

## EXPLORING THE ENERGY PERFORMANCE OF WOOD CHIPS FROM *SALIX VIMINALIS* – KLON TORDIS

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### ABSTRACT

The article presents the methodology and results of an experimental testing of the calorific value and ash content of wood chips, used as a fuel for heating and electricity plants. The wood chips was extracted from willows' short rotation plantation of *Salix Viminalis* – klon Tordis. Studies were conducted in the “Department of Forest Harvesting, Logistic and Amelioration” of the Technical University in Zvolen, R of Slovakia. Wood chips produced from *Salix Viminalis*, klon Tordis indicates a high gross (20,597 MJ.kg-1) and net calorific value of dry mass (19,255 MJ.kg-1) under the specific production conditions. Naturally dried wood has a relative humidity  $W_r = 11,3 \%$  and according to ISO 1928:2011 it has a clean net calorific value 16,907 MJ.kg-1. This gives grounds to assume that the wood produced from such an energy plantation will have high energy characteristics and will satisfy the market for energy chips.

**Key words:** wood chips, willow, calorific value, ash contents

### 1. INTRODUCTION

The wood energy chips are solid fuel, which is characterized by certain quality indicators - calorific value, ash content and moisture (STN EN 14961-1:2010). The quality and cost of manufactured chips is determined by these parameters. The wood chip for energy production is the primary product from wood biomass (Fig. 1). The total energy equivalent of the produced biomass energy in

2011, reached 961 ktoe here in the country (AEBIOM). Biomass forms 5,03 % of the gross domestic energy consumption in the country. It should be noted, however, that the greater part of this biomass – over 95 %, consists of a solid fuel wood (Trichkov 2012). These logs are designed for heating of individual households that use heating devices of an older generation and with lower efficiency.



Figure 1: Energy wood chips

In order to achieve higher energy efficiency and better use of this energy, it is necessary to introduce new and advanced high-tech heating systems. These systems operate with biomass in the form of wood energy chips and pellets. Pellet heating systems are used for local heating of individual households or for entire buildings. The pellets are

suitable for transport and storage, but they require an additional drying and pressing, resulting in a slight increase in their prices. Wood energy chips is about two times cheaper than pellets and is suitable for powering larger heating systems such as industrial steam raising plants, local and municipal heating plants and power plants (Fig. 2).



**Figure 2: Municipal heating plant using wood chips, Topolčany, Slovakia**

Energy plantations from fast-growing tree species (SRF) is a relatively new kind of intensive crops intended for the production of wood energy chips. Nowadays, these crops are created and developed successfully in many European countries, with clear rules and regulations for development, use and trading with this type of fuel. Currently in our country these plantations are at the stage of experimental study and still do not have industrial and commercial significance.

One of the main reasons for this are the few and limited energy capacities, operating on biomass. The lack of uniform regulations and a market for energy energy chips are limiting factors. At the same time, the growing of energy plantations requires certain investments and represents certain economic and market risks for the entrepreneurs. Benefits from energy plantations are indisputable, and

the more important of them are rhythmic and secure of fuel supply, providing of jobs, providing additional income for farmers, utilization of fallow land, rural development and others.

Of specific interest for our country are trees such as willow and poplar with suitable branch selection. There is extensive experience in terms of breeding and selection of these fast-growing species for the production of CTL (technological and construction) wood in our scientific and research organizations. This is a prerequisite for the provision of quality seeds for energy plantations on our market too.

The aim of this study is to investigate the main energy characteristics of wood chips produced from a willow energy plantation of *Salix Viminalis* – klon Tordis.

## 2. MATERIAL AND METHODS

The study material is wood energy chips



from willow sticks, derived from an experimental energy plantation from *Salix Viminalis* klon Tordis (Fig. 3).



Figure 3: Soil-preparation and current view of willow plantation – Hrabiny, Slovakia

The experimental plantation is owned by the Technical University of Zvolen. The plantation area is 25 dka and is located near the village of Hrabiny in Slovakia. The area is located on flat terrain with a slope of  $2\div 3^\circ$ . The soil is sandy and loamy and slightly acidic with medium heavy mechanical composition. Humus content is low to moderate. The content of nutrients in the soil it is favorable for the crop, as the greater part is supplied with calcium, magnesium, phosphorus and potassium. The altitude is 595 m, annual rainfall is 805-850 mm, and the average annual temperature is  $7,5^\circ\text{C}$ .

The greater part of the area is well-supplied with water, accessible for the plants. The plantation was established in May 2007.

Willow cuttings of  $1,20 \times 0,5$  m were planted for this purpose. Reverse plow was used for the primary treatment of the soil to a depth of 35 cm, and rotary cultivator for the pre-planting. The annual yield of dry biomass is expected to be within  $8$  to  $11 \text{ t}\cdot\text{h}^{-1}$  per year (Dzurenda L., Jandačka J. 2010). Rods produced in early 2012 and stored in piles in the open, were used for the purpose of this survey. The test samples were taken in September the same year, and they were used for analytical samples (Fig. 4). The test was conducted in a measuring laboratory at the Department of "Forestry Harvesting, Logistics and Ameliorations" in the Technical University of Zvolen, Slovakia.



**Figure 4: Willow sticks and test sample of wood chips**

In order to achieve the goals, the experimental study was aimed at identifying the main characteristics of biomass energy - moisture content, calorific value and ash content in the sample ((Dzurenda et al 2012, Lieskovský et al 2009).

### 2.1. DETERMINING THE RELATIVE HUMIDITY

The determination of the moisture content was performed by laboratory drying of an analytical sample (gravimetry), according to EN 14774-1, EN 14774-2. This process describes how to determine the water content of wood chips, which may be used as fuel.

The principle of this method is to find out the weight of wet and dry wood, weighed to the nearest 0,01 g. Drying takes place in a laboratory oven "Memmert". Drying of the samples is carried out at a temperature of  $103 \pm 2$  °C, until constant weight is achieved, wherein the weight change between two weightings, with an interval of two hours, does not exceed 0,01 g. The relative humidity  $W_r$  may be calculated on the basis of the

weight of the sample before and after drying. The relative humidity of the wood is defined as the ratio of the weight of the water contained in the sample wood material and the weight of the moist wood sample.

Determining the relative humidity of the sample is represented by the equation,

$$W_r = \frac{m_w - m_o}{m_w} \times 100, \% \quad (1)$$

where  $m_w$  is the mass of the fresh sample, g;

$m_o$  – the mass of the dry sample, g.

### 2.2. DETERMINATION OF CALORIFIC VALUE

Higher heating value  $Q_s$  or gross calorific value is defined as the heat, released in the complete combustion of 1 kg of fuel and cooling the flue gases and ash to the initial temperature ( $T_N = 25$  °C) in which water vapor condenses into water (STN 48 0058:2004 and БДC ISO 1928:2011). A calorimeter is used for solid fuels, model IKA C200 (Fig. 5) in order to determine the calorific value.



**Figure 5: Calorimeter IKA C-200**

The lower heating value or net calorific value  $Q_n$  is defined as the heat, released by the complete combustion of 1 kg fuel, with fuel cooling to an ambient temperature in which water remains in the gaseous state. It

is calculated based on the gross calorific value of the samples combustion in accordance with STN 48 0058:2004. For determina-

tion of the parameters of the heating equipment, the net calorific value of the fuel is usually used.

*Method for determining gross calorific values in the calorimeter IKA C200*

The analytical sample is mixed and a test sample between 0.8 and 1.5 grams is weighted. The measurement accuracy is up to 0,0002 g. The test sample is placed in a ring-shaped crucible for burning and is closed in the decomposition vessel. A cotton thread, two electrodes and ignition wire is used for the ignition of the sample. The calorimeter vessel is sealed with a union nut and is filled with oxygen under pressure 2,5÷3,5 MPa. A filling oxygen station "Messer" is used for this purpose. The calorimeter is filled with 2 liters of water, dispensed automatically. The water temperature in the jacket of the calorimeter is maintained within  $\pm 0,5$  °C to the ambient temperature in the laboratory.

Determination of the upper calorific value is done using specialized software C 5040 Calwin. After ignition of the control sample, the main stage of the measurement commences, as the temperature is displayed on the calorimeter. At the beginning of this stage, the temperature rises more quickly, and after that it starts to decrease and at the

end of this stage it reaches its maximum. After about 5 minutes, the final stage of the measurement occurs, at which the temperature drops slowly. After deduction of the last temperature, the measurement is considered completed. The value obtained from the measurement of the gross calorific value is displayed on the screen of the calorimeter. It is defined by the formula

$$Q_s = \frac{C(D_t - K) - c}{m}, \quad (2)$$

where  $C$  is the heat capacity of the calorimeter,  $J \cdot ^\circ C^{-1}$ ;

$D_t$  – general rise in temperature at the main stage, °C;

$K$  – correction for heat exchange with the environment, °C;

$m$  – the mass of the test analytical sample, g;

$c = c_1 + c_2 + c_3 + c_4$  – are the corrections,  $c_1 = 50$  J is the correction for the heat released from the burning of the thread, whereas  $c_2$ ,  $c_3$  and  $c_4$  are negligible, J.

*Method for the determination of net calorific value*

Net calorific value is calculated according to STN ISO 1928:2004 by the following formula:

$$q_{V,net,m} = [q_{V,gr,d} - 206,0 \cdot w(H)_d] \cdot (1 - 0,01 \cdot M_T) - 23,05 \cdot M_T, \quad (3)$$

where  $q_{V,net,m}$  is the net calorific value of the fuel at constant volume and water content, kJ/kg;

$q_{V,gr,d}$  – gross calorific value at constant volume and free water, kJ/kg;

$w(H)_d$  – the hydrogen content of the sample, %;

$M_T$  – the relative humidity of the sample, %.

### 2.3. DETERMINATION OF ASH CONTENT

The practical method for determining the ash content is carried out in accordance to STN ISO 1171 "Solid fuels". A sample of about 2 g is weighted on a porcelain vessel. The mass of the sample is determined by a laboratory electronic scales "Kern", with an accuracy up to 0,0001 g. Samples are dried beforehand in a "Memmert" oven at a temperature of  $103 \pm 2$  °C to constant mass. The

essence of the method is a sample combustion in a muffle electric furnace, model VEB LM 212 (0-1200 °C).

The sample is heated in air at a specific rate to a temperature  $815 \pm 10$  °C to constant weight. For this purpose, the furnace temperature is gradually increased for 60 min to 500 °C, then the temperature is maintained for 30 min. Afterwards the temperature is increased again to 815 °C and is maintained constant for 60 min. After completion of the process, the vessel with the sample is removed from the muffle furnace and cooled on a metal plate for 10 min. Thereafter, the sample is transferred to a desiccator or other closed container and is left to cool to room

temperature. After cooling, the sample is weighed to an accuracy of 0,0001 g. The ash content is calculated according to the weight of the residues after combustion of the sample.

### 3. RESULTS AND DISCUSSION

Annual willow branches, obtained in experimental plantation in early 2012 were used for this survey. The branches have been stored in a warehouse plantation outdoors. The samples were taken on 11.09.2012 and tested the next day in a laboratory of the Technical University in Zvolen. The survey results are presented in Table 1, 2 and 3.

**Table 1: Estimation of relative moisture content**

Parameters	Estimation
Weight of wet sample, [g]	316,19
Relative moisture, [%]	11,3

**Table 2: Estimation of gross and net calorific value**

Parameters	Estimation
Weight of the sample, [g]	1,4514
Gross calorific value, [MJ.kg <sup>-1</sup> ]	20,597
Net calorific value according to ÖNORM M 7132 for moisture 0%, [MJ.kg <sup>-1</sup> ]	19,255
Calorific value according to ÖNORM M 7132 as supplied, [MJ.kg <sup>-1</sup> ]	16,797
Calorific value according to ISO 1928 as supplied, [MJ.kg <sup>-1</sup> ]	16,907

**Table 3: Estimation of ash content**

Parameters	Estimation
Sample weight, [g]	2,4075
Weight of ash, [g]	0,0683
Ash content in weight percent, [%]	2,84

The measured relative humidity of the test sample is relatively low – 11,3 % , which is a consequence of the natural drying of the wood in the open. The measured average calorific value of the sample in dry state is 19,255 MJ.kg<sup>-1</sup>. This value is a good indicator of wood that will be used as fuel. Due to the relatively low humidity of the tested material, the net calorific value is relatively high – 16,907 MJ.kg<sup>-1</sup>. Ash content of the

sample is 2,84 %. This is due to the younger age (1 year old) of harvested willow sticks and correspondingly the higher content of bark in the mass of the sample.

The obtained results show high energy values of the wood of *Salix Viminalis*, klon Tordis. Natural drying of the material to 11,3 % relative humidity improves its net calorific value. The produced chips from this wood material have high energy values and

are suitable for solid fuel for direct combustion in thermal biomass power plants. In order to reduce the ash content in the fuel, it is necessary to use more mature wood with less bark content in the chips.

### CONCLUSION

Energy plantations from *Salix Viminalis* are suitable for Bulgarian condition. Klon Tordis is selected and heavy-duty willow species, from which it can be obtained between 8 and 11 tons dry biomass per year on average. There are objective natural and climatic conditions for the establishment of industrial plantations of this fast-growing tree species in our country. One rotation cycle of this energy crop may vary between two and five years, depending on the type and quality of the soil, the average temperature, the amount of rainfall and the machines used for production of biomass.

The analysis of the energy characteristics of the wood chips produced from *Salix Viminalis*, klon Tordis indicates a high gross (20,597 MJ.kg<sup>-1</sup>) and net calorific value of dry mass (19,255 MJ.kg<sup>-1</sup>) under the specific production conditions. Naturally dried wood has a relative humidity  $W_r = 11,3\%$  and according to ISO 1928:2011 it has a clean net calorific value 16,907 MJ.kg<sup>-1</sup>. This gives grounds to assume that the wood produced from such an energy plantation will have high energy characteristics and will satisfy the market for energy chips. To reduce the ash content in the wood, it is necessary that the yield occurs not earlier than the second or third growing season of the crop.

Wood energy chips as a renewable bio-fuel for heating are becoming more and more important substitution for fossil fuels. Their big advantages are the utilization of biomass waste from logging and forest industry and the ability to establish energy plantations on

unproductive agricultural areas. The energy chips have price about 100 – 110 € (EU) per one ton, with calculated price about 5,8 – 6 € per one GJ of energy is present attractive bio-fuel for heating and electricity plants.

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