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Transpirational drying of wood: A review

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Abstract: This paper presents the basic assumptions and state of the research pertaining to the drying of wood in a forest. A clear distinction needs to be made between wood drying in the form of logs and whole trees that have been felled and left in a leafy state. The drying of whole trees has been known for many years as transpirational drying. This method is based on using the leaves to speed up the drying process. It is useful for both deciduous and coniferous trees, the difference being that, for deciduous trees, felling is limited to the growing season. This method is not used on a larger scale because of the lack of standardised technical solutions based on scientific research. There is growing interest in this type of method, however, mainly because of the economic benefits that can be obtained relatively simply. Solutions based on transpirational drying are being taken more and more seriously by the wood industry, and this is also being reflected in current scientific works. The aim of this paper is to present the benefits and limitations of transpirational drying.

Keywords: wood drying, natural drying, caloric value, logging operations

INTRODUCTION

Immediately after felling a tree, the raw wood has a high moisture content, which is undesirable for further processing. This moisture content depends on the felling date, tree species, heartwood percentage, site conditions, geographic location and other factors (Clark and Gibbs 1957; Steward 1967; Nurmi 1995). Trees with a large proportion of heartwood show different moisture contents between the sapwood and heartwood. After felling, the moisture content decreases slowly, and the wood dries out. Because this process is slow, wood defects can occur. Such defects have biological origins, which can be serious in sapwood tree species, such as beech, birch and alder. In order to avoid defects, the wood is transported out of the forest quickly or harvested only during the winter. In either case, the load is wet and heavy. A potential solution to this for young trees is to dry the wood on site, using the leaves (Fig. 1). A rapid reduction in moisture protects against wood defects and reduces the weight of the raw material. This is beneficial for transport and energy (calorific value) reasons (Cutshall et al. 2013). Some studies have investigated the course of the change in moisture content and the mass of the raw material during storage of the wood, with most focusing on small, round wood stacked in piles or prepared as wood chips (Nurmi 1995; Nurmi and Hillebrand 2007; Roser et al. 2011). The research in this area is relatively advanced, with several models having been developed to predict natural wood drying (Erber et al. 2012, 2014, 2016).

RESULTS

Benefits and limitations of transpirational drying

The first, and most important, benefit of transpirational drying is the rapid and significant reduction in wood moisture, even in the first few days (Wang et al. 2018). Conversely, when drying wood without a crown, it takes weeks to obtain a significant drop in moisture content (Erber et al. 2012, 2014). A comprehensive review of transpirational drying was presented by Stockes et al. in 1993, wherein they examined the research conducted mainly in the 1980s. Most of the studies cited described drying carried out mainly within a few weeks after cutting. The findings of that review suggested that the effectiveness of transpirational drying varies according to tree species. Species with large proportions of heartwood are less susceptible to transpirational drying, while sapwood species, such as birch, dry out quickly. Diffuse-porous species dry out faster than ring-porous species. Younger trees, a few years old, also dry better and faster than older trees. The best result is achieved in the first few weeks of drying.

An interesting experiment was presented by Uzoh (1987), in which the transpirational drying of young Douglas fir and lodgepole pine trees produced a reduction in moisture content to that optimal for chipping, regardless of species, after the first week for delimbed trees and after between 1 and 2 weeks for limbed trees. That study took place in summer, and the optimum chipping period may differ in other seasons. Experiments carried out in the UK on Sitka spruce and lodgepole pine illustrated the long-

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term behaviour of conifer wood (Mitchell et al. 1988). The experiment achieved a reduction in moisture content of 12–13% for Sitka spruce over a 5-month period and 17% for lodgepole pine over 13 months.

Short-term observations of transpirational drying were described by Cutshall et al. (2013) for 14-year-old pine trees, where it was allowed to proceed for 4 and 8 weeks. After these periods, the trees were chipped. The initial wood moisture content was 53% (49–57%), decreasing to 43% (30–49%) after 4 weeks and to 39% (29–50%) after 8 weeks. An experiment conducted at the end of the summer revealed significantly better drying performance during the first 4 weeks.

Despite the obvious effects of the short-term natural drying of wood, long periods have also been examined (Kofman and Kent 2007) because this can be important when planning logistics or during major natural disasters. Transpirational drying, which is efficient in its early stages, has also been studied over a longer period, mainly in coniferous species (Johnson and Zing 1969). Nurmi (1995) described one experiment on a 7-year-old willow tree that lasted for 18 months, from April 1992 to September 1993. The initial moisture content of the willow wood was 53.9% (47.7–53.9%), which dropped to 26% by the end of the experiment. The greatest drop in moisture content was recorded at the beginning of the drying period, with the moisture content having fallen steadily to 34.6% by July 1992. The calorific value of the dry wood varied within a small range of between 19.8 and 20.2 J/g during this time, while the calorific value of the fresh wood increased from 15.979 to 18.876 J/g.

Klepack et al. (2014) presented a study conducted on a 14-year-old loblolly pine, focused on the drying of large and small piles. The drying period was for 70 days, from August to October. The trees were arranged in large and small piles (skidder bundles). After the drying period, the average moisture content in the large piles was 39.3%, and in the skidder bundles, 25.6%. However, significant differences were noted in different zones in the piles. These differences were much greater in the large piles (48.9% in the bottom zone, 40.5% in the middle, 28.6% in the outer zone) than in the skidder bundles (29.2, 24.3 and 23.8%, respectively). Large differences in moisture content were also recorded in different parts of the tree, with the bottom part of the trunk (the butt) containing 26.8% and the top, 48.2% (in the large piles), while in the skidder bundles, the butt contained 15.4% and the top, 27.7%. This suggests a very uneven drying of the raw material. Overall, the calorific value after drying increased by 72.6% in the large piles and 111.8% in the skidder bundles.

The concept of bunching in ponderosa pine, based on transpirational drying, was presented by Riquelme et al. (2019, 2020), who demonstrated the benefits of natural drying and the possibility of the industrial application of small-diameter ponderosa pine trees. Their work concluded that the bunching method can be an effective way of pre-drying such raw materials, although, since the drying of wood is affected by various factors, such as tree species, geographic location and weather conditions, further research is needed on this topic.

Not all studies, however, have proven the utility of transpirational drying. An experiment carried out on loblolly pine, sweetgum and oak showed a greater benefit from crushing than from not crushing—an effect that only disappeared after long-term drying over the course of 10 weeks (Sirois et al. 1991). This was explained as being mainly due to the effect of precipitation, which is followed by faster drying of the crushed raw material. Filbakk et al. (2011) described an experiment conducted at three different locations in Norway on three deciduous species (birch, alder, goat willow). Part of the experiment concerned the winter storage period (of trees harvested in autumn) and the other part the summer storage period (of trees harvested in spring). In addition, the piles examined were divided into covered and uncovered. The best results were achieved by covering the wood during rainy periods and uncovering it during dry weather. However, this is only a theoretical consideration that is difficult to implement in practice. For the winter drying period, there was no dependence on geographical location found, although there was a covering effect. For the summer-dried trees, there was an obvious effect of temperature and precipitation, which varied at each location. In this case, there was a large influence of leaves on the drying effect.

The influence of weather has been particularly emphasised in studies on natural wood drying (without a crown), in which various methods are tested in order to limit the negative influence of the prevailing conditions, such as the date on which the drying starts, the size of the pile or covering of the pile during storage (Nurmi and Hillebrand 2007; Kofmann and Kent 2009; Klepac et al. 2014; Erber et al. 2017; Kizha et al. 2018; Tomczak et al. 2018).

With transpirational drying, however, the initial drying period, which is closely linked to transpiration, appears to be crucial. The transpiration process itself may be related to the weather. Wang et al. (2018) demonstrated the effect of transpiration on drying efficiency in poplar trees. The moisture content of the wood and the transpiration process itself were investigated. The moisture content was tested on felled trees (with and without a crown), while the degree of transpiration was determined on felled trees in the crown and on control trees (live, not felled). The drying efficiency was the highest in the first 9 days, during which a reduction in moisture content of about 20% was achieved for the trees with crowns, but only a few percent in the wood without crowns.

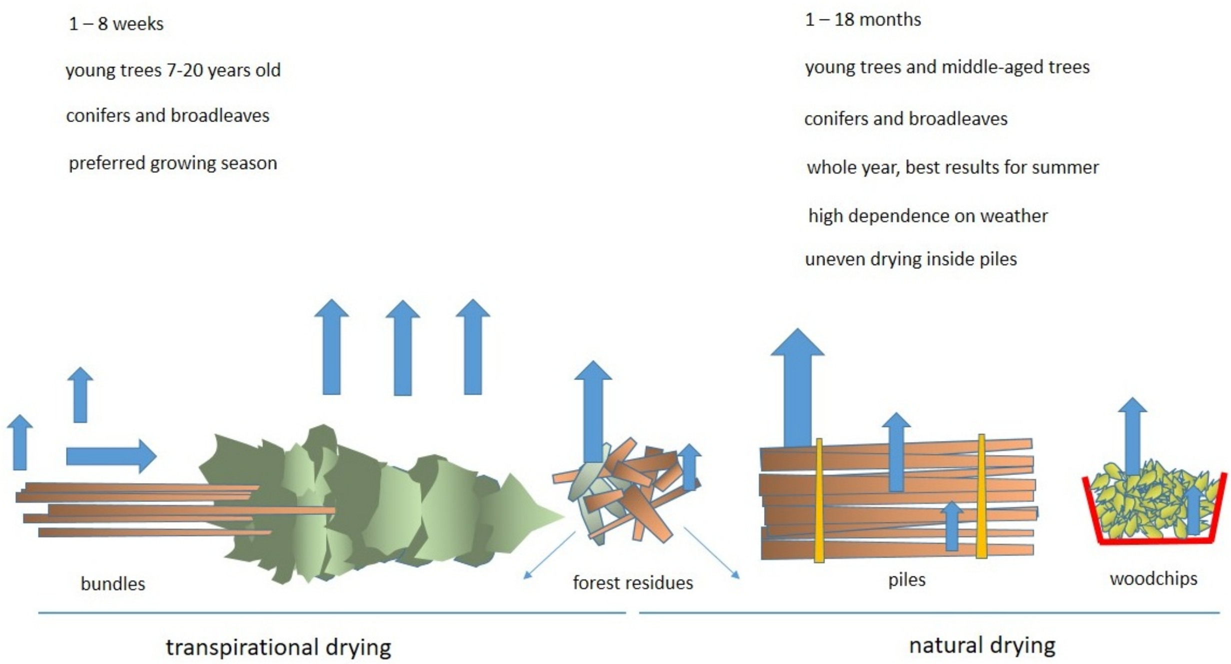

Figure 1. Scheme of natural drying methods.

CONCLUSIONS

Transpirational drying is a relatively simple method that leads to a reduction in the moisture content of felled wood and, as a result, to a reduction in its transport costs and an increase in its calorific value when used for energy. It is generally applied to young trees of various species aged several dozen years. The drying process has only been partially investigated, mainly in relation to selected production methods. Based on the research, it can be concluded that such drying is strongly influenced by tree species, the season of the year, and the geographical location in relation to weather. The most influential weather parameters are temperature, precipitation and air humidity. The method of drying is also important, especially in relation to the size of the wood pile and where it is stacked. Usually, the top of the pile dries well, while the bottom does not. Therefore, relatively small piles are more desirable. The primary effect of drying, which is a rapid reduction in moisture, is visible within 1 to 4 weeks, depending on the species of tree. Thereafter, drying fluctuates depending on the weather. Both short- and long-term drying require specific logistics and processing of the raw material. Timber without a corona can be loaded and transported out. Crowned wood usually requires on-site processing into woodchips. Even though the basics of the transpirational drying process are known, further research is needed to clarify the guidelines for industry, especially in terms of different regions and their local conditions.

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