ENERGY CHARACTERISTICS OF THE WOOD-CHIP PRODUCED FROM SALIX VIMINALIS

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Abstract

This article explores the energy characteristics of the wood-chip produced from Salix viminalis. which was cultivated at an energy plantation. The higher heating value of wood and bark of the Salix viminalis was assessed through an experimental measurement in a special calorimeter for solid fuels, model IKA C 200. Lower heating value of wood and bark were calculated from the higher heating value Qs, as well as the hydrogen [H] and water content [W] in the fuel samples that were assessed in a laboratory. These analyses assessed the higher heating value and lower higher heating value of a dry Salix viminalis wood (Qs = 19753 kJ.kg^{-1} and Qn = 18339 kJ.kg^{-1}). The higher heating value and lower heating value of a dry Salix viminalis bark was also assessed Qs = 19732kJ.kg^{-1}, and Qn = 18209 kJ.kg^{-1}. The share of bark in the wood-chip produced from Salix viminalis was assessed 23,86%, in accordance with the Slovak technical norm STN 48 0058 for assortments of wood, wood chips containing leaves, and sawdust. The lower heating value of wood chip produced from Salix viminalis in a dry state was calculated, based on the lower heating value of salix wood, the lower heating value of salix bark, and the share of bark in the wood chip as a weighted average. Qn = 18308 kJ.kg^{-1}.

Key words: higher heating value, lower heating value, salix, wood, bark, wood chips, energy plantations

Intrduction

Wood, and wood residues from forestry and wood processing industry, can be used as a fuel. Wood fuel has an average higher heating value, a high share of siccative combustibles and a low content of ash. It is an important renewable energy source.

Numerous plantations of short rotation coppice were established in Central Europe in the last thirty years, mainly to increase production of biomass for production of energy. A minimum annual production of biomass from these plantations was 10 m^3.ha^{-1}. According to several studies [5, 11, 10, 13, 14] the most suitable short rotation coppice for energy production in the Central Europe are acacia (Robinia psedoacacia L.), selected poplar clones (Populus), and salixes (Salix alba L., Salix viminalis).

This article presents some results of the experimental work undertaken to assess energy characteristics of wood chips produced from short rotation coppices of Salix alba L. that was cultivated at plantations for energy purposes. The energy characteristics assessed contain two values: the higher heating value, and the lower heating value.

Experimental research

Samples of wood and bark of Salix viminalis. to assess the energy characteristics were taken from a wood chip produced from four-year-old plantations, Fig. 1.

The higher heating value of the above mentioned samples of salix viminalis, which were dried beforehand to a constant weight (W_a = 0%), was assessed in a special calorimeter for solid fuels, model IKA C 200 in accordance with the Slovak technical norm STN 44 1352 for assessment of the higher and lower heating values of solid fuels.

Fig. 1. Plantage of Salix viminalis

Elementary analyses of wood and bark samples of Salix viminalis, including the assessment of share of ash in wood and bark, were undertaken by team of experts from the Forestry Laboratory of the National Forest Centre in Zvolen, Slovakia.

The content of hydrogen in the analysed samples of wood and bark was assessed on a special analyzer, model NCS-FLASH EA 1112, produced by Thermo Finnigen.

The lower heating value of wood and bark samples in a dry state was calculated using the formula stated below. Inputs into the formula were: the measured higher heating values of the wood and bark samples, and a laboratory assessment of the contents of hydrogen and water of the same wood and bark samples.

$Q_n = Q_s - 24{,}54.(W_r + 9.H^{daf})$ (kJ.kg^{-1}) (1)

where:

Q_s – higher heating value of analysed sampled in a dry state (kJ.kg^{-1});

W_r – water content in the analysed sample, $W_r = 0$ (%);

H^{daf} – share of hydrogen in the combustible sub-stance of analysed sample (%).

The share of bark on the wood chip produced from Salix viminalis was assessed by a laboratory technique at the Faculty of wood sciences and technology of the Technical Univerzity in Zvolen. The assessment was undertaken in accordance with the Slovak technical norm STN 48 0058:2004 on assortments of wood and wood chips containing leaves, and sawdust. The share of bark was assessed using the following formula:

$$X_K = \frac{m_K}{m_Š}.100 \quad (\%) \qquad (2)$$

where:

m_K = weight of bark in a wood chip sample (g);

$m_Š$ = weight of wood chip sample (g).

Based on the above specified energy characteristics of wood chip produced from Salix viminalis, an average energy value of the higher heating value of the wood chip in a dry state was calculated using the following formulas:

Higher heating value of a dry wood chip:

$$Q_S = \left[\frac{100 - X_K}{100}\right].Q_{S-D} + \frac{X_K}{100}.Q_{S-K} \quad (\text{kJ.kg}^{-1}) \qquad (3)$$

Lower heating value of a dry wood chip:

$$Q_n = \left[\frac{100 - X_K}{100}\right].Q_{n-D} + \frac{X_K}{100}.Q_{n-K} \quad (\text{kJ.kg}^{-1}) \qquad (4)$$

where:

X_K – share of bark in the wood chip (%);

Q_{S-D} – higher heating value of wood (kJ.kg^{-1});

Q_{S-K} – higher heating value of bark (kJ.kg^{-1});

Q_{n-D} – lower heating value of wood (kJ.kg^{-1});

Q_{n-K} – lower value of bark (kJ.kg^{-1}).

Results and discussion

Elementary chemical analysis of samples of wood and bark of wood chip produced from Salix viminalis. are shown in Table 1 below.

Table 1. Shares of elementary *combustible* particulates and ash in wood biomass *Durkovicova (2009)*

Salix alba L.		C^{daf} (%)	H^{daf} (%)	O^{daf} (%)	N^{daf} (%)	Ash (%)
Wood	Sample 1	49,16	6,35	44,04	0,45	0,17
	Sample 2	50,00	6,47	43,08	0,45	0,18
	Sample 3	49,58	6,38	43,16	0,43	0,16
	Averages	*49,58*	*6,4*	*43,43*	*0,44*	*0,17*
Bark	Sample 1	52,44	6,90	39,39	1,27	2,1
	Sample 2	51,15	6,91	40,70	1,24	2,5
	Sample 3	51,35	6,87	40,49	1,29	2
	Averages	*51,64*	*6,89*	*40,19*	*1,26*	*2,2*
Extended relative indeterminateness of the measurements						
U [%]		5	5	2	5	

Comparative analyses of the chemical composition of juvenile wood and the bark of wood produced from Salix viminalis cultivated at the/an energy plantation, and the chemical composition of mature wood and bark from overmatured broadleaves trees show that the juvenile wood of Salix viminalis contains between 3%-19% more hydrogen than is commonly found in mature broadleaves wood [4, 9, 7, 12]. The comparative analyses also show that the juvenile Salix viminalis wood contains between 140%-380% more nitrogen than is commonly found in mature broadleaves wood [2, 8, 11].

The assessed higher content of nitrogen in the juvenile wood of Salix viminalis proves that there is a higher content of albumin in the plexus of the juvenile wood. The content of nitrogen in an immatured bark of Salix viminalis is about 121%-126% higher than the common share of nitrogen in bark of older broadleaves. This is caused by presence of albumin in cambium cells, as well as by chlorophyl in the surface plexus of the immature bark.

The experiments undertaken resulted in an assessment of the average share of bark X_K on the analysed wood chip:

$$X_K = 23{,}86 \pm 0{,}334 \quad (\%)$$

The assessed value X_K does not exceed the maximum limit ($X_K = 30\%$) set by the Slovak technical norm STN 48 0058, which was endorsed in 2004. The assessed value of the share of bark X_K is about 3 times higher than the share of bark on the wood of beech, about 2 times higher than the share of bark on the wood of oak and poplar, and about 1,7 times higher than the share of bark on the wood of alder [1].

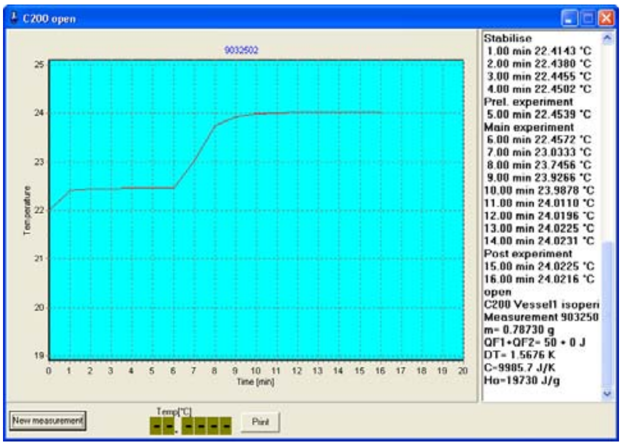

Fig. 2. Equilibrium of a higher heating value of the analysed wood sample Salix viminalis

The graph on the Figure 2 shows the temperature equilibrium of a higher heating value, measured in a calorimeter, of the wood sample of Salix viminalis and the graph on the Figure 3 shows the temperature equilibrium of a higher heating value, measured in a calorimeter, of the bark sample of Salix viminalis.

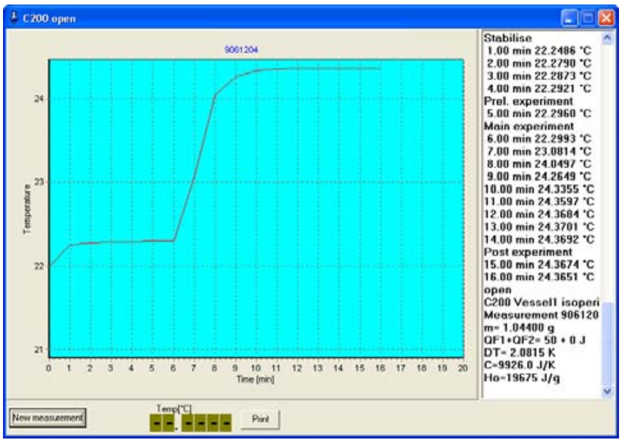

Fig. 3. Equilibrium of a higher heating value of the analysed bark sample Salix viminalis

Table 2 below includes the results of measurement of the higher heating value of three samples of wood and bark of Salix viminalis. which were dried beforehand into a constant weight.

Table 2. Higher heating value and lower heating value of wood and bark of Salix viminalis

Samples	Wood (kJ.kg^{-1})		Bark (kJ.kg^{-1})	
	Higher heating value	Lower heating value	Higher heating value	Lower heating value
Sample 1	19 805	18 402,5	19 809,1	18 285,2
Sample 2	19 730	18 301,1	19 700,4	18 174,3
Sample 3	19 724	18 314,9	19 685,7	18 168,4
Average values	19 753	18 339,5	19 731,7	18209,3

The assessed higher heating value of Salix viminalis. in a dry state is comparable with the value poplar published by [6]: $Q_s = 19880$ kJ.kg^{-1}.

The average value of the lower heating value of wood chip produced from Salix viminalis in a dry state with the average share of bark $X_K = 23{,}86\%$ is determined by the formula (4) as $Q_n = 18\ 308$ kJ.kg^{-1}.

Conclusions

Based on the experiments, the following conclusion can be made: Wood chip produced from Salix viminalis which was cultivated at an energy plantage contains significantly higher shares of both hydrogen and nitrogen than is commonly found in the wood biomass of matured broadleaves. The share of bark on the same wood chip was assessed as $X_K = 23{,}86\%$ Analyses of energy characteristics of wood chip produced from Salix viminalis. show that the higher heating value of the juvenile wood of Salix viminalis. in a dry state is $Qs = 19753$ kJ.kg^{-1}; for dry bark of the same wood it is $Qs = 19732$ kJ.kg^{-1}. The lower heating value of the wood chip of Salix viminalis. in a dry state is $Qn = 18308$ kJ.kg^{-1}.

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