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RESEARCH ON THE CALORIFIC VALUE OF THE HARDWOOD SPECIES

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Abstract: Romania is a country with a great potential in the field of biomass energy. At the level of 2016, an area of 229973 km^2 was used for agricultural and forestry purpose of which the forest area was 4.7%. The lands covered by the forest are widely exploited and the waste resulting from the processing of cut wood is often left to degrade producing water pollution. Renewable energy resources represent one of the replacement variants for fossil fuels in Romania and worldwide with high development perspectives in the future. Presently, biomass contributes by approximately 12% to the production of primary energy in worldwide and in the developing countries this occupies 40-50% of the necessary energy. Biomass resources presently represent the raw material resulted from wood processing, agricultural, municipal waste and animal dejections. The determination of the calorific value for wood is similar to that of coal (as solid fuel) and with little differences as compared to liquid fuel (benzene) or gaseous one (natural gas, biogas).
Keywords: biomass, hardwood, calorimetric bomb, calorific value

INTRODUCTION

In the year 2000, the estimated contribution of the biomass to the European Union's energy supply was of 1900 PJ. This contribution was of approximately two thirds of the entire energy production achieved by renewable resources in the European Union.

For bioenergy, the following tendencies have been observed:

- Heat: In the year 1990, the production of thermal energy from biomass was of approximately 1500 PJ;
- Electricity: the production of electric energy from biomass was of 54 PJ in the year 1990 and increased to 166 PJ in 1999 (an increase of 9% per year);
- Fuel: the present contribution of biofuels is of approximately 25 PJ, almost negligible in the overall production of bio-energy.

Despite the modest role of bio-fuel in terms of energy, the production and use of biomass increased rapidly in the last 10 years. The production of bio-diesel increased from 80 Ktons in 1993 to 780 Ktones in 2001. The production of ethanol in the European Union increased from 48 to 216 ktones in the same period. France, Spain and Sweden are the three main players on the European energy market (*Berkesy. 2011*).

Up to the present, six member states of the European Union wish to enforce tax programs to support the use of bio-fuel (Austria, Belgium, Germany, Spain, Italy and Sweden). In these charts biofuels are exempt from taxes, as compared to fossil fuels used for transportation.

Renewable energy resources represent one of the replacement variants for fossil fuels in Romania and worldwide with high development perspectives in the future. In Romania, it is estimated an energy consumption of 34.9 Mtoe (million tones oil equivalent) until 2020. Biomass covers more than 60% of the entire renewable energy sources, respectively 190-200 PJ/year. (Gherghicescu,1997).

Presently, a great part of the energy necessary for humankind is produced from fossil fuels. Fuel can be found under three forms, respectively fossil fuel, nuclear fuel and renewable fuel. Researchers from all countries applied a multitude of projects in order to reduce carbon dioxide emissions (*Astburg. 2000*) .

In approximately 50 years, according to European Union statistics, all fossil fuels in the world will be exhausted. It is predicted that the entire world will suffer from a huge energy deficit which must be covered by production of alternative energy (*Eisentraut. 2012*). The biggest risk of fossil fuel use is represented by the toxic emission discharged in the atmosphere.

The production and consumption of fuel materials ensured the quality of living necessary for humankind. The biomass reserves differ throughout the territory of the European Union, as well as worldwide. The forest spreading area varies from 27. 6 million hectare in Sweden to 117 hectares in Cyprus. Worldwide, the forest fund occupies approximately 4 billion hectares, the biggest quantity being distributed on the territory of the Russian Federation- 809 million hectares, Brazil 478 million hectares, Canada 310 million hectares, U.S.A. 303 million hectares, China 197 million hectares.

Biomass is a renewable energy source by its renewal year after year; it is widely spread worldwide and possesses great costs as compared to fossil fuel. Biomass resources of which fuel material is produced. It may include wood, wood waste, agricultural cereals and waste resulted from their production, municipal waste, and animal dejections (*Beldean. 2004*).

Biomass under vegetal form is a complex compound and differs from a species to another. It contains all form of vegetal matter, growing on the surface of the earth, in the water or above the water, as well as substances produced by biological development (*Lunguleasa 2007.2008*).

Research performed in the field of energy proves that electrical energy and heat can be produced from biomass by conversion processes. In 2009, biomass ensured approximately 10% (50 EJ) (1EJ=10^{18} J) of the entire primary energy produced worldwide.

Biomass takes part in the carbon cycle in nature by use of carbon dioxide. Carbon dioxide participates to the photosynthesis processes during the growth, but it is the component determining a more complete burning during wood combustion (*Aghamohammadi. 2011*).

Presently, biomass contributes by approximately 12% to the production of primary energy in worldwide and in the developing countries this occupies 40-50% of the necessary energy.

Romania holds a surface of 6300 thousand hectares representing 27% of the existing territory.

Biomass resources presently represent the raw material resulted from wood processing, agricultural, municipal waste and animal dejections (Cleveland. 2009).

Biomass differs from the other renewable sources by the fact that it represents a rich raw material which can be transformed by various conversion processes in liquid, gaseous and solid fuel. Biomass is divided in 4 categories described in the Regulation SR EN 14961-1:

- Forestry production: wood, waste resulted from wood cutting, sawdust, shrubs;
- Waste resulted from agricultural production, cereal waste.
- Energetic cereals: crops from short term processing, starch crops (corn, wheat, barley), sugar crops (sugarcane, sugar beet), fodder crops (grass, alfalfa), oleaginous crops (sunflower, soy, safflower)

MATERIAL AND METHOD

The determination of the calorific value for wood is similar to that of coal (as solid fuel) and with little differences as compared to liquid fuel (benzene) or gaseous one (natural gas, biogas).

The equipment used for the determination of the calorific value of the wood biomass was the calorimeter with explosive burning type XRY-1C, manufactured by Shanghai Changji Geological Instrument Co. din China (Fig1).

Before performing the proper said attempt, the calorimetric bomb is calibrated with benzoic acid with a known calorific value (usually 26 463 kJ/kg (1kJ/kg=1J/g) with slight differences of maximum ±3% as compared to this value) in order to assess the *k* calorific coefficient of the calorific equipment.

$$PCS_s = k \cdot \left(\frac{(t_f - t_i)}{m_l}\right) - q_s - q_b [kJ/kg]; \quad (1)$$

where: k – calorific coefficient determined by calibration with benzoic acid, expressed in kJ/grad; t_f – final temperature, in degrees; t_i – initial temperature, in degrees; m_l – wood mass, in kg; q_s – heat consumed for the burning of the nickeline wire in kJ; q_b – heat obtained by burning of the cotton thread, in kJ.

The assessment procedure of the calorific value of the wood mass refers first to all to the preparation of the raw material and the equipment, then to the proper said assessment and finally to the obtainment of the final result. The preparation of the wood mass for testing consists of sampling a small part of a approximately 0.6 – 0.8 grams of the entire material weighted with a precision of 0.0002 g. The sample must be clean originating from freshly cut wood because old wood does not have all volatile and flammable substances, fact that might influence its calorific value. This sample is placed in a porcelain crucible and placed in a laboratory autoclave to allow drying at a temperature of 103±2 °C.

The obtainment of the anhydric state of the wooden mass is checked by successive weighting until the difference between the two successive weightings becomes smaller than the double of weighting precision or covers for a piece of such size of at least 2 hours of keeping the piece in the autoclave.

After drying, the samples are kept in exsiccator to cool down and maintain the humidity content until its placement into the calorimetric bomb.

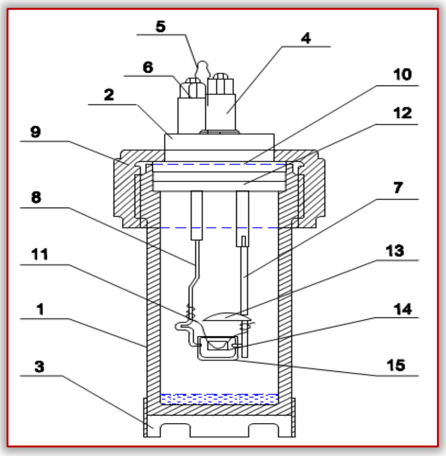

Figure 1 - Equipment for the assessment of the calorific value of the wood biomass with calorimetric bomb with own soft

In industrial practice there are manufacturing by remains from all wood species that can be processed. Therefore, in the research process the indigenous broadleaf category was used: Acer Pseudoplatanus and Salix Alba.

The inferior calorific value of wood is determined on basis of higher calorific value: by means of the ratio:

$$PCI_i = PCS_s - 6 \cdot (U + 9 \cdot h) \ [kJ/kg] \quad (2)$$

where: PC_s- superior calorific value (kJ/Kg); U- dampness of the wood sample (Kg/Kg); h- hydrogen content of the wood sample (3.6%).

The preparation of the equipment for the trial refers to the checking of the water quantity from the calorimeter or hod Cu (so as not to exceed by 1-2 mm the lid of the calorimetric bomb). The water Ap agitator A from the hod, the computer software C. the exterior thermometer of the calorimeter T and the gas pressure in the oxygen tank Bo. The test sample 1 is connected to the cotton thread 2 and placed in the calorimeter crucible 3. The nickeline spiral thread is tied 4 to the cotton thread after which the protection lid is properly placed. 5. The crucible is connected to the calorimetric bomb's lid 6 by means of two electrodes 7 and 8 which continue with the connective electric wires of the calorimetric bomb 9 and 10. By screwing in the lid of the calorimetric bomb, the bomb is connected 11 by screw 12 to the oxygen tank, entering 30 atmospheres. The bomb is placed in the equipment calorimeter Cu, it is connected by means of the two electric wires. The calorimeter's lid is closed and the thermostat T is placed inside to determine the temperature (Figure1).

Next, the computer software is accessed filling in the type of test (assessment or calibration), sample name, sample mass of the nickeline and cotton thread, as well as further necessary information. After this, the operation for the assessment of the calorific value begins by selection and activation of the "START" button from the computer program displayed on the computer display (Figure2). This is the start moment of the calorific value assessment.

The final result of wood biomass burning is expressed by calorific value, notion by which is understood the quantity of heat obtained by burning of the mass unit. For combustible materials with high hydrogen and water content such as the wood biomass, two calorific values can be distinguished, namely the superior calorific (PCS) and inferior calorific value (PCI). PCS is determined directly by means of the calorimetric bomb where the water vapors are formed by burning of the hydrogen contained in the wood, as well as the ones formed by decomposition of the water are condensed in the bomb. Discharging approximately 2 510.4 kJ (600 kcal) for every kilo of condensed water vapors (the so-called condensation heat). PCS cannot be used, practically due to the fact that the water vapors are discharged outside by a funnel and only the PCI can be used effectively.

RESULTS

The test contains three distinct stages (Figure2), namely:

— the fore period ("fore"). Its purpose being the determination of the temperature variations in the calorimetric pot due to heat exchange with the exterior before the burning. During this period, usually lasting 5 minutes, the temperature is displayed and read every minute using the precision thermocouple meter. The last temperature from the fore period represents in fact the first temperature from the main period. The values of the recorded temperature in this period are usually seven. After recording the sixth value, the burning of the material takes place (Figure 2) and it is displayed on the menu bar ("Burning time").

— The main period ("main") starts by ignition of the sample having as consequence the temperature rise in the calorimetric pot due to burning of the wood particle and heat discharge. In order to determine the final temperature, the temperature values are displayed every minute. The final temperature is given by the maximum value of the temperature, because after its decrease, the calorimetric pot is not receiving heat from the bomb. The values recorded during this period vary depending on the burning time of the combustible material in the calorimetric bomb. The number of values may vary in the range of 19-42 temperature values recorded during this period.

— The after period ("after") has the purpose of determining the average temperature variation in the calorimetric pot due to heat exchange with the exterior after the burning. Just like in the fore period, the temperature is displayed every half minute for a period of 4-5 minutes, being recorded an average of 8-10 temperature variation values.

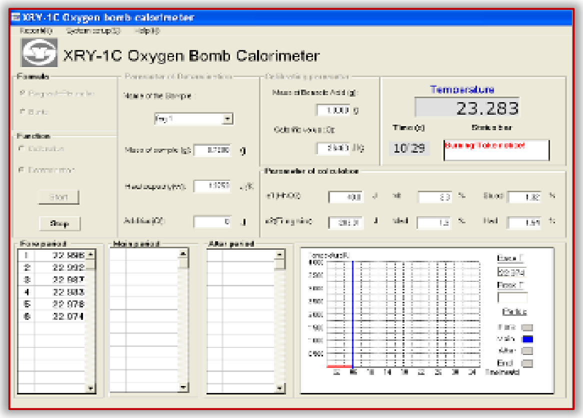

Figure2 - Description of the process
for determining the calorific value

For acer pseudoplatanus for 0% humidity was obtained the superior calorific value 18802 kJ/kg. and inferior calorific value 18336 kJ/kg; for 10% humidity was obtained the superior calorific value 16805 kJ/kg and inferior calorific value 16618 kJ/kg; for 20% humidity was obtained the superior calorific value15041 kJ/kg and inferior calorific value 14668 kJ/kg; for 50% humidity was obtained the superior calorific value 9749 kJ/kg and inferior calorific value 9166 kJ/kg.

In Figure 3, is presented the variation calorific value function moisture content for Acer pseudoplatanus.

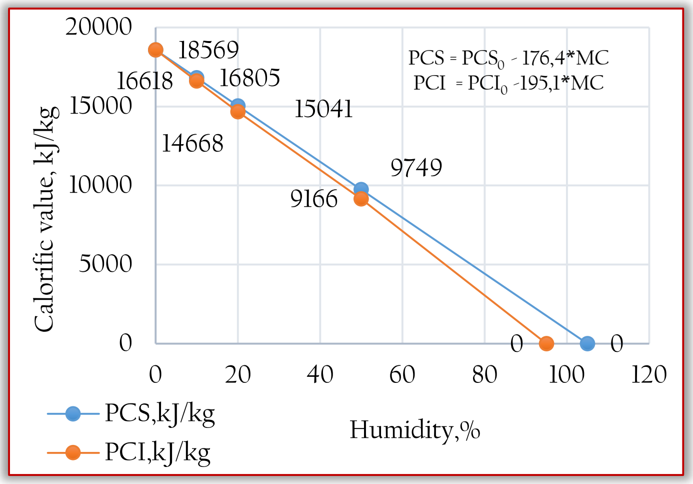

Figure 3 - The graphic calorific value
for Acer pseudoplatanus

For salix alba for 0% humidity was obtained the superior calorific value 20830 kJ/kg. and inferior calorific value 20224 kJ/kg; for 10% humidity was obtained the superior calorific value 17846 kJ/kg and inferior calorific value 17259 kJ/kg; for 20% humidity was obtained the superior calorific value14862 kJ/kg and inferior calorific value 14294 kJ/kg; for 50% humidity was obtained the superior calorific value 6364 kJ/kg and inferior calorific value 4944 kJ/kg.

In figure 4 is presented the variation of calorific value function moisture content for Salix Alba.

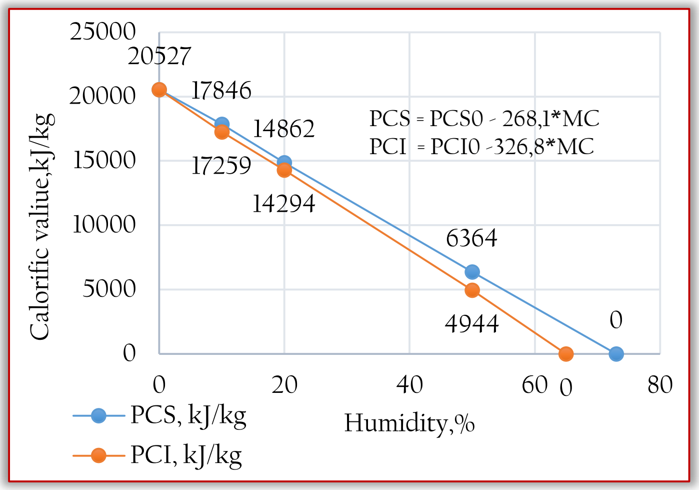

Figure 4 - The graphic of calorific value for Salix alba

CONCLUSIONS

- The wood biomass burning is a non-ecological process, but indispensable to human activity due to the thermal energy it produces;
- Wood biomass is twice renewable, first by being part of the vegetal world obtained by photosynthesis and secondly by trees recycling the carbon in the nature;
- For Acer Pseudoplatanus for 0% humidity the superior calorific value is 18802 kJ/kg and for 50% humidity the superior calorific value is 9749 kJ/kg; for Salix Alba for 0% humidity the superior calorific value is 20224 kJ/kg; for 50% humidity the superior calorific value is 6364 kJ/kg;
- The research shows that as the humidity of the wood is lower the superior calorific value is higher.

Note: This paper is based on the paper presented at ISB-INMA TEH' 2017 International Symposium (Agricultural and Mechanical Engineering), organized by University "POLITEHNICA" of Bucharest – Faculty of Biotechnical Systems Engineering, National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Scientific Research and Technological Development in Plant Protection Institute (ICDPP), National Institute for Research and Development for Industrial Ecology – INCD ECOIND, Research and Development Institute for Processing and Marketing of the Horticultural Products "HORTING" and Hydraulics, Pneumatics Research Institute INOE 2000 IHP, University of Agronomic Sciences and Veterinary Medicine of Bucharest (UASVMB) – Faculty of Horticulture and Romanian Society of Horticulture (SRH), in Bucharest, ROMANIA, between 26 – 28 October, 2017.

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