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Research paper

Drying effects and dry matter losses during seasonal storage of spruce wood chips under practical conditions

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ABSTRACT

The storage of wood chips is important for the biomass supply chain as it compensates for temporal differences in production and consumption. Typical storage-related problems are dry matter and energy losses due to microbial activity.

In extensive field trials, we investigated the storage of spruce wood chips from forest residues (FRC) and from energy roundwood (ERC) with and without rain protection under Central European conditions. Additionally, we examined the storage of unchipped piles.

The results indicate that the investigated factors, i. e. storage duration, season, assortment and rain protection, have a statistically significant influence on moisture content and dry matter loss of wood chips. During five months of storage, the highest decline in moisture content was 22.6 %-points, the highest dry matter loss 11.1 %. In winter, energy losses reached up to 11.3 %. In summer, energy contents did not change or even increased slightly (max. 4.7 %). Pile temperature and dry matter losses were significantly positively correlated in FRC. Formation of different layers within the piles could be detected. Storage performance was better in unchipped than in chipped energy roundwood. Storage of unchipped forest residues was not beneficial concerning energy content, but fuel quality increased due to reduced ash and fine particle content.

Clear best practice recommendations could be drawn regarding wood chip storage under Central European conditions. During winter, FRC should be stored with rain protection or as short as possible while during a dry and warm summer, wood chips can be stored with only few restrictions.

1. Introduction and aim

Consistent development and efficient use of renewable energy sources are essential to achieve national and international climate protection targets and to reduce the dependency on finite energy sources. Solid biofuels, mainly woody biomass, are important for the German energy supply, especially for heat production. In 2016, 13.4 % of the total final heat energy consumption in Germany were covered by renewable energy sources, primarily by solid biofuels (68.1 %) [1].

Wood chips from forest biomass provide the largest share of biofuels used in German biomass heating and power plants besides waste wood [2]. Simultaneously, an increasing number of small- to medium-scale wood chip heating systems for combustion of forest wood were installed in the German private and municipal sector during recent years [3]. As a consequence, the regional demand for wood chips strongly increased during the last years.

Forest wood chips are usually a side product of forest management and accrue e. g. during thinning and harvesting operations or in the course of bark beetle control. Thereby, storage is an important component of the wood chip supply chain as it compensates for temporal differences in production and consumption. Furthermore, storage can be applied systematically to increase fuel quality concerning moisture content by natural convection drying. However, the storage of fresh wood chips can have negative consequences such as dry matter losses and a decline in fuel quality (e. g.

Abbreviations: FRC, forest residue chips; ERC, energy roundwood chips; CHP, combined heat and power plant; M, moisture content; DML, dry matter losses.

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increasing ash content [4, 5]). This is mainly caused by microbial decomposition and, at higher temperatures, by chemical reactions. Fresh forest residue chips have a high moisture content of about 50 % (defined as moisture content on wet basis; i. e. moisture mass fraction) and many easily available nutrients, which offer an ideal breeding ground for wood-decaying fungi and bacteria [6]. In addition, wood chips have a large specific surface area leading to a high contact surface for these microorganisms [7].

Investigations of storage processes in wood chip piles, particularly with respect to dry matter losses, moisture content and pile temperature show that a rapidly starting self-heating is symptomatic for the storage of fresh wood chips which can reach temperatures of up to 65 °C within a few days [6, 8–10]. Usually, pile temperatures remain on a high level for several weeks before they slowly approach ambient air temperature due to decreasing microbial activity. However, if the airflow inside the pile is limited because of a very large pile height or due to compaction of the pile, chemical-physical processes can cause temperatures far above 100 °C which might lead to self-ignition [11–13].

Due to evaporation as an effect of strong self-heating and due to precipitation, the moisture content within piles can change distinctly during storage. Thereby, wood chips in the center of the pile often dry considerably while the surface layer becomes even wetter during storage because of condensation and precipitation [14–16].

During storage of coniferous wood chips (spruce, pine), monthly dry matter losses between 0.3 and 5.5 % are reported, mostly by Scandinavian studies [6, 7, 15, 17]. In piles of poplar and willow chips from short rotation coppice, dry matter losses amount up to 0.8–4.4 % per month [8, 18, 19]. Thereby, studies on short rotation coppices were conducted mainly under Central or South European conditions. Storage behavior of other deciduous wood chips have rarely been investigated so far, but in a Canadian trial with wood chips from birch, monthly dry matter losses ranged from 0.7 to 2.3 % [4].

Major challenges in comparing experiments on wood chip storage are that experimental conditions of these investigations (climate, tree species, assortment, storage designs etc.) are often very different and that important information on storage conditions is not reported consistently. Additionally, studies are also hard to compare due to the method used for analysis. A representative sampling method and a sufficient number of samples for statistical calculations are not always applied. Only few studies compared different sampling and measurement approaches for dry matter losses and fuel quality, so far [18, 20]. These aspects frequently cause high data variation within and between studies, leading to different results and conclusions. Moreover, applicability of these results towards other tree species, storage designs or locations might be limited causing disadvantages in applying the results into supply chain planning.

Therefore, focusing on the German wood chip market, the aim of this study was to determine the changes in wood chip piles under a moderate Central European climate with reliable and statistical methods, considering the most relevant tree species for the wood fuel sector in South Germany (i. e. Norway spruce – *Picea abies*). Besides the effect of a rain protection by a fleece, the influence of two common assortments (forest residues, energy roundwood) on storage processes was investigated. Since these processes are highly dependent on the weather and because wood chips are stored throughout the whole year, two trials were performed, i. e. one during winter and one during summer.

The study was conducted by means of a complex experimental setup allowing for highly accurate and extensive data. Thereby, in contrast to many former studies, sampling was not only done at the end of the storage period, but also during storage to enable conclusions on temporal progression. Furthermore, we wanted to facilitate a spatial resolution of the pile cross-section, because other studies often report a development of different layers within the piles – at least with respect to moisture content [8, 15–17]. However, the hypothesis of layer development within piles was so far not tested statistically.

In addition to wood chip storage, the storage of unchipped wood was investigated simultaneously as this is also a common storage method in private forests in Germany. The bio-physical processes as well as the resulting storage behavior may differ strongly from chip storage as there is no or only very little self-heating, the decomposition is generally lower and the fuel quality can be increased by trickling down of needles, bark and leaves [4, 15, 21, 22]. Although some studies already investigated the storage of unchipped wood piles in Central Europe [23], this was rarely done simultaneously to wood chip storage, making it difficult to directly compare results from different studies and thus allowing for no clear recommendation regarding best practice.

2. Material and methods

Storage experiments were carried out from November 2014 to April 2015 (winter trial) and from May 2015 to October 2015 (summer trial) on a storage site of a biomass supplier in Bavaria (South Germany, 48.96° N, 11.18° E). The experimental setup was identical for both periods. Four wood chip piles of approx. 200 m^3 each were built up next to each other, including two piles of forest residue chips (FRC, crown biomass) and two piles of energy roundwood chips (ERC, thin delimbed stem sections of low quality). For both assortments, one pile was covered with a vapour-permeable, nonwoven polypropylene fleece (PolyTex, 200 g m^{-2}, Zill GmbH & Co. KG) as rain protection (Fig. 1).

In addition, two unchipped wood piles per trial, i. e. one pile per assortment, were stacked on the storage site without rain protection. Unchipped pile volume was approx. 65 m^3 for energy roundwood and approx. 120 m^3 for forest residues.

The wood originated from stands managed under a continuous cover forestry system. The age of stands was between 60 and 110 years. The harvested wood consisted mainly (> 80 %) of Norway spruce (*Picea abies*) but also to smaller portions of Scots pine (*Pinus sylvestris*) and very little hardwood (mainly European beech – *Fagus sylvatica*).

Wood chips were produced with a truck-mounted drum chipper (Heizohack HM 14–800 KL, Heizomat Gerätebau-Energiesysteme GmbH) with a 294 kW engine and an open 500 mm drum. The

Fig. 1. Storage site with the four wood chip piles after the start of the winter trial. Left: two ERC piles, right: two FRC piles, each assortment with and without rain protection (fleece). FRC: forest residue chips, ERC: energy roundwood chips. In the black frame: Balance bag for retrieving wood chip samples from the piles, consisting of a net bag with wood chip sample (1), wire mesh for stabilization (2) and a drag rope (3).

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