resistance to compression (Fig. 5).

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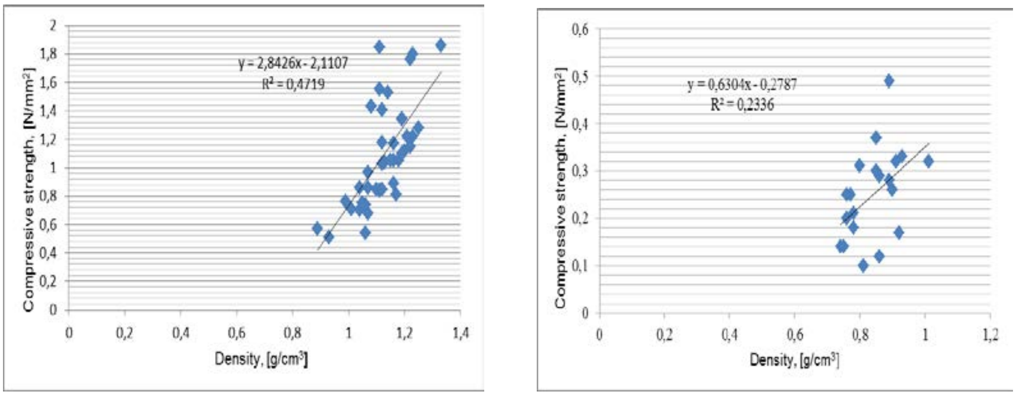

a. ***b.***

Fig. 5.
The density influence on compressive strength
a.- spruce; b.-beech

The net calorific value and gross calorific value in case of spruce and beech briquettes are shown in table 3.

Table 3
The net calorific value and gross calorific value in case of spruce and beech briquettes

Calorific power	**Spruce briquettes (kJ/kg)**	**Beech briquetes (kJ/kg)**
Net calorific value	17 177	17 862
Gross calorific value	19 320	19 503

The beech's caloric value was 6,85% higher than the one of spruce.

Going further with the analysis, we may notice that only the density and the caloric value remain as main features, as the perpendicular compression is directly dependent on the density. The influence of briquettes species is different, i.e. spruce briquettes have a higher density, but a lower caloric value. Threfore, in order to perform an accurate qualitative analysis of the types of briquettes, we need a new characteristics which shall group the two previously mentioned, characteristics called caloric density and representing the result of the following formula:

$$\xi_c = NCV \cdot \rho_b \qquad [MJ/m^3] \tag{3}$$

where:
NCV is net calorific value, in MJ/kg;
ρ_b is density of briquettes, in kg/m^3.

Using the formula (3), we will obtain the following values for ξ_c:
- for spruce briquettes: 1120 * 17,17 = 19,2 * 10^3 MJ/m^3.
- for beech briquettes: 840 * 17,86 = 15 * 10^3 MJ/m^3.

It may be noticed that spruce briquettes are better to those of beech, of course due to the higher density of this type of briquettes.

CONCLUSIONS

Wood briquettes are superior ecologic products, used increasingly often in order to replace the fossil combustibles. This is the reason why this study comes to confirm once more the importance of knowing their performances for the purpose of having clear comparisons. After processing the experimental data, it may be noticed that resistance to compression in case of spruce briquettes is of 1.090 N/mm^2, and in case of beech briquettes it is of 0.256 N/mm^2, this major difference being determined by the difference of densities. In case of spruce briquettes we may notice that for a difference of 0.44 g/cm^3 in density, the resulted difference of 1.36 N/mm^2 is very high. In case of beech briquettes we may notice that for a difference of 0.27 g/cm^3 in density, the resulted difference of compression is of 0.39 N/mm^2. It was noticed that there is a correlation between the compression resistance and briquettes' density.

Because of the fact that beech briquettes caloric value is higher than of spruce briquettes, a new way to characterise the briquettes was found – through their caloric density. This feature made possible the comparison of the two types of briquettes, being noticed once again that density is one of the most important characteristics of briquettes.

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