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CHEMICAL STAIN IN HARDWOODS & CONTROL

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Summary

Wood stains are directly related to lower quality, resulting in a loss of product value. In 2004, a study about financial losses due to coloration revealed that the cause may be either fungal or chemical, depending on the species. Moreover, the findings clearly indicate that one of the main causes of discoloration in sugar maple is chemical in origin (45% of cases), which results in the direct downgrading of nearly 37% of products (sap grades) from logs that had been stored in an open sawmill yard.

To better define and understand the mechanism responsible for the different types of chemical stains that develop in hardwood, a research project was developed to assess the different types of stains occurring in sugar maple during storage as well as evaluate the potential of different treatments to prevent or at least minimize this type of stain. Testing under actual storage conditions was then performed with sugar maple and yellow birch logs. They were subjected to four treatments that demonstrated the greatest potential: waxing, pasteurization, steam treatment at 100°C, and steam treatment at 75°C.

The evaluation criteria were based on visual assessment of the presence and degree of fungal and chemical (oxidation) discoloration. Specific attention was paid to the proportion of pieces with measurable end oxidation (visible to the naked eye) and to oxidation penetration based on the type of treatment applied to the logs before storage. A colorimeter was used to measure the color on each piece of lumber sawn from these logs.

1. Introduction

According to several American studies, chemical discoloration of wood actually refers to a process resulting from oxidation and enzymatic reactions of the sapwood's chemical constituents (nutrient reserves) (Xu & Clement, 2005; Forsyth & Amburgey, 1992). Since the parenchyma cells continue to live for several weeks after the tree is felled, they are present in logs and lumber for a certain time. Chemical stains develop when naturally occurring chemicals in wood react with air (an enzymatic oxidation reaction) to form new chemicals that are typically dark in color. The chemical precursors, which develop in the wood and will eventually lead to discolouration, are developed above 40% of moisture content (MC) (Wengert, 1992; Chauret & Giroux, 1999). Once the precursors develop, staining is probably inevitable. However, it is difficult, or impossible, to detect when the precursors have formed and when they will appear on wood. These reactions can produce a variety of shades, ranging from greenish, pinkish to bluish, yellowish, greyish, or even reddish brown to dark brown (Panshin & de Zeeuw, 1980).

Treatments to prevent this type of discoloration must be able to block or at least alter oxidation or enzymatic reactions in the wood by destroying the living parenchyma cells present or by reducing oxygen availability.

2. Methodology

A literature review was initiated to determine the different types of chemical discoloration and identify treatments offering a good level of potential protection.

The preliminary laboratory assessment focused on the different types of stains occuring in sugar maple logs and lumber during storage. Various treatments with potential to prevent or minimize this type of stains were evaluated. Five treatments on logs were assessed: a) methyl-bromide fumigation, b) pasteurization at 56^oC for 30 minutes (internal temperature), c) steam treatment at atmospheric pressure – 100^oC for 60 minutes (internal temperature), d) vacuum treatment, and e) sealing the ends of logs for storage (waxing). Six treatments on lumber were assessed: a) methyl bromide fumigation, b) pasteurization at 56^oC for 30 minutes (internal temperature), c) steam treatment at atmospheric pressure – 100^oC for 60 minutes (internal temperature), d) vacuum treatment, e) soaking in sodium-bisulfite solution, and f) soaking in a solution containing a sequestering agent – Busperse 2290. Storage conditions were 90% of relative humidity and 28^oC in a controlled chamber. The logs were assessed after 15 weeks of storage; the lumber after 12 weeks.

In the second year of the study, testing was initiated under field storage conditions with freshly harvested (August 2006) sugar maple and yellow birch logs that were treated within five days of harvesting. Four treatments were assessed: a) waxing, b) pasteurization at 56^oC for 30 minutes (internal temperature), c) steam treatment at atmospheric pressure – 100^oC for 60 minutes (internal temperature), and d) steam treatment at atmospheric pressure – 75^oC for 60 minutes (internal temperature). Following treatment, the logs were stored outside in Forintek's yard. In October 2006, after eight weeks of storage, the logs were sawn into 2.54 cm thick lumber with a portable sawmill (Wood-Mizer). The lumber was immediately kiln dried according to a schedule for white wood and then individually assessed. The evaluation criteria were based on visual assessment of the presence and degree of fungal and chemical (oxidation) discoloration. Specific attention was paid to the proportion of pieces with measurable end oxidation (visible to the naked eye) and to oxidation penetration based on the type of treatment applied to the logs before storage. A colorimeter was used to measure the color on each of the lumber pieces.

3. Results and Discussion

Literature review
From the literature review, six types of chemical stains were identified as commonly found in wood: 1) surface stain, 2) sapwood discolouration, 3) internal stain, 4) sticker stain, 5) compression marks (harvester, spiked feed roller, debarker, etc.), 6) log end oxidation.

1) Surface stain
Hardwood species are more susceptible to oxidative stain than softwood. For certain hardwood species, intense stain can appear on lumber within an hour after the green wood surface is exposed to the air (Figure 1). Most of the oxidative discolorations are confined to within 1/16 inch of the outer layer of the board and can be eliminated by planing (Simpson, 1991).

Figure 1 Surface Oxidation (white birch)

2) Internal stain
Sometimes oxidative discolorations are not evident until the outer 1/32 to 1/16 inch surface has been planed off. This is because the outer surface of the green board has dried to a lower moisture content (<40% MC) before oxidative chemical reactions can be completed, but the major inner portion of the board is still green. This can happen with stacked lumber that begins to air dry before kiln drying is started (Figure 2).

Figure 2 Internal greying in maple

3) Sapwood discolouration

A greyish to brownish discoloration of the sapwood of several hardwood species is quite common. The exact origin of grey stain is unknown but it is believed to be resulted from enzyme-mediated reactions within the parenchyma cells. The discoloration frequently originates at the heartwood-sapwood interface and spreads throughout the sapwood (Figure 3). Usually the stain is not noticeable until rough-sawn lumber has been air-seasoned and planed (Forsyth & Amburgey, 1992).

Figure 3 Sapwood discolouration (sugar maple)

4) Sticker stain

Sticker marking, which occur during air seasoning and kiln drying, develops on and beneath the surface of the board, where stickers come in contact with it (Figure 4). It is believed that this stain develop as a result of chemical changes in wood extractives during drying (Panshin & de Zeeuw, 1980). This discoloration can occur in heartwood, but is much more prevalent and troublesome in sapwood. The causes can be chemical, microbial, or a combination of both (Simpson, 1991).

Figure 4 Sticker stain

5) Compression marks
Several other types of stains can develop on hardwood such as compression marks (Figure 5). This type of stain is often associated with logs and green lumber manipulation and appears on localised strong pressure areas: harvester, spiked roller, debarker, etc. (Chauret & Giroux, 1999).

Figure 5 Compression marks

6) Log end stain
This type of stain develops in logs during storage when temperature and moisture conditions of the air are favourable (long storage in warm weather) (Figure 6).

Figure 6 Log End Stain

Laboratory testing

Four types of stains were identified on the control logs under the harsh storage conditions reproduced in the laboratory. The stains can be broken down into two groups according to origin: 1) stains resulting from chemical or enzymatic oxidation: surface oxidation and end oxidation and 2) fungal stains: rot and green discoloration (***Figure 7***). Specimen slices were taken at different depths from a control log (5.5 cm, 11.0 cm, 16.5 cm, 22.0 cm, and 27.5 cm from the end of the log), making it possible to quantify the extent of each occurrence in terms of stained surface. Consequently, end oxidation is by far the most important type of staining, affecting 55% of the surface of a slice taken at a depth of 5.5 cm and 18% of the surface of one taken at a depth of 27.5 cm. This contrasts with the other slices taken from the log, in which surface oxidation and rot stains affected 6% of the surface taken at a depth of 5.5 cm and were no longer visible at a depth of 16.5 cm. Green stains covered 12% of the surface at a depth of 5.5 cm and were no longer visible at a depth of 27.5 cm. In the case of the lumber, only surface oxidation stains occurred and were found more or less evenly distributed across the entire surface of the piece.

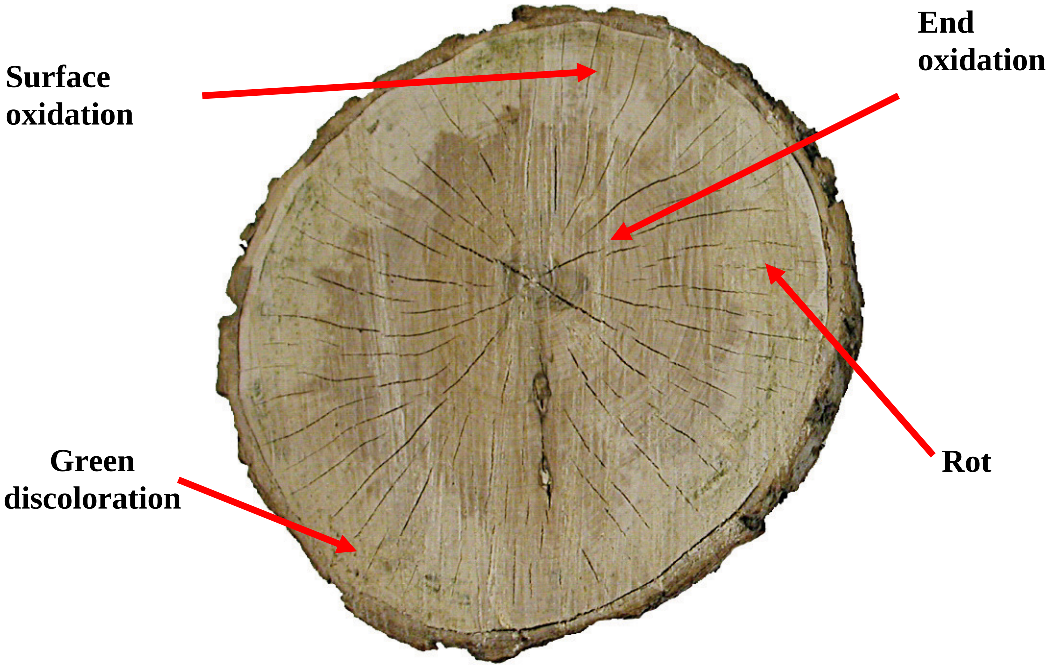

Figure 7 Types of staining developed in sugar maple logs under harsh storage conditions

For the different treatments tested against chemical stains, pasteurization, steam, and fumigation proved to be the most effective in reducing the occurrence and intensity of oxidation stains. These treatments, which were carried out before storage, were equally effective on logs and lumber. These three treatments also proved to be very effective in preventing compression marks, making it possible to eliminate 100% of such marks when the lumber was steam treated before storage (Figure 8).

Figure 8   Compression marks (upper piece: control; lower piece: steam treated)

Validation in field storage conditions

Testing in field storage conditions indicated that steam treating logs at 100^{o}C was quite promising. This treatment made it possible to significantly reduce end oxidation, while promoting more color uniformity in the lumber. Consequently, after eight weeks of outdoor storage, nearly 90% of the sugar maple untreated logs evidenced end oxidation visible to the naked eye (Figure 9), contrasting with less than 10% of pieces of maple taken from logs that had been steam treated at 100^{o}C. In the case of yellow birch, 40% of lumber pieces sawn from untreated logs showed end oxidation visible to the naked eye, compared to 0% of pieces from logs that had been steam treated at 100^{o}C.

Figure 9   End oxidation (visible to the naked eye)

The depth of oxidation was also substantially reduced by the steam treatment at 100^{o}C, representing an average of 0.5 cm for lumber from treated maple logs, compared to 9.4 cm for the control lumber (untreated logs) (Figure 10). In the case of yellow birch, the depth of end oxidation varied from 14.5 cm in the untreated control lumber to no oxidation in lumber from steam treated logs.

Steam treatment also appeared to reduce green stain in maple. This type of treatment, however, appeared to be more conducive to the development of fungal staining.

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Figure 10 Average depth of end oxidation

This study will be followed up by a study to validate and optimize heat treatment as a method to prevent sapwood oxidation in hardwood species. Before the treatment can be contemplated for use under industry conditions, the existing mill processes will have to be changed: handling logs in the yard, adapting treatment units (kilns), and modifying schedules. However, the whole-log treating capability offers the advantage of being able to rapidly treat the raw material as soon as it arrives at the mill, thereby preventing deterioration caused by discoloration during storage.

4. Conclusions

This study identified certain treatments that are promising for the prevention or attenuation of chemical discoloration in hardwood species. Steam treatment at 100^{o}C proved the most effective method for preventing oxidation stains in sugar maple and yellow birch. This treatment minimized wood oxidation and made lumber color more uniform. Furthermore, it appeared to attenuate the development of green staining in sugar maple. On the other hand, the treatment seemed to be more conducive to the development of fungal stains. Before any industrial application is contemplated, consideration should be given to pairing this treatment with a fungicide.

5. Literature

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