LOSS REDUCED STORAGE OF SHORT ROTATION COPPICE

MEDIENOS KURO SAUGOJIMO NUOSTOLIAI

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The storage of chips of recently harvested field wood in unventilated piles may cause a high loss of dry matter and a significant increase of allergy-inducing mould fungi. The following paper presents the results of various storage experiments on a half-technical scale with poplar, willow and pine of different size, as chips, chunks and whole trees. It is shown that the moisture content of chunks in rain-protected piles decreases from more than 50% to nearly 20% during a storage period of one year and that the loss of dry matter is approximately only half of that in chip piles. Considering the moisture content, there is no loss of energy in protected chunk piles, while fine chips lose more than 10% per annum (p.a.). As regards the total amount of fungi and yeast there are no significant differences between the various sorts and sizes of wood, but in chunk and whole-tree piles the hazardous thermophilic fungi species are very rare.

Fuel from wood, storage loss, dry matter, harmful microflora.

Introduction

Short rotation coppice as poplar and willow is a promising biofuel. This wood, also called field wood or fast growing trees, can be cultivated on set-aside land and secures additional income for farmers. Compared with other energy plants, the main advantages of this wood are the environment-friendly cultivation without fertiliser and pesticides, the flexible harvest time intervals, and in particular the wood properties of this fuel, which make it appropriate for combustion in conventional wood boilers [1].

However, there is a problem with logistics and the technology of mechanised harvesting of field wood, because the storage of chips has not been solved in a reasonable fashion so far. After a certain duration conventional wood chips stored in piles develop an extreme increase in microbes and a loss of dry matter [2-10].
The former is associated with a health risk for the operator, and the latter results in loss of energy.

The objective of these investigations is to find a storable size of field wood which prevents these problems and which is appropriate for mechanised harvesting and storage.

**Literature review**

According to various forecasts the volume of energy gained from biomass will increase more than fivefold worldwide within the next 50 to 100 years. The European Community aims to increase the share of biogenic energy sources in primary energy consumption from the current level of 3 % to 8.5 % by the year 2010 [11], and Germany plans to provide 5.75 % of all fuels from biomass by the same date. These goals are high, since only about 1.6 % of primary energy demand is currently covered by biomass in Germany (FNR, 2003).

Wood harvesting is an important operation in the management of field wood areas, accounting for over 50 % of the production costs and influencing the entire post-harvest technology, especially storage and drying. That is why efficient processes and machines have to be selected, taking into account on the one hand the cropping features (space between rows, trunk diameter, weight etc.) and on the other hand the requirements of further processing (conditioning form, fibre length, storage and drying properties etc.). Basically it is possible to distinguish between three different harvesting methods, whole-tree, bundle and chip technologies. Chip technology in which the trees are felled, chopped and loaded up in a single operation is preferred for energy-specific use thanks to the high working rates of the harvesting machinery developed to date.

A variety of firms supply different machines for this purpose. Claas has developed a special cutter (Salix header). This cutter, designed for double rows, has been used in Sweden for willow harvesting for several year now. The Austoft 7700 is a sugar cane harvester manufactured by the Australian firm Austoft Industries, slightly modified for harvesting 2 to 4-year willows and poplars and used in Sweden and Great Britain, as well as other countries [12, 13]. The bush chopper after Wienke and Döhrer (University of Göttingen and Forestry Office Diemelstadt) was developed specially for harvesting energy coppices and woods.

A major objective of cultivating field wood is to use it as an energy medium. In isolated cases it will be possible to use this material as loose or log wood (small firing systems), but it is mainly fired as chopped matter in automatic firing systems. Chips are fired in boilers of size 30 kW upwards with underfeed stoking or pre-furnace firing (in compact form with combustion chamber). The smaller systems require a high level of fuel homogeneity as regards both geometry and moisture content. They demand chiefly fine chips (10 mm to 30 mm) to at most medium-sized chips of 50 mm (corresponding to the Austrian standard Ö-Norm G30 to G50). The chips must be delivered suitable for storage (<30 % water content) or air-dry (<20 % water content). For larger boiler systems (100 to 300 kW)
grate combustion with a movable grate also enters into consideration. In very large heating systems (from 10 MW upwards) wood is also fired in fluidised bed combustion systems. This process does not make any demands on the fuel quality as regards moisture content, but generally very small material is used (20 to 30 mm) [14]. The greater use of wood in chip form for energy purposes requires defined properties of the product. Consumers want to be supplied with wood chips of a high, constant and uniform quality. As the scope of the market for energy-reducing wood chips grows in various countries, efforts to standardise the wood chips as regards geometry, water content and composition (foreign bodies) are being reinforced. Since Austria is one of Europe's leading countries in the field of wood combustion as regards both technological development and the number of burners, rules concerning the standardisation of wood fuels were developed at an early stage there. ÖNORM 7133, that has existed as a preliminary standard since 1988, defines classes in accordance with the following criteria: water content (5 classes), chip size (3 classes), bulk density (3 classes), and ash content (2 classes). The water content and chip size are the most important parameters in practical use.

In the past a number of facilities carried out chip drying experiments using different approaches. Unfortunately the relevant storage conditions are not always evident from the literature. This fact as well as the different parameters advised lead to a wide scatter in the results (Table 1).

Table 1. Losses sustained during storage of wood chips.

<table>
<thead>
<tr>
<th>Wood variety</th>
<th>Chip length, mm</th>
<th>Rain cover</th>
<th>Storage duration, day</th>
<th>Water content</th>
<th>Max. temp., °C</th>
<th>Dry matter loss, % p. month</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poplar</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>0.8-1</td>
<td>5</td>
</tr>
<tr>
<td>Poplar</td>
<td>80-150</td>
<td>-</td>
<td>0-48</td>
<td>-</td>
<td>14-60</td>
<td>0.4-0.8</td>
<td>5, 15</td>
</tr>
<tr>
<td>Field wood</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.4-3.3</td>
<td>16</td>
</tr>
<tr>
<td>Spruce</td>
<td>25</td>
<td>yes</td>
<td>50</td>
<td>41</td>
<td>35</td>
<td>0.5-4</td>
<td>17</td>
</tr>
<tr>
<td>Conifer</td>
<td>94.1</td>
<td>yes</td>
<td>60</td>
<td>-</td>
<td>14</td>
<td>0.6</td>
<td>15</td>
</tr>
<tr>
<td>Linden</td>
<td>23.8</td>
<td>yes</td>
<td>46</td>
<td>-</td>
<td>65</td>
<td>11.5</td>
<td>15</td>
</tr>
<tr>
<td>Beech</td>
<td>-</td>
<td>yes</td>
<td>14-84</td>
<td>-</td>
<td>25</td>
<td>6.5-8.8</td>
<td>18</td>
</tr>
</tbody>
</table>

Both biological and chemical processes contribute to the loss of substance in the wood. On the one hand the living cells still breathe, and on the other hand there is intensive metabolism on the part of the microorganisms. The consequences are losses of dry matter, the formation of carbon dioxide, water and other compounds, as well as heat development.
Objects and methods

Since 1998 eleven storage experiments have been conducted on a half-technical scale, each with a duration of about one year. The materials were poplar, willow and pine from 16 mm (chips) to 6000 mm (whole trees) in length. Poplar and willow came from 4 to 6-year plantations and pine from the forest. The wood was stored immediately after cutting or chopping. The fine chips and the coarse chips were produced by two different mobile chippers, and the chunks by a special stationary chopping machine. The material was stored in up to 7 rectangular boxes of 2.5 m in height and 2.0 m in width with thermally insulated sides, similar to a segment of a pile. In contrast to the first experiment (1998/1999), during the second experiment (1999/2000) the storage boxes were rain-protected and had some wooden floors, permeable to air. In the third experiment (2002/2003) the storage boxes were only rain-protected. During storage 4 to 8 balance bags with determined weight and moisture content were placed in the pile. Each was made of small-meshed polypropylene net and filled with approximately 10 litres of the same material as that in the pile.

During the storage process the temperature in the pile was measured by an electronic thermometer. Various samples were taken to determine the content of water as well as fungi and yeast, alternately using the openings in the front side. To analyse the number of fungi on the wood, fine-chopped wood was shaken in physiological solvent, which then was used to make a raw serial dilution. A part of each solvent plot was put on a special nutrient plate and incubated for nearly one week at a temperature of 21°C and for two days at a temperature of 37°C. After that, the number of colonies developed was counted and the number of cells in colony forming units per g fresh wood weight (cfu/g) was calculated. An air sampler MD 8, Comp. Satorius, was used to determine the spores in the air.

Results and discussion

Temperature

Due to the activity of microbes, the temperature in chip piles increases rapidly. Within one week the temperature of fine chips reaches about 60°C and begins to drop after 6 to 10 weeks. After 5 to 8 months the heat exchange has generally finished and the pile temperature corresponds to the ambient temperature (Fig. 1).

The height of the pile exerts a certain influence, so that the highest temperatures are found in the upper layers, depending on the permeability of the floor to air. Independently of the species of wood, the coarse chips reach a lower temperature level (≈ 50°C) and the peak lasts a shorter time. As a result of the good air flow conditions, no rise in temperature is measured in chunk and whole-tree piles, but the pile temperature approximates to the ambient temperature.
Moisture Content

Recently harvested wood has moisture content of about 50-60%. During storage the water evaporates and the wood dries. Although the pore volume of chip piles is relatively low, the chips dry because of the self-heating process. Therefore after finishing the main heat production, i.e. after 6 to 7 months, the average moisture content remains more or less constant and does not fall below approximately 40% (Fig. 2).

Thanks to good ventilation conditions whole trees of small diameter, which are typical for field wood, dry very quickly even without any protective roof, i.e. within 4 to 5 months, to a moisture content of 20% to 30%. This applies to trees with an average diameter of 40 mm for poplar and a diameter of 18 mm for willow at a height of 1.3 m. Subsequently the moisture content remains nearly constant. Chunks in rain-protected piles show a steady drying course. After one year the chunks reach well-storable moisture content of less than 25%.

It has been demonstrated that the moisture content is higher in upper layers of chip piles, up to 0.6 m below the top surface, than it is in deeper layers, where the moisture content is 55% to 75%. At the bottom the moisture content is also higher than the average content, but this can be partly reduced by an air permeable floor. In chip and chunk piles covered by a rainproof roof or awning, the total loss of water is significantly less than in unprotected piles, which partially contradicts
some opinions in literature [5, 7]. The difference in the average moisture content between the storage intake and the storage outtake processes in winter time is only 0 % to 19 %, while in protected wood piles this figure reaches 26 % to 38 %.

![Graph of moisture content over time](image)

**Fig. 2.** Drying course of different kinds of chopped wood

2 pav. Skirtingų rūšių kapotos medienos džiūvimo dinamika

### Mould and yeast

The entire number of moulds and yeasts increases within 1 to 2 months from $10^5$ (pine) and $10^6$ (poplar) to about $10^8$ colony-forming units per g wood (cfu/g), with the highest increase in the first two weeks. Afterwards the number slowly falls to approximately $10^7$ cfu/g. This decrease is possibly caused by the drop in temperature. There is no correlation with moisture, but there is a connection with the temperature and the loss of dry matter. Although the total number of mould cfus in pine and willow chips evidently seems to be less than in poplar chips or chunks, there is no significant difference between varieties or sizes of wood either (Fig. 3).

By contrast with the quantity of mould, the quality shows significant differences between the sizes of wood particles investigated. Because it requires temperatures of 25 °C to 55 °C, one of the most hazardous species of fungi, the thermophilic *Aspergillus fumigatus*, occurs only in very low numbers in chunk or whole-tree piles ($<10^2$ cfu/g). The spores of this species are not only allergenic, but also toxic and opportunistically pathogenic.
Measurements of the number of spores in the air at a distance of 0.1 m to 10 m from the investigated wood piles show an increase of concentration from $10^2$ to $10^4$ cfu/m$^3$ at rest to $10^4$ to $10^7$ cfu/m$^3$ during handling, depending on distance, storage time and current weather. Thus during handling processes such as loading or refilling, the spore concentration in the ambient air of wood piles sometimes exceeds the German limits in work hygiene or guide values of $5 \cdot 10^3$ or $5 \cdot 10^4$ cfu/m$^3$. However, there is a wide range of variation in the measuring results caused by the natural distribution of the microbes [6, 9, 10].

**Dry matter loss**

The production of heat in wood piles as a result of the activity of microbes is connected with a loss in dry matter. Thus the piles with the highest temperatures have the highest losses during storage. Therefore the yearly dry matter loss of field wood chips is 17 % to 26 %, while chunks lose only 9 % to 13 % p.a.

These results agree with corresponding data from literature, where a loss of 16 % to 22 % p.a. for fine chips and 8 % to 10 % p.a. for chunks [3, 5, 6] is noted. The dry matter loss of whole trees could not be determined by the method used (balance bags) and the very low value of pine coarse chips may be caused by the large length of these chips or by the large share of needles in this pile.
Fig. 4. Water content, dry matter and lost energy of poplar during the storage in unventilated piles (data all samples from 1998 to 2003)

The local temperature, moisture content and number of fungi and yeasts as well as the dry matter loss depend on the height of the pile. Thus, in piles of poplar fine chips, the dry matter losses show an extreme maximum at a height of 2.1 m exceeding the average by more than 60%.

For the energetic use of wood the energy loss is more relevant than the dry matter loss. The former depends on the water content. Therefore rain-protected poplar chunks do not lose energy, whereas fine chips lose 11% to 27% p.a. An increasing particle size obviously leads to reduced energy losses.

Conclusion

1. The storage of recently harvested field wood chips in unventilated piles causes a rise in temperature to nearly 60°C associated with a loss of dry matter and the growth of hazardous thermophilic fungi.

2. During the first year after harvest in winter, the moisture content of fine chips does not fall below 40%. For durable storage of wood, moisture content of less than 30% or 25% is necessary. This is reached by whole trees and chunks within 4 to 8 months without any rise in temperature.

3. The dry matter loss of poplar chunks ranges between 9% and 19% p.a., which is around half of the loss in chip piles. Including the moisture content, the total energy loss in chip piles is 12% to 28% p.a., while rain-protected chunk piles
do not sustain energy losses. A rainproof roof or awning has a significant improving effect on drying of the whole pile, whereas the effect of a floor permeable to air is restricted to the lower layers only.

4. Regarding the quantity of fungi and yeast, there is no significant difference between the various varieties and sizes of wood. During the first weeks the total number reaches about $10^8$ colony forming units per g wood and slowly falls to approximately $10^7$ cfu/g after one year, occasionally involving a health risk for the operator during the handling of wood.

5. In chunk and whole-tree piles the number of one hazardous thermophilic fungus, *Aspergillus fumigatus*, is very low. However, there is a high degree of randomness in the measuring of fungi, requiring further investigations, particularly in larger wood piles.

6. It may be concluded that during storage of field wood in unventilated piles, the energy loss and the human health risk from chunks are lower than those from chips.

7. Under economic aspects the chunks are more favourable than whole trees, and in some cases more so than chips [7]. Therefore appropriately mechanised technologies for harvest, storage and use of field wood chunks should be developed.

References


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**MEDIENOS KURO SAUGOJIMO NUOSTOLIAI**

**Reziume**

Medienos skiedų laikymas neventiliuojamose kaupuose susijęs su sausų medžiagų nuostoliais ir alergiją sukéliantios mikrofloras vystymosi intensyvumu. Straipsnyje pateiki gamybinių bandymų rezultatai laikant įvairiais būdais paruoštą
medienos kurą. Tirti tuopų, gluosnių ir pušų skiedrų, trinkų bei rastų laikymo nuostoliai. Nustatyta, kad laikant medienos trinkas apsaugotoje nuo lietaus aplinkoje, jų drėgnis per metus sumažėja nuo 50 % iki 20 %, o sausų medžiagų nuostoliai yra dvigubai mažesni nei laikant skiedras. Nagrinėjant energijos nuostolius nustatyta, kad laikant medienos trinkas jie yra nežymūs, o saugant skiedras, energijos nuostoliai siekia 10 % per metus. Kenksmingos mikrofloros vystymasis nepriklausė nuo medienos rūšies ir jos paruošimo būdo, tačiau saugant trinkas bei rastus jause aptiktas mažesnis kiekis šilumą mėgstančių kenksmingų sveikatai grybelių.

Mediena, kuras, saugojimo būdas, drėgnis, sausosios medžiagos, kenksminga mikroflora.

К. Идлер, В. Шольц, В. Дарисе, И. Эгерт

ПОТЕРИ ПРИ ХРАНЕНИИ ДРЕВЕСНОГО ТОПЛИВА

Резюме

Хранение щепы из свежезаготовленной древесины в невентилированной насыпи приводит к значительным потерям сухого вещества и интенсивному развитию болезнетворной микрофлоры. В статье изложены результаты производственных исследований хранения чипсов, колод, цельных бревен тополя, ивы и сосны. Установлено, что хранение колод в защищенных от атмосферных осадков условиях в течение года приводит к снижению их влажности с 50 % до 20 %. Потери сухого вещества при этом в 2 раза меньше чем при хранении щепы. Энергетические потери при хранении колод незначительны, а при хранении щепы в течение года составляют до 10 %. Количество болезнетворной микрофлоры мало зависит от вида и способа подготовки древесины. Однако, при хранении колод и бревен обнаружено меньшее количество теплолюбивых грибов.

Древесина, топливо, способ хранения, потери сухого вещества, микрофлора.