

# Calorific properties of the wood biomass from some softwood species

Cosmin Spîrchez<sup>1,\*</sup>, Aurel Lunguleasa<sup>1</sup>, Constantin Ștefan Ionescu<sup>2</sup>, and Anamaria Avram<sup>2</sup>

<sup>1</sup>Transylvania University of Brasov, Wood Processing and Design of Wooden Products Department, 50068 Universitatii str., Brasov, Romania

<sup>2</sup>Laboratory of Research and Restoration Restaurare Ionescu Constantin SRL, Sibiu, Romania

**Abstract.** The aim of the paper is to highlight the importance of the calorific properties of softwood biomass. The paper presents the calorific power and ash content, important calorific properties in the assessment of wood biomass. Biomass, in the form of wood, was and will remain an important combustible material. The value of ash content for spruce was 3.8% and 4.2% for fir. These values are within the international standards. Wood biomass, as a material can provide the energy need for the population at a reduced price. The combustion process are possible only in the presence of oxygen, which is usually introduced into the focal spot through the combustion air.

## 1 Introduction

The research conducted in the energy field has shown that biomass has combustible characteristics, that determine its competitive qualities in the energy market. Encouraging the use of biomass as a combustible material is also outlined by the combustion plants adapted for burning various combustible materials (firewood plants, pellets, briquettes, cogeneration). [1]

Biomass include biological material that can be used as fuel. Biomass is represented by plant organic matter, but also microorganisms. Agricultural biomass includes by products of cultivated plants (straw, stems) [8, 9, 10].

Coal and crude oil as fossil fuels have their origins in the plant biomass of past eras. Studies by researchers have shown that biomass can be burned to generate heat and electricity. Biomass is biodegradable and renewable [17, 18, 19].

The classification of crops for energy purposes is presented as follows [20]:

- trees with high growth rate (poplar, willow, eucalyptus);
- agricultural crops (sugar cane, sugar beet);
- perennial crops (miscanthus).

Obtaining energy from biomass is done by [15]:

- direct combustion with thermal energy generation;
- combustion by pyrolysis, with the generation of singaz;
- fermentation or generation of biogas (CH<sub>4</sub>) or bioethanol (CH<sub>3</sub>-CH<sub>2</sub>-OH).

---

\*Corresponding author: [cosmin.spirchez@unitbv.ro](mailto:cosmin.spirchez@unitbv.ro)

Energy content of different type of biomass: 1 ton of coal = 2.5 MWh, 1 ton of wood pellets = 1.8 – 2.2 MWh, 1 ton sawdust = 1.8 MWh, 1 ton of wood chips = 0.8 – 1.5 MWh [17].

The important characteristics of biomass that determine its use as fuel in the energy market are: chemical composition, combustion rate, calorific value, combustion density, water and ash content [5]. The combustible characteristics of wood biomass differ from one material to another and from that of fossil fuels [19].

Biomass, besides the main advantages, has a number of disadvantages compared to fossil fuels [3, 7, 9]:

- the density of biomass and the calorific value of wood species is lower compared to that of fossil fuels;
- some biomass sources are largely generated only seasonally, usually during the harvest period, therefore resulting in the need to store and keep the material in optimal conditions, that don't affect the biodegradation;
- the thermal systems used for different conversion processes must have large capacities, leading to the equivalence of the price of fossil fuel plants;
- untreated biomass usually has a high moisture content, which is the main factor that determines a low heat content achieved from the material due to the combustion processes.

Over the period of biomass decomposition, when the volatile substances in the biomass evaporate, in the remaining ash there are found mineral elements: sodium, potassium, magnesium, aluminium and calcium [12]. Ash treated by chemical processes can become a good fertilizer.

The wood from temperate areas is poor ash, containing 0.2-1%, while trees in the tropical areas contain up to 4% ash [10].

The ash content from the wood represents the mineral part remaining after combustion until the constant mass, at temperature of 850 °C of a sample of the analyzed material, incinerated under well-determined conditions [2]. The ash consists of a mixture of soluble mineral substances (10-25% of the total ash), composed mostly of potassium, chlorides, magnesium, iron and sulphates, as well as insoluble mineral substances (75-90%), consisting of silicates, phosphates, oxides [4].

During the combustion processes, ash is produced in powder form [11]. This ash is an organic material with fine particles, that represents the amount of carbon resulting from the incomplete combustion of carbon. This resulting amount negatively influences the thermal plants that use combustible biomass [6]. The carbon content, depending on the wood species used, is 40.5% (dry material), hydrogen and nitrogen 5.25% (dry material) and 0.44% (dry material), the sulphur content is 0.03% dry material.

For instance, the lower calorific value of wood varies between 15480 kJ/kg-19440 kJ/kg [13]. Thermochemical conversion technologies, such as pyrolysis, gasification and heat processing, along with the cogeneration of biomass in coal-fired power plants, could play an important role in thermal energy production [15]. The amount of renewable energy that could be achieved if energy crops were introduced would be 216-960 GWh/year (considering 1 ton of dry wood in air energy equivalent to 3 MWh).

Technological development has led to the implementation of highly improved pellet heating systems, that are fitted with automatic catalyst gas cleaning systems [14, 16, 20].

## 2 Materials and Methods

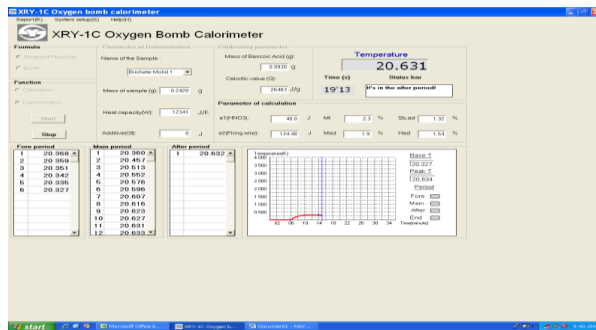
The ascertainment of the caloric power for biomass wood is almost similar to the one for the coal and with a few distinct features than the fuels under liquid state (gas, diesel fuel) or the ones under gas state (biogas).

The value of calorific power for benzoic acid is 26463 KJ/kg. The method to find out the caloric power is made separately for the fuels under solid (ASTM D3286-96). The procedure to determine the caloric power of wood refers firstly to preparing the raw material and the installation, then the proper determination of the caloric power, and finally obtaining the results. The sample (0.6-0.8 grams of wood biomass) is put in a crucible pot. Wood samples for measuring caloric value and ash content were taken from tree trunks. For dry wood biomass used at a temperature of 103 +/- 2°C.



**Fig. 1.** Calorimetric bomb XRY-1C

The final result of burning the lignocellulose biomass is expressed by the caloric power, notion through which one understands the heat quantity obtained by burning a mass unit. The proper test contains 3 distinct periods, respectively (Figure 2): the initial period ("fore"), the main period, the final period ("after").



**Fig. 2.** The periods for determining the caloric power

The higher caloric power is determined with the relation:

$$Q_s = \frac{K \cdot (t_f - t_i)}{m} - q_s \quad [\text{kJ/kg}] \quad (1)$$

where:

- K is the calorimetric factor, expressed in kJ/ °C;
- t<sub>f</sub>- final value of the temperature, in °C;
- t<sub>i</sub>- initial value of temperature, in °C;
- q<sub>s</sub>- heat consumed for the burning of incandescent wire and the cotton wore, for the initiation of burning, expressed in kJ/kg;
- m- fuel sample weight, in kg.

In order to determine the ash content of biomass, there was used the general method of standardized determination. According to this method, material is minced and dried until 0% moisture content at a temperature of 650 °C in a laboratory stove, at least for 30 minutes. The advanced burning operation is performed on a high temperature proof metallic pot, and the weighting is performed on an analytical scale with a precision of 3 decimals.

Ash content of biomass is determined as a ratio between calculated mass and oven-dry mass of grinded piece from biomass.

Relation for the determining the ash content:

$$A_c = \frac{m_f - m_c}{m_i - m_c} \cdot 100 [\%] \quad (2)$$

where:

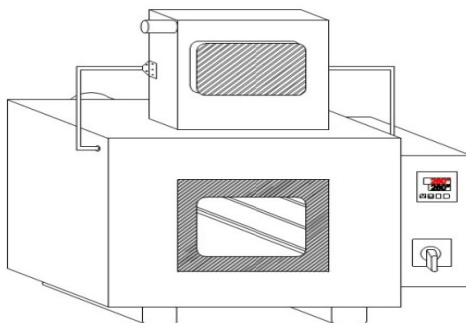
$A_c$ - ash content, in %

$m_i$ - initial mass of the pot with the work ground sample, in g;

$m_f$ - final mass of the pot with ash, in g;

$m_c$ - empty pot weight, in g.

In Figure 3 is presented the calcination furnace for determining ash content.



**Fig. 3.** Calcination furnace for determining ash content

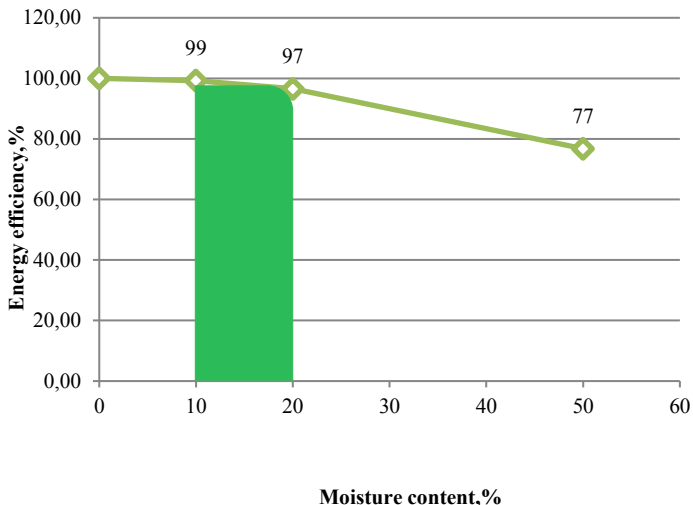
### 3 Results and discussions

In table 1 is presented the values for the spruce (moisture content, mass, higher caloric power, energy density, burning speed). The caloric values are higher for spruce, because it has resin.

**Table 1.** The caloric values for the spruce

Moisture content (%)	Mass (g)	Higher caloric power (Kj/kg)	Lower caloric power (Kj/kg)	Energy density (Kj/cm <sup>3</sup> )	Burning speed (Kj/min)
0	0.7000	20051	19476	15.271	715
10	0.9020	18121	17833	14.623	457
20	0.8808	16480	15904	12.735	417
50	1.3080	11555	10115	12.028	304

In Figure 4 is presented variation of the energy efficiency for the spruce. This graph shows that forest species with low moisture content have a fast burning rate, compared to those with higher moisture content.



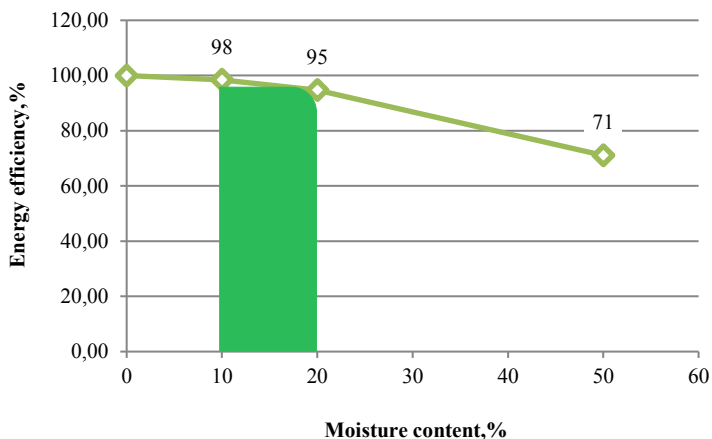
**Fig. 4.** The variation of the energy efficiency for the spruce

Table 2 presents the values for the fir (moisture content, mass, higher caloric power, lower caloric power, energy density, burning speed).

**Table 2.** The caloric values for the fir

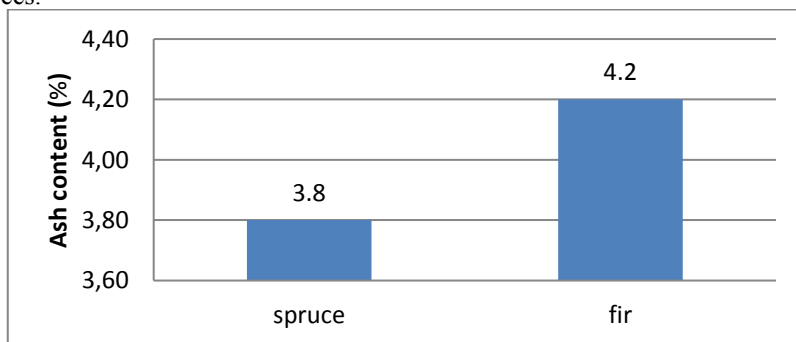
Moisture content (%)	Mass (g)	Higher caloric power (Kj/kg)	Lower caloric power (Kj/kg)	Energy density (Kj/cm <sup>3</sup> )	Burning speed (Kj/min)
0	0.6800	19117	18622	K3.380	589
10	1.0494	17081	16883	12.730	398
20	1.0536	15293	14897	12.643	322
50	1.0455	9929	8939	8.496	215

In Figure 5 is presented the variation of the energy efficiency for the fir. The graph shows that the optimal combustion percentage is between 10 – 20% of the moisture content the solid combustible material.



**Fig. 5.** The variation of the energy efficiency for the fir

In Figure 6, there is comparatively graphically presented the ash content values for the two types of fuels obtained from the spruce and fir. The variation of chemical compounds in wood species depends on the physical and mechanical characteristics of the soil, the age of the trees.



**Fig. 6.** The values of the ash content for spruce and fir

## 4. Conclusions

Combustion is one of the most important thermo-chemical processes for energy production. The combustion processes are possible only in the presence of oxygen, which is usually introduced into the focal spot through the combustion air. The values of higher calorific power for spruce are 20051 kJ/kg and 19117 kJ/kg for fir, are similar coal. The value of ash content for wood biomass (spruce and fir) falls within international standards. Over the past period, the countries of the world are channelling their investments on the production of energy from alternative sources, which, according to the forecasts carried out, are estimated to reach by 2025 a quantity of 20% of the total energy used at the European level. Regarding the biomass consumption of Romania, wood based biofuels are used for industrial steam or hot water boilers.

## References

1. J.P. Boutin, G. Gervasoni, R. Help, K. Seyboth, P. Lamers, M. Ratton, *Environ. Eng. Manag. J.* **6**, 3 (2007)
2. A.V. Bridgwater, *Biomass Bioenerg.* **38** (2012)
3. C. Ciubota-Rosie, M. Gavrilescu, M. Macoveanu, *Environ. Eng. Manag. J.* **7**, 5 (2009)
4. A. Demirbas, *Energ. Convers. Manage.* **42** (2011)
5. R.S. Dhillon, G. von Wuelhlich, *Biomass Bioenerg.* **48** (2013)
6. O.O. Fasina, *Bioresource Technol.* **99** (2008)
7. F.F. Felfli, J.M. Mesa, D.J. Rocha, D. Filippetto, C.A. Luengo, W.A. Pippo, *Biomass Bioenerg.* **35** (2011)
8. D. Gavrilescu, *Environ. Eng. Manag. J.*, **7**, 5 (2008)
9. M. Gavrilescu, *Environ. Eng. Manag. J.*, **7**, 5 (2008)
10. C. Gong, D. Lu, G. Wang, L. Tabil, D. Wang, *BioResources* **10**, 3 (2015)
11. N. Kaliyan, R.V. Morey, *Biomass Bioenerg.* **33** (2009)
12. J. Kers, P. Kulu, A. Aruniit, V. Laurmaa, P. Krizan, L. Soos, *Est. J. Eng.* **19** (2013)
13. J. Lako, J. Hancsok, T. Yuzhakova, G. Marton, A. Utsai, A. Redey, *Biomass Bioenerg.* **40** (2012)
14. A. Lunguleas, *Environ. Eng. Manag.*, **9** (2010)
15. A. Lunguleasa, C. Spirchez, *Wood Res - Slovakia* **60** (2015)
16. N.P.K. Nielsen, D.J. Gardner, T. Poulsen, C. Felby, *Wood Fiber Sci.* **41** (2009)
17. C. Okello, S. Pindozi, S. Faugno, L. Boccia, *Biomass Bioenerg.* **56** (2013)
18. N.A. Pambudi, K. Itaoka, A. Chapman, N.D. Hoa, N. Yamakawa, *Int. J. Smart Grid Clean Energ.* **6** (2017)
19. J. Swithenbank, Q. Chen, X. Zhang, V. Sharifi, M. Pourkashamiani, *Biomass Bioenerg.* **3** (2011)
20. V.K. Verna, S. Bram, J. de Rucky, *Biomass Bioenerg.* **33** (2009)