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Research paper

Influence of the chip format on the development of mass loss, moisture content and chemical composition of poplar chips during storage and drying in open-air piles

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ABSTRACT

In order to use wood chips from short-rotation coppices cost-efficiently, it is necessary to optimise the storage process depending on the planned use of the chips. The goal of all storage is to ensure low dry matter losses. Wood chips intended for energy-related use should have low moisture and ash contents, as well as a low fines fraction. If wood chips are to be put to material use, e.g. as peat substitute, a reduction of the C:N ratio during storage is necessary.

The objective of this study was to identify favourable storage conditions to ensure low dry matter losses and high quality of wood chips for energy-related use. Furthermore, the study aimed to examine, whether disintegration processes during storage change the C:N ratio to such an extent that wood chips can be used as raw material for plant substrates.

Three wood chip piles with different chip formats (small, medium, large - produced with a forage harvester and a mower chipper) were stored for seven months and compared regarding storage properties and physico-chemical parameters.

After seven months, medium wood chips displayed with a moisture content of 26w-%, dry matter losses of only 17% and a fines fraction of < 5w-% the best results for energy-related use. Small chips with dry matter losses of 19%, moisture contents of 34w-% and a fines fraction of 12.6w-% displayed very unfavourable conditions for energy-related use. However, small chips showed the highest reduction of the C:N ratio (from 145:1 to 57:1) due to the storage process.

1. Introduction

The decentral production and use of wood chips from short rotation coppices (SRC) is a favourable alternative in the field of energy and raw material provision from agriculture and an additional source of income for farmers [1–4].

Short rotation coppices are harvested in winter with moisture contents of 50–60 w-%. Demand for the material continues throughout the year, however, and thus makes storage absolutely necessary. Dry matter losses of up to 30% can result from the hitherto customary method of storing and drying wood chips in naturally ventilated outdoor piles [5–10]. Although fast drying could be carried out technically, it is not always realisable or economically expedient. Natural drying during storage is admittedly less expensive, but its success depends on the environmental conditions during storage [11–13]. Connected to dry matter losses are not only economical losses for the producer but also quality losses, microbiological contamination, greenhouse gas emissions and the risk of self-ignition of wood chips due to biological and chemical degradation processes [10,14–22]. The tree species, treatment, weather conditions, analysis methods and storage procedures can substantially influence the storage process and the dry matter losses determined. The wood chip quality respectively the particle size distribution of wood chips from SRC at storage intake is also significant for the storage and drying behaviour. The natural circulation of ambient air through the pile is crucial for the drying process and is strongly influenced by the porosity of the wood chip pile [13,23]. The porosity and hence the extent to which the air can circulate through the pile increase with rising mean size of the wood chips [24,25]. Various questions concerning the influence of the particle size on storage and drying have been examined in a number of different experiments, initially on a laboratory and pilot scale [6,14,22] and later on a practical scale [5–9,26,27]. Whittaker et al. [17,28] reported dry matter losses of 18–21% for willow stored as chips and of 10% for willow rods after six to eight months of storage. Gigler et al. [23] measured even lower dry

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matter losses during storage of willow chunks of 3.5–5% after seven months storage.

Scholz et al. [14,29] investigated the influence of particle size on storage losses and drying of poplar wood chips in piles at pilot scale (10 m^3, approx. 6 months of storage). For small chips (16–22 mm chip length) dry matter losses of approx. 25% have been determined. With an increase of chips length, dry matter losses have been reduced to 24% (56–63 mm chip length) and 12% (120–156 mm chip length). The higher porosity of a pile of large chips compared to small chips has been seen as the main cause for better natural aeration leading to improved drying and reduced dry matter losses [14,30]. With the reduction of dry matter losses also a source for the production of CO_2 in the piles has been reduced [30]. Pari et al. [7] investigated the influence of chips size and chip quality on storage of small wood chips from poplar at practice scale. It has been shown that modifications of the design of a chipping drum of a forage harvester used for harvesting of poplar from SRC can lead to a significant reduction of the fine content and an increase of the fraction of chips with a length from 12.5 mm to 50 mm. Dry matter losses have been reduced from 13% to 7% for the chips harvested with the modified system (4 months storage). Weather conditions do also have a very important influence on losses and drying during storage of wood chips in piles. Lenz et al. [31] presented a comparison of different storage results from Italy, Germany and England. The results support the assumption that dry matter losses are lower and drying of wood chips is faster at weather conditions typical for spring and summer in south Europe compared to north Europe.

The quality requirements for wood chips to be used for energy purposes are defined in EN ISO 17225–4 [32] and EN ISO 17225–4 [33]. The requirements of EN ISO 17225–4 focusing on wood from forestry are quite strict compared to the current requirements of medium scale boilers using wood chips from SRC at practice [2,34]. In dependence to the age of trees, tree variety, harvest technology and storage technology, SRC wood chips often contain higher amounts of moisture, fines, overlengths and bark [2,35,36]. Thus, SRC wood chips are often used as a blend with chips from forestry to avoid problems during incineration [3,4,37–39]. According to practice experience of medium size heating plants, SRC wood chips should at least fulfil the following quality requirements [37–40]:

- low ash contents, below 3 w-%[1]
- fines fractions (≤3.15 mm particle diameter) of max. 10 w-%[1]
- low moisture contents, preferably under 30 w-%[1]

From an economical point of view, dry matter losses should be reduced to a minimum, preferably to values below 10%. Although stored wood chips are currently used mainly for energy-related purposes, the demand in the material use sector is growing [41]. If the wood is to be used for material purposes, the requirements made of the raw material properties change. For example, a low C:N ratio of between 15:1 and 25:1 is very important for use of the wood chips as a raw material for peat substitutes, as only then are the nutrients available to plants [42]. The C:N ratio of freshly harvested wood chips from short-rotation coppices is well above this level however, at values of 130:1 to 180:1 [28,30]. According to other studies on chemical components of trees from SRC, the concentrations of carbon and nitrogen of freshly harvested wood are not only depended on the tree variety but also on tree age, stem diameter and bark content. In the case of poplar and willow a low trunk base diameter correlates with a higher bark fraction. Due to the fact that nitrogen content in the bark is higher than in the wood the C:N ratio is naturally reduced for smaller trees [28,30,35,36,43–49].

A current problem of the monitoring of storage behaviour of wood chip piles at practice scale (pile size of 200 m^3 and more) is the very labour intensive sampling. If dry matter losses should be investigated over storage time, recovery of sampling bags from the pile is connected to disturbances of the storage conditions in the pile [10,31]. In previous practical trials a new method for regular and distortion-free sampling have been introduced and verified to determine dry matter losses and further storage parameters in dependence to storage time [26,32,50]. Integrated lattice columns in the storage piles served to support the measurements and made it possible to withdraw wood chips samples completely without damage every four weeks. In this way more detailed findings about the course of the storage process over time could be obtained.

This study aimed to compare the course of storage in three different wood chip piles on a practical scale over a period of seven months. Three wood chip formats of the standards classes P31 (small), P45 (medium) and P63 (large) were to be produced and their properties as well as the change of selected chemical parameters during storage were to be examined.

The objective was to identify conditions for low-loss storage under which wood chips of high quality can be produced from SRC for energy-related use. The following questions were to be answered:

1. Do large wood chips dry more quickly than small wood chips?
2. Are the dry matter losses lower when large wood chips are stored than when smaller chip formats are stored?
3. What influence does the particle size have on the concentrations of O_2 and CO_2 in the storage pile?
4. Does the C:N ratio change during storage in the different chip formats?

2. Material and methods

From February to March 2015 three poplar plantations (Clone Max 1, 3 and 4) in North-East Germany (52°15′ N; 13°40′ E) were harvested and taken into storage using three different harvesting machines/machine settings. The harvesting machines were selected/set in such a way that three different chip formats with theoretical cutting lengths of 30–120 mm resulted (Table 1).

The wood chips were stored in piles on a concrete surface for seven months. Each pile had a volume of 500 m^3 and was covered by a water-vapour-permeable fleece of type TOPTEX (weight 200 $g\,m^{-2}$, Tencate, Austria) (Fig. 1).

Eight measuring columns arranged at intervals of 2 m along the middle of the pile were installed in each pile for periodical recording of the essential storage and drying parameters. The test samples were drawn from heights of 0.8 m, 1.6 m and 2.4 m with the aid of these measuring columns (Fig. 2).

The sampling method using measuring columns has already proved successful for describing the course of storage in a number of preceding trials [31,50].

Every four weeks a measuring column was drawn up out of each pile and the measuring equipment and samples were recovered. A chain pulley block mounted on a tripod mast has been used for the extraction of the columns from the wood chip pile. The resulting hole was then immediately filled up again with the residual material from the measuring columns.

Each measuring column was equipped with balance bags (plastic net bags, sample weight 2 kg fresh material), temperature sensors and gas extraction hoses (Fig. 2). Net bags with a small size of holes (1 × 1 mm) have been chosen to minimize mistakes due to losses of fines during handling of the bags. During built up of the experiment, the sample bags have always been filled and weighted immediately after taking samples for moisture measurements. For gas analysis (CO_2 and O_2), gas tight sample bags (2 L volume) have been filled with gas samples extracted with a membrane vacuum pump (VWR Model VP86, Germany) right before each removal of one of the sampling columns. Gas

[1] %-values for ash content, losses and content of fines are defined as mass fraction on dry matter basis; only values for moisture contents are defined as water mass fraction on wet basis.