CHARACTERISTICS OF WOOD CHIPS FROM LOGGING RESIDUES AND QUALITY INFLUENCING FACTORS

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Abstract
The aim of this paper is to characterize and ascertain quality influencing factors of wood chips produced from forest residues in clear-cuts. The quality of food fuels varies according to the harvesting season, site characteristics and silvicultural treatment. For this study 89 piles of logging residues from clear-cuts located in Western part of Latvia were used. Piles were stored in different parts of clear-cut according to its direction against nearby stand. Piles of logging residues were pre-dried and then chipped. A period of chipping and sample acquisition was from February to May of the year 2012. Results show that chips from forest residues can be successfully used for medium scale boilers. Chips with lower carbon content, calorific value, relative moisture and bulk density of wet chips can be produced in May. Location of the pile in centre and SE part of the clear cuts can decrease resulting ash content in wood chips.

Key words: wood chips, quality.

Introduction
During the last years logging residues from clear-cuts are considered an important resource for renewable energy production. In the year 2007, Finland produced 21.9 PJ of energy from wood chips obtained in forests, and it is estimated that by the year 2015 this number will be increased from 51 to 71 PJ per year (Heinimö and Alakangas, 2009). It is calculated that in Ireland 150 000 - 200 000 t of forest residues may be available for harvesting (Hoyne and Thomas, 2001), but data obtained in Latvia show that after clear-cuts approximately 20 to 30% of biomass from above ground tree volume is left in area and 2.5 milj. m³ is usable as fuel resource. (Lazdans, 2006) According to FAO Forestry paper 93, approximately 33% from the total tree volume is usable as wood fuel straight from the forest (The potential use of wood residues for energy generation, 1990).

Available wood residue volumes from forest that could be used for energy production is imposing, but the quality of food fuels varies according to harvesting season, site characteristics and silvicultural treatment. Bulk density, moisture content, size and shape of wood fuels are important for wood fuel handling, storing and transporting (Picchio et al., 2012), but calorific value can be seen as essential quality indicator for any fuels (Spinellia et al., 2011).

Storage of forest residues in small piles in cutting area can result in loss of needles and improve nutrition recycle to forest ecosystem (Nurmi, 1999) and decrease ash content due to needle loss (Jirjis and Lehtikangas, 1991). Study by Lehtikangas and Jirjis (1993) show that moisture content in softwood forest residues stored for 7 months in covered piles reduced to 26%, but in uncovered 37% from initial 55%, but after 11 months of storage moisture content rose to 29% in covered and 51% in uncovered piles. Liaqat (2011) in his study observed that piles placed in a slope and under the shade of trees showed higher moisture and ash content than those who were located in a plain site. Increment in ash content could be explained by higher amount of contamination and led to lower calorific value.

The aim of the study was to determine quality of wood chips produced from harvesting residues in final felling, depending from storage time, location of piles and presence of coverage.

Materials and Methods
Data material for this study was obtained in the beginning of the year 2012 from February till May from 89 piles of logging residues located in clear-cuts during comminution process. All piles were located in the western part of Latvia in forests managed by joint-stock company ‘Latvijas valsts meži’.

Before chipping operation piles were pre-dried. 8 piles were covered but 81 were not. The shortest drying period for some was 17 days but the longest – 4 years (in reality they consisted of mixed – fresh and

<table>
<thead>
<tr>
<th>Storage time, months</th>
<th>No information</th>
<th>1 to 12</th>
<th>13 to 24</th>
<th>25 to 36</th>
<th>37 to 48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of piles</td>
<td>12</td>
<td>55</td>
<td>15</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1

FORESTRY AND WOOD PROCESSING

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Characteristics of wood chips from logging residues and quality influencing factors

Summary of chip particle size characteristics (n=88), %

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3.15 mm</td>
<td>0.0</td>
<td>51.5</td>
<td>18.1</td>
<td>1.2</td>
</tr>
<tr>
<td>3.15-16 mm</td>
<td>22.4</td>
<td>78.5</td>
<td>44.5</td>
<td>1.3</td>
</tr>
<tr>
<td>16-45 mm</td>
<td>4.9</td>
<td>68.6</td>
<td>32.1</td>
<td>1.6</td>
</tr>
<tr>
<td>45-63 mm</td>
<td>0.0</td>
<td>12.1</td>
<td>3.5</td>
<td>0.3</td>
</tr>
<tr>
<td>&gt; 63 mm</td>
<td>0.0</td>
<td>7.0</td>
<td>1.8</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Summary of chip quality characteristics

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Error</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs. Moisture</td>
<td>%</td>
<td>17.6</td>
<td>203.3</td>
<td>97.8</td>
<td>5.2</td>
<td>87</td>
</tr>
<tr>
<td>Relative moisture</td>
<td>%</td>
<td>20.6</td>
<td>73.1</td>
<td>49.2</td>
<td>1.5</td>
<td>88</td>
</tr>
<tr>
<td>Density (wet)</td>
<td>kg L⁻¹</td>
<td>0.242</td>
<td>0.531</td>
<td>0.382</td>
<td>0.008</td>
<td>82</td>
</tr>
<tr>
<td>Density (dry)</td>
<td>kg L⁻¹</td>
<td>0.128</td>
<td>0.267</td>
<td>0.189</td>
<td>0.003</td>
<td>81</td>
</tr>
<tr>
<td>Carbon content</td>
<td>g kg⁻¹</td>
<td>450</td>
<td>567</td>
<td>520</td>
<td>3</td>
<td>84</td>
</tr>
<tr>
<td>Ash content</td>
<td>%</td>
<td>1.5</td>
<td>23.3</td>
<td>7.9</td>
<td>0.7</td>
<td>84</td>
</tr>
<tr>
<td>Calorific value</td>
<td>kWh kg⁻¹</td>
<td>4.36</td>
<td>5.49</td>
<td>5.04</td>
<td>0.03</td>
<td>84</td>
</tr>
</tbody>
</table>

Pearson correlation values between density and moisture of wood chips from logging residues

<table>
<thead>
<tr>
<th>Value</th>
<th>Density (wet)</th>
<th>Density (dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs. Moisture</td>
<td>0.726</td>
<td>-0.648</td>
</tr>
<tr>
<td>Relative moisture</td>
<td>0.705</td>
<td>-0.655</td>
</tr>
</tbody>
</table>

Results and Discussion

On average 76.6% of wood chips produced from logging residues and used for this study are in size from 3.15 to 45 mm, but only 5.3% of total amount of chips is larger than 45 mm. According to Kofman (2005) wood chips with such particle size distribution can be successfully used for medium size boilers (0.250...1MW) and on average only 44.5% (3.15...16 mm) of wood chips produced from forest residues can be used in small size boilers (<250 kW), because they acquire nominal particle sizes from 8 to 15 mm. As shown in Table 2, in some cases such particle size can contain up to 78.5% from the total volume of separate piles.

Average absolute moisture (Table 3) for analysed samples was from 17.6 to 203.3% on average 97.8%, but relative moisture ranged from 20.6% to 73.1%, on elemental analysis according to LVS ISO 10694. Calorific values were estimated according to LVS CEN/TS 14918 standard.
Figure 1. Correlation between bulk density of wet chips and relative moisture.

Figure 2. Correlation between bulk density of dry chips and relative moisture.

Figure 3. Correlation between sample preparation month and carbon content in chips (p = 0.04 < 0.05).
average is 49.2% confirming results obtained by the study of Lehtikangas and Jirjis (1993) that average moisture of wood chips produced from stored forest residues is approximately 50%.

Bulk density of wet chips ranged from 0.242 to 0.531 kg·L⁻¹, on average 0.382 kg·L⁻¹, but dry bulk density ranged from 0.128 – 0.267 kg·L⁻¹, on average 0.189 kg·L⁻¹. When compared, wet and dry bulk density show significant correlation at 1% significance level with absolute and relative moisture (Table 4, Figure 1 and 2) in all 4 pairs (p = 0 < 0.01).

Carbon content in wood chips varies between 458 and 567 g·kg⁻¹, but ash content in chips varies between 1.5 and 23.3%, both show significant correlations at 5% level with time of comminution (Figure 3 and 4). The highest content of ash was found in wood chips highly polluted with soil particles and consisting of mixed material stored for up to 3 years.

As shown in Figure 4, the ash content in chips increases with time of comminution (more ash in chips produced in May). This could be explained by higher amount of contaminants in chips after melting of snow. The calorific value (Figure 5) of chips decreases by the same period and could be effected by needle loss and higher contamination as mentioned by Liaqat (2011) and found in this study.

Figures 6 and 7 demonstrate that relative moisture and density of chips is smaller in samples produced in May than for those that are produced in February. This could be explained by drying of wood, which is approved also in other studies (Francescato et al., 2008). Smaller moisture content in wood is associated with higher evaporation rate of logging residues in this time.

Location of the pile in clear-cut has no significant impact on ash content from burned forest residues.

Figure 4. Correlation between sample preparation month and ash content in chips (p = 0.001 < 0.01).

Figure 5. Correlation between sample preparation month and calorific value of chips (p = 0.04 < 0.05).
Figure 6. Correlation between comminution date and density of wet chips ($p = 0.00 < 0.01$).

Figure 7. Correlation between comminution date and relative moisture of wet chips ($p = 0.00 < 0.01$).

Figure 8. Pile location impact on ash content in chips (± 1 Standard error).
(r = -0.17, r<sub>0.01</sub>=0.28, n=84). Smaller ash content is found in chips from piles that are stored in the middle of the clear cut area (Figure 8) and at the SE of the forest wall. There was only one pile located at the NE of the forest wall, thus leaving the values for this location questionable.

Absolute and relative moisture is slightly higher for covered piles with similar drying period durations, but still the difference of absolute (p = 0.2> 0.01) and relative (p = 0.4 > 0.01) moisture is not significant between covered and uncovered piles. Higher content of moisture in covered piles could be explained by the fact, that tarpaulin was used as coverage material which prevents air circulation (Liaqat, 2011). Absence of significant difference in moisture content in covered and uncovered piles could be explained by the fact that piles were formed over longer period of time, thus consisting of mixed – fresh and stored material.

Conclusions
1. On average 76.6% of wood chips produced from logging residues and used for this study are in size from 3.15 to 45 mm and can be used for medium size boilers (0.25...1 MW), and 44.5% of wood chips produced from forest residues can be used in small size boilers (<250 kW)
2. Calorific value of wood chips from forest residues varies from 4.36 to 5.49 kWh·kg<sup>-1</sup>, on average 5.04 kWh·kg<sup>-1</sup> and carbon content from 450...567 g·kg<sup>-1</sup>, on average 520 g·kg<sup>-1</sup>.
3. Time of wood chip production is important factor for woodchip quality because during the period from February to May carbon content, calorific value, relative moisture and bulk density of wet chips decrease, whereas ash content increases.
4. Location of the pile in the centre and SE part of the clear cuts can decrease resulting ash content in wood chips.

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References