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# Storage

*The temporal imbalance between production and demand for wood fuel creates a need for storage, either as e.g. untreated residues, as bark or as residue wood chips. Storage is an inevitable step within the supply chain and serves as a method to increase fuel quality, i.e. decrease moisture content and increase net calorific value. Screening of biomass could be used as a method to improve fuel quality by removing contaminants. Comminution to a large faction is profitable, but the screening cost is quite high. Thereby the economic profitability depends on both storage time and deposition of the fines.*

## STORAGE

Logging residues are stored in windrows at the roadside or at the clear-cut site prior to comminution. It is possible to reduce the moisture content in windrows from 50 % (fresh weight) to 30 %. However, to achieve such progress both successful management and favourable weather conditions are required and if the windrow storage is unsuccessful, the moisture content increase due to ambient rewetting.

Forest residues are stored in small piles in-stand at the clear-cut for a few weeks and then gathered into windrows at road-side. The placement of the windrows as well as the shape of the windrow is determinative for the result and prevailing wind direction facing the longitudinal side of the windrows as well as maximum sun exposure has to be considered. If possible, windrows should be placed at a high and dry position at the roadside or as a second choice at the clear-cut area. In Sweden and Finland, windrows are covered with paperboard as a quite common practice to protect the biomass from precipitation, i.e. ambient rewetting (Fig. 1).

Fig. 1. Forest residues stored in a covered windrow at roadside.

Covering is performed by using a specially equipped forwarder crane, which rolls out the cover material on top of the windrow. The paperboard has to be burdened using logging residues/tree parts to prevent the cover to blow off. Therefore, the top layer of the windrow has to be flat, smooth and without pits were precipitation, i.e. rain, snow, can be accumulated and freeze, which could increase moisture content and put much strain to the comminution equipment.

## STORAGE OF FUEL CHIPS AND BARK AT TERMINALS

Storage at terminals is an important component in securing the supply of forest fuels to industries. For bark, which is produced all year long, there is no real alternative than terminal storage. Large-scale storage of fuel chips can reduce the risk of disturbances in the fuel supply chain affecting heat and power production during peak demand. In addition, large-scale storage of fuel chips increases the annual utilisation of chippers and chip trucks, which can reduce the supply cost if costs related to storage are minimised.

However, storage of chipped material is associated with a risk for excessive storage costs and excessive dry matter losses, which in worse case can cause self-ignition. The mechanisms and processes behind temperature development and degradation, e.i. living cell respiration, biological degradation by microbes and thermo-chemical oxidative reactions, are well documented. The microbes involved use glucose as their energy source and their level of activity is related to moisture content, combined with oxygen level and the surrounding temperature.

Storage properties are thus rather complex since it depended on both the amount of easily assessable nutrias and moisture content as well as particle size, permeability of the pile and ambient weather conditions. The characteristics of the assortments differ significantly. For instance, the bark has a higher proportion of parenchyma cells and more easily accessible nutrients than wood, which makes bark more suitable for microbes (Fig. 2). Freshly harvested biomass contain more nutrients and in general, has a higher moisture content. One of the most important things is to avoid the storage of mixed assortments since it unconditionally leads to poor storage properties. Many attempts to improve storage techniques aiming to improve fuel quality, decrease dry matter losses and energy losses have been made.

Fig. 2. Massive microbial infection during storage of bark in an uncovered pile.

## PILE FORM, HEIGHT, AND COMPACTION

Size, shape, and compaction of the storage pile have a significant effect on both temperature development, moisture reduction, and material- and energy losses. The outcome is related to a number of factors, such as the pile permeability, since it directly affects the distribution of moisture and heat within the pile. Low permeability impairs the ventilation, leading to accumulated heat within the pile. Permeability is negatively correlated to pile size and in particular to the height of the pile. It is also negatively correlated with compaction.

Thereby, it is important to enable conditions that facilitate heat transfer of accumulated heat by considering both the pile shape and height as well as the wind direction and pile placement at the terminal. Compaction deteriorates the permeability of the pile and rises unevenness within the pile leading to accumulation of heat at the same time as uncompact areas work as an acceleration of oxygen supply.

The combination leads to a potential risk for spontaneous self-ignition. All piles are affected by local weather conditions. Moisture content decreases rather fast in both small and large piles during favourable conditions. However, due to condensation, moisture content could rather than decreased be redistributed within the pile during storage. Small piles are more affected by ambient weather conditions than large piles, due to the relationship between surface area and stack volume.

## COVERAGE AND COVERAGE MATERIAL

Moisture content is one of the most important parameters since it affects both the microbial activity, the permeability, and the net calorific value. Reducing moisture content is an important objective for storing biomass used for energy generation and a cover that can protect biomass from ambient rewetting is desirable.

However, a compact covering material, which not allows heat and water vapour pass through will not decrease the average moisture content of the pile, only redistribute it within the pile leading to favourable conditions for microbes. Methods of covering that prevent precipitation from reaching the biomass and at the same time allow water vapour to be released are needed. This implies using an effective method to ventilate the water vapour or using a semi-permeable covering material. The profitability with coverage is dependent on cost for material and labour and it is likely that it is more favourable to use a covering material during long-term storage.

## SCREENING OF FINES

Screening of fines in combination with comminution to a large and homogenous faction of the produced chips is a possible method to reduce heat accumulation by increasing the permeability within the pile during storage. A higher permeability results in better ventilation. Thereby larger pieces dry more quickly and attained lower moisture content than fine particles.

Layers of fines can reduce heat dissipation leading to increased accumulation of heat followed by increased microbial- and chemical activity. Fines, especially if it contain twigs and bark, contain high concentrations of easily assessable nutrition, leading to favourable conditions for microbes. In addition, fines have the highest resin content leading to a potential risk for spontaneous self-ignition.

Screening of biomass could be used as a method to improve fuel quality by removing contaminants. Comminution to a large faction is profitable, but the screening cost is quite high. Thereby the economic profitability depends on both storage time and deposition of the fines.

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