EFFECT OF SCREENING ON STORAGE BEHAVIOUR OF WOOD CHIPS

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ABSTRACT: The removal of fine particles such as needles or small pieces of wood and bark by screening might improve storage behaviour of wood chips due to increased pile ventilation and decreased degradation by microbes. Field trials on storage of screened and unscreened wood chips (forest residues, energy roundwood) in large piles (100 m^3, each) were performed for 5 month during the summer of 2017. To monitor changes in fuel quality and dry matter losses, a total of 36 balance bags were placed into each wood chip pile. Highest pile temperatures were measured in the unscreened forest residue wood chip pile (63.1 °C). Screening strongly reduced pile temperature and, thus, might reduce the risk of pile self ignition. Best drying (-20.9 w-%) was observed for the screened forest residue chips. Overall, wood chip piles of forest residues showed better drying, but wood chip piles of energy roundwood revealed smaller dry matter losses.
Keywords: wood chip storage, screening, drying, fuel quality, dry matter losses

1 INTRODUCTION

Storage of fresh wood chips in large piles is important for biomass supply chains as it is used for drying of the bulk material but also to compensate for temporal and spatial differences in fuel supply and demand [1]. Biological degradation processes during storage may cause high dry matter losses and a decline in fuel quality [1][2][3][4]. These degradation processes might be increased by a large amount of fines, such as needles and leaves, due to their relatively large surface area and high amount of easily available nutrients for microbial growth. Furthermore, a large quantity of small particles might decrease pore volume within storage piles and, thus, decrease air exchange rates, leading to longer drying periods [3][4][5].

Therefore, the aim of this study was to investigate the effect of screening, i. e. the segregation of fines, on the storage behaviour of wood chips.

2 MATERIALS & METHODS

A field trial with four piles (100 m^3 each) of fresh wood chips was conducted in 2017 from May until October (22 weeks). The piles were established using two raw materials (coniferous wood chips from forest residues, see Figure 1, and from energy roundwood, see Figure 2) and two treatments (screened and unscreened).

Figure 1: Unchipped forest residues

Figure 2: Unchipped energy roundwood

Chipping of fresh wood chips was done using a Jenz A 582 R mobile chipper equipped with a 30 × 30 mm screen and conveyor belt output. Screening was done before storage using a horizontal screening machine with 10 mm round hole sieves to separate the fines.

Figure 3: Fleece-covered storage piles

Wood chip piles (10 m length × 6 m width × 3 m height) were build-up at a wood chip storage area near Munich (48.06° N, 11.74° E). The ground was neither graveled nor tarred. Piles were aligned in North-East direction. Each pile was equipped with a temperature sensor and covered with a vapour-permeable fleece (PolyTex, 200 g m^{-2}, Zill GmbH & Co. KG) to prevent remoistening by precipitation (see Figure 3). Pile temperature was measured at three heights within each pile (1.5 m, 2 m and 2.5 m) and on-site meteorological data was continuously monitored using a climate station (iMetos pro, Pessls Instruments).

During pile build-up, moisture content (*M*) was determined according to ISO 18134-2 (see Table 1) for all four wood chip assortments, each (n = 24). Ash content (*A*) was determined according to ISO 18122 (n = 12 per pile), net calorific value according to ISO 18125 (n = 6 per pile). Particle size distribution of wood chips was measured according to ISO 17827-1 (n = 3 per pile).

Table I: Analysis methods for fuel quality parameters

Fuel quality parameter	Unit	ISO
Moisture content (*M*)	w-%	18134-2
Ash content (*A*)	w-% d.b.	18122
Net. calorific value (*Q*)	MJ/kg d.b.	18125
Particle size distribution	n.d.	17827-1

Further analyses included bulk density (ISO 17828) or concentration of chemical elements (ISO 16948, ISO 16967). However, these data are not presented in this text.

To monitor dry matter losses and changes in moisture content, a total of 36 balance bags were placed in each wood chip pile during build-up (see Figure 4 and Figure 5). Thereby, bags were aligned in three cross-sectional areas per pile including three bags within the outer layer, 5 bags within the middle layer and 4 bags within the pile center (see Figure 5). After five months of storage, bags were pulled out of the piles using a wheel loader.

Figure 4: Balance bags for the measurement of dry matter losses and changes in moisture content

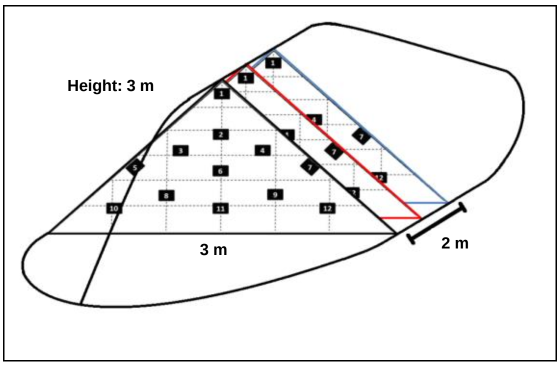

Figure 5: Distribution of balance bags (black squares) within a wood chip pile

Bag contents were analysed for dry matter losses, i. e. for changes in dry weight before and after storage, but also for fuel quality parameters such as moisture content, ash content, net calorific value and particle size distribution.

3 RESULTS & DISCUSSION

3.1 Fuel quality before storage

Before storage, moisture content of the unscreened biofuels was above 50 w-% (see Table I) as it is typical for fresh wood chips [6]. After screening, moisture content of wood chips was somewhat lower while the moisture content of the fine particle fraction was higher.

Ash content was typical for energy roundwood but rather low for forest residues, probably due to overall low shares of twigs and needles in the forest residues used [6]. As expected, screening reduced ash content in wood chips [7].

Table II: Mean fuel quality of screened and unscreened forest residue chips (FRC) and energy roundwood chips (ERC) before storage

Wood chip piles	*M*	*A*	*Q*
FRC unscreened	50.8	1.0	18.6
FRC screened	47.0	0.7	18.3
FRC fine particles	55.4	2.7	18.7
ERC unscreened	50.3	0.9	18.7
ERC screened	49.6	0.9	18.7
ERC fine particles	54.3	2.4	18.8

All four wood chip assortments could be classified as particle size class P31S according to ISO 17225-4 due to overall low shares of particles with a diameter < 3.15 mm (see Figure 6).

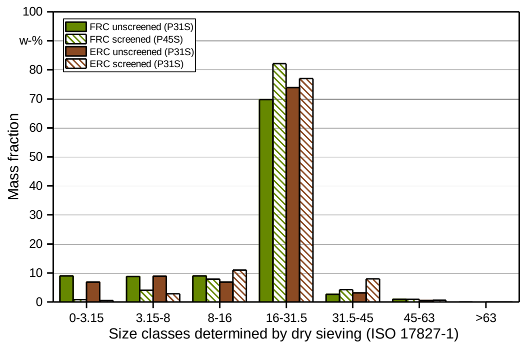

Figure 6: Mass fraction of size classes determined by dry sieving according to ISO 17827-1. (FRC = forest residue chips, ERC = energy roundwood chips)

Overall, wood chip quality before storage was typical for energy roundwood chips. In contrast, chip quality of forest residues was higher compared to typical values [6].

3.2 Meteorological data and pile temperature

During the 22 weeks of storage, precipitation amounted to a total of 570 mm. Mean air temperature was 15.8 °C, mean relative humidity was 80.3 % (see Figure 7). Maximal air temperature during storage was 35.9 °C. Thereby, mean air temperature was similar compared to long-term mean values (May till October

2004–2016: 15.6 °C, climate station "Ebersberg" of the German Weather Service (DWD)). However, both May and June were warmer and dryer than long-term means of these two months.

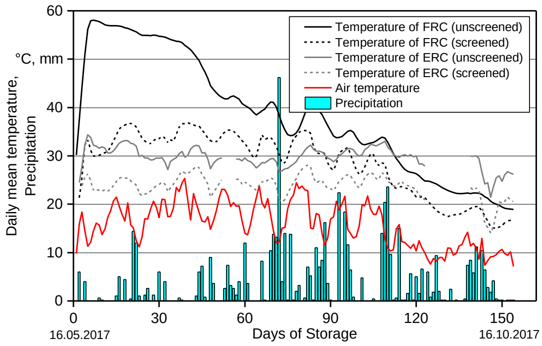

Figure 7: Daily means of air temperature, pile temperature (mean of three sampling points at 1.5 m, 2 m and 2.5 m above ground) and precipitation during storage (FRC = forest residue chips, ERC = energy roundwood chips).

Within five days after build-up, pile temperatures of forest residue wood chips reached their maximum, followed by unscreened energy roundwood chips at day 16, screened forest residue chips at day 19 and screened energy roundwood chips at day 99 (see Figure 7). Highest absolute temperatures were measured in the unscreened forest residue wood chip pile (63.1 °C, see Table III).

Overall, pile temperature was higher for forest residues compared to energy roundwood and for unscreened compared to screened chips [1]. High shares of green biomass (e. g. needles) may offer easily available nutrients for microbial growth. Thus, microbial activity should be higher in forest residues compared to energy roundwood, leading to higher temperature due to respiratory processes [1][5]. Similar, screening might reduce piles temperature due to lower shares of green biomass but also due to an increased pile porosity and, thus, due to better ventilation [3][4][5]. Therefore, warm air within piles might be removed more easily in screened compared to unscreened piles. As a side effect, pile temperature of screened wood chips followed daily changes in air temperature more closely than for unscreened wood chip piles.

3.2 Fuel quality after storage and dry matter losses

During 22 weeks of storage, all wood chip piles dried for 14.8 to 20.9 w-% (see Table II and Table III). Best drying was observed for screened forest residues (-20.9 w-%) leading to a moisture content of 26.1 w-%.

Thereby, moisture content of screened forest residues was significantly lower compared to the other assortments ($p \leq 0.05$, Student's T-Test). Overall, wood chip piles of forest residues showed better drying than wood chip piles of energy roundwood. This might be due to the overall higher pile temperatures within forest residue piles (see Figure 7 and Table II).

Dry matter losses ranged from 5.4 to 8.6 w-% during the 22 weeks of storage (see Table III). Thereby, dry matter losses were higher in forest residues compared to energy roundwood. The higher amount of green biomass in forest residues chips such as needles compared to energy roundwood chips might offer higher shares of easily available nutrients for microbial growth and, thus, might enhance biological degradation.

Table II: Mean fuel quality of screened and unscreened forest residue chips (FRC) and energy roundwood chips (ERC) after storage

Wood chip piles	*M*	*A*	*Q*
FRC unscreened	35.4	1.0	18.9
FRC screened	26.1	0.7	18.6
ERC unscreened	35.0	0.9	18.9
ERC screened	34.8	0.8	19.0

Table III: Maximale pile temperature (T_{max}), change in moisture content (ΔM) and dry matter losses (*DM*) of screened and unscreened forest residue chips (FRC) and energy roundwood chips (ERC) before storage

Wood chip piles	T_{max} °C	ΔM w-%	*DM* w-%
FRC unscreened	63.1	-15.4	7.3
FRC screened	44.5	-20.9	8.6
ERC unscreened	37.8	-15.3	7.0
ERC screened	32.8	-14.8	5.4

Interestingly, for forest residues, dry matter losses were higher in screened compared to unscreened chips while for energy roundwood, the opposite was observed.

In case of forest residues, screening might increase dry matter losses as microbial activity (and pile temperature) was still high due to remaining shares of green biomass and bark while increased ventilation might have led to high O_2 concentrations in piles throughout the whole storage period. As most microbes require O_2 for growth, this might increase degradation.

In contrast, microbial activity and dry matter losses were lowest in screened energy roundwood as mean pile temperature was usually below 25 °C and, thus, below the optimal temperature for fungal growth. However, this also led to the lowest drying efficiency.

Ash content did not change during storage. In contrast, the net calorific value increased slightly for approx. 0.2–0.4 MJ/kg (see Table II). This might be due to higher degradation of cellulose compared to lignin due to the abundance of individual species of fungi. However, no correlation could be observed between dry matter losses and net calorific value or dry matter losses and ash content.

The energy content before and after storage was calculated by dry weight, moisture content and net calorific value. Overall, energy content during the 22 weeks of storage increased for all 4 wood chip piles due to strong drying and low dry matter losses by 0.5 to 2.7 % compared to the energy content at the beginning of the trials. Thus, dry matter losses could be compensated by drying during the warm summer of 2017. No clear trend could be observed between assortments. However, approx. 18 w-% and 16 w-% of dry mass were removed by screening from forest residues and energy roundwood chips, respectively. Thus, taking these dry matter losses into acount, approx. 19.3 % of energy is lost for screened forest residues and 14.7 % for screened energy roundwood. Consequently, suitable uses for the screened fine particle fractions such as compostation, combustion in large biomass heating plants or bedding of farm animals is recommended.

4 CONCLUSION

Screening of wood chips reduced pile temperature due to higher porosity (i. e. better ventilation) and lower microbial activity (i. e. lower shares of nutrients). Thus, screening may reduce the risk of pile self ignition. For dry matter losses and fuel quality, no clear trend could be observed, as microbial activity, pile temperature, porosity, O_2 abundance and ventilation are strongly interlinked leading to better drying and higher dry matter losses in forest residues but not in energy roundwood.

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