Energy Characteristics of Wood-Chips Produced from Salix Viminalis - Clone ULV

Energijska obilježja iverja proizvedenoga od drva Salix viminalis – klona ULV

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ABSTRACT • This article explores the energy characteristics of wood-chips produced from Salix viminalis - clone ULV, which was cultivated in an energy plantation.

The higher heating value of wood and bark of Salix viminalis was assessed through an experimental measurement in a special calorimeter for solid fuels, model IKA C 200. The lower heating value of wood and bark was calculated from the higher heating value $Q_h$, taking into account hydrogen $H_{daf}$ and water content $W_r$ in fuel samples that were assessed in a laboratory.

The higher heating value and lower heating value of a dry Salix viminalis wood ($Q_{SW} = 19,520$ kJ/kg and $Q_{nW} = 18,044$ kJ/kg) were assessed by these analyses. The higher heating value and lower heating value of a dry Salix viminalis bark were also assessed ($Q_{SB} = 19,389$ kJ/kg, and $Q_{nB} = 17,997$ kJ/kg).

The share of bark of 19.35 % was assessed in wood-chips produced from Salix viminalis - clone ULV, in accordance with the Slovak Technical Norm STN 48 0058 for wood assortments, wood chips containing leaves, and sawdust.

The lower heating value of wood chips produced from Salix viminalis - clone ULV in 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 wood chips as a weighted average $Q_{nC H} = 18,035$ kJ/kg.

Keywords: higher heating value, lower heating value, salix wood and bark, wood chips, energy plantations

SAŽETAK • U radu se prikazuju istraživanja energijskih obilježja iverja proizvedenoga od drva Salix viminalis – klona ULV, koje se plantažno uzgaja. Gornja ogrjevna vrijednost drva i kore određena je mjerenjem uz pomoć kalorimetra za dvrtstvogoriva, model IKA C 200. Donja ogrjevna vrijednost drva i kore izračunana je iz gornje ogrjevne vrijednosti $Q_h$ uzimanjem u obzir sadržaj vodiča $H_{daf}$ i sadržaja vode koji su određeni na uzorcima u laboratoriju.

Provedenim analizama dobivene su gornje i donje ogrjevne vrijednosti suhog drva Salix viminalis – klona ULV ($Q_{SW} = 19,520$ kJ/kg i $Q_{nSW} = 18,044$ kJ/kg). Također su dobivene i gornja i donja ogrjevna vrijednost kore drva Salix viminalis – klona ULV ($Q_{SB} = 19,389$ kJ/kg, i $Q_{nSB} = 17,997$ kJ/kg).

Određen je udjel kore u iverju proizvedenome od drva Salix viminalis – klona ULV prema normi STN 48 0058 i iznosi 19,35 %. Donja ogrjevna vrijednost iverja proizvedenoga od drva Salix viminalis – klona ULV u sukom stanju izračunana je na bazi donje ogrjevne vrijednosti drva i donje ogrjevne vrijednosti kore te udjela kore u iverju, a dobivena je vrijednost $Q_{nC H} = 18,035$ kJ/kg.

Ključne riječi: gornja ogrjevna vrijednost, donja ogrjevna vrijednost, drvo i kora Salix viminalis – klona ULV, drvno iverje, energijske plantaže

1 The authors are professor and assistants at the Faculty of Wood Sciences and Technology, Technical University in Zvolen, Republic of Slovakia.
2 Autori su profesor i asistenti Fakulteta znanosti o drvu i drvne tehnologije Tehničkog sveučilišta u Zvolenu, Republika Slovačka.
1 INTRODUCTION

1. UVOD

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 succinatic combustibles and a low content of ash. It is an important renewable energy source.

Numerous plantations of short rotation coppice have been 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 m³/ha. According to several studies (Varga and Godó, 2002; Trenčiansky et al, 2007; Habovštíak and Daniel, 2005) the most suitable short rotation coppice for energy production in the Central Europe are acacia (Robinia pseudoacacia L.), selected poplar clones (Populus), and salixes (Salix alba L., Salix viminalis).

The Grassland and Mountain Agriculture Research Institute in Banska Bystrica, Slovakia, has been cultivating short rotation coppice on low productive agricultural soils for several years. At its research station in the city of Nižna in the Orava region (North-West Slovakia), reproduction possibilities of three clones of Salix viminalis, ULV, ORM and RAPP, are being (have been) assessed. These three clones were originally cultivated in the Swedish University of Agricultural Sciences in Svålov.

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

2 MATERIAL AND METHODS

2. MATERIJAL I METODE

Samples of wood and bark of Salix viminalis - clone ULV to assess the energy characteristics were taken from wood chips 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 (Ww = 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.

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

\[ Q_n = Q_s - 24.54 \cdot (W_r + 9 \cdot H_{daf}) \]  

\( Q_n \) – lower heating value of analyzed sample in dry state / donja ogrjevna vrijednost u suhom stanju, kJ/kg  
\( Q_s \) – higher heating value of analyzed sample in dry state / gornja ogrjevna vrijednost u suhom stanju, kJ/kg  
\( W_r \) – water content in analyzed sample / sadržaj vode u analiziranim uzorcima, W_r = 0 %  
\( H_{daf} \) – share of hydrogen in combustible substance of analyzed sample / udjel vodika u gorivim supstancijama analiziranih uzoraka, %.

The share of bark in wood chips produced from Salix viminalis - clone ULV was assessed by a laboratory technique at the Faculty of Wood Sciences and Technology of the Technical University in Zvolen. The assessment was carried out 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:

\[ X_B = \frac{m_B}{m_{w-ch}} \cdot 100 \]  

\( X_B \) – share of bark in wood chips / udjel kore u drvenom iverju, %  
\( m_B \) – weight of bark in a sample of wood chips / masa kore u uzorku iverja, g
Based on the above specified energy characteristics of wood chips produced from Salix viminalis - clone ULV, an average energy value of the higher heating value of wood chips in dry state was calculated using the following formulas:

**Higher heating value of dry wood chips:**

\[
Q_{CW} = \frac{100 - X_B}{100} \cdot Q_{SB} + \frac{X_B}{100} \cdot Q_{SW}
\]

**Lower heating value of dry wood chips:**

\[
Q_{CN} = \frac{100 - X_B}{100} \cdot Q_{nB} + \frac{X_B}{100} \cdot Q_{nW}
\]

where:
- \(m_{W,CH}\) – weight of wood in a sample of chips / masa uzorka drvenog iverja, g.
- \(X_B\) – share of bark in wood chips / udjel kore u drvnom iverju, %
- \(Q_{SW}\) – higher heating value of wood / gornja ogrjevna vrijednost drva, kJ/kg
- \(Q_{SB}\) – higher heating value of bark / gornja ogrjevna vrijednost kore, kJ/kg
- \(Q_{nW}\) – lower heating value of wood / donja ogrjevna vrijednost drva, kJ/kg
- \(Q_{nB}\) – lower heating value of bark / donja ogrjevna vrijednost kore, kJ/kg

### Table 1: Shares of elementary combustible particles and ash in wood biomass

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Wood / Drvo</th>
<th>Bark / Kora</th>
<th>Wood / Drvo</th>
<th>Bark / Kora</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1/ uzorak 1.</td>
<td>Wood: 49.66% H: 6.28%</td>
<td>Bark: 50.21% H: 6.27%</td>
<td>43.64%</td>
<td>41.81%</td>
</tr>
<tr>
<td>Sample 2/ uzorak 2.</td>
<td>Wood: 50.39% H: 6.49%</td>
<td>Bark: 50.63% H: 6.34%</td>
<td>42.73%</td>
<td>41.35%</td>
</tr>
<tr>
<td>Sample 3/ uzorak 3.</td>
<td>Wood: 50.29% H: 7.28%</td>
<td>Bark: 50.40% H: 6.30%</td>
<td>41.66%</td>
<td>41.58%</td>
</tr>
<tr>
<td>Averages / srednja vrijednost</td>
<td>Wood: 50.11% H: 6.68%</td>
<td>Bark: 50.41% H: 6.30%</td>
<td>42.68%</td>
<td>41.58%</td>
</tr>
</tbody>
</table>

### Table 2: Higher heating value and lower heating value of wood and bark of Salix viminalis - clone ULV

<table>
<thead>
<tr>
<th>Samples / Uzori</th>
<th>Wood / Drvo</th>
<th>Bark / Kora</th>
<th>Wood / Drvo</th>
<th>Bark / Kora</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample No. 1/ uzorak 1.</td>
<td>(Q_{SW}) 19.587 kJ/kg</td>
<td>(Q_{SB}) 19.428 kJ/kg</td>
<td>18.200 kJ/kg</td>
<td>18.444 kJ/kg</td>
</tr>
<tr>
<td>Sample No. 2/ uzorak 2.</td>
<td>(Q_{SW}) 18.469 kJ/kg</td>
<td>(Q_{SB}) 19.423 kJ/kg</td>
<td>18.036 kJ/kg</td>
<td>18.323 kJ/kg</td>
</tr>
<tr>
<td>Sample No. 3/ uzorak 3.</td>
<td>(Q_{SW}) 19.505 kJ/kg</td>
<td>(Q_{SB}) 19.107 kJ/kg</td>
<td>17.897 kJ/kg</td>
<td>17.716 kJ/kg</td>
</tr>
<tr>
<td>Average values / srednja vrijednost</td>
<td>(Q_{SW}) 19.520 kJ/kg</td>
<td>(Q_{SB}) 19.389 kJ/kg</td>
<td>18.044 kJ/kg</td>
<td>17.997 kJ/kg</td>
</tr>
</tbody>
</table>
This is caused by the presence of albumin in cambium cells, as well as by chlorophyl in the surface plexus of immature bark.

The experiments undertaken resulted in an assessment of the average share of bark $X_B$ in the analyzed wood chips:

$$X_B = 19.35 \pm 0.65\%$$

The assessed value $X_B$ does not exceed the maximum limit ($X_B = 30\%$) set by the Slovak Technical Norm STN 48 0058, which was endorsed in 2004. The assessed value of the bark share $X_B$ is about 2.7 times higher than the share of bark in beech wood, about 1.7 times higher than the share of bark in oak- and poplar wood, and about 1.5 times higher than the share of bark in alder wood (Černák, 1969).

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

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

The average energy values of the higher heating value of dry wood of *Salix viminalis* - clone ULV are about 1.0 % higher than the average energy values of the higher heating value of dry bark of the same plant. This is caused by a higher share of combustible substance in the wood (lower ash content in the wood) and by a lower share of nitrogen in the wood, which is an endothermic part of the combustible substance of wood biomass.

The assessed higher heating value of *Salix viminalis* - clone ULV in dry state is comparable with the higher heating value of poplar published by Longauer et al (1987) \( Q_{SW} = 19\,880 \text{ kJ/kg} \).

The average value of the heating value of wood chips produced from *Salix viminalis* - clone ULV in dry state with the average share of bark \( X_B = 19.35 \% \) is determined by the formula (4) as \( Q_{c, CH} = 18\,035 \text{ kJ/kg} \).

### 4 CONCLUSIONS

#### 4. ZAKLJUČI

Based on the experiments, the following conclusion can be made: Wood chips produced from *Salix viminalis* - clone ULV, which was cultivated in an energy plantation, contains significantly higher shares of both hydrogen and nitrogen than is commonly found in wood biomass of matured broadleaves. The share of bark in the same wood chips was assessed as \( X_B = 19.35 \pm 0.65 \% \).

The analyses of energy characteristics of wood chips produced from *Salix viminalis* - clone ULV show that the higher heating value of the juvenile wood of *Salix viminalis* - clone ULV in dry state is \( Q_{SW} = 19\,520 \text{ kJ/kg} \); while for dry bark of the same wood it is \( Q_{SB} = 19\,389 \text{ kJ/kg} \). The lower heating value of wood chips of *Salix viminalis* - clone ULV in dry state is \( Q_{c, CH} = 18\,035 \text{ kJ/kg} \).

### 5 REFERENCES

#### 5. LITERATURA


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#### Corresponding address:

Prof. Ing. LADISLAV DZURENDA, Ph.D.

The Faculty of Wood Sciences and Technology
Technical University in Zvolen
T. G. Masaryka 24
960 53 Zvolen, Slovak Republic
E-mail: dzurenda@vsl.tuzv.sk