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Drying Temperature to Reduce Oxidative Discoloration in Soft Maple

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Abstract

Color degrade in soft maple can be minimized by drying soon after harvest at temperatures that do not exceed 43 °C.

Keywords: Drying temperature, oxidative stain, soft maple

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Cover photo: Oxidative discoloration levels shown in internal cross sections of soft maple, ranging from none to severe.

Contents

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Drying Temperature to Reduce Oxidative Discoloration in Soft Maple

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Introduction

This research is a continuation of a project that began as an attempt to reduce or eliminate oxidative discoloration in the wood of Bolivian ochoó (*Hura crepitans* L.). The results of the original study (Wiemann et al. 2007) showed that mechanical methods resulted in only localized elimination of discoloration, and that an effective chemical treatment would probably not be economical. Therefore, we decided to explore control of drying temperature as a possible means to solve the discoloration problem. We designed a system of temperature-controlled chambers that could be easily and cheaply transported to Bolivia to test the effects of temperature on degree of oxidative discoloration. Here we discuss the validation of the method using soft maple in the United States.

Previous research indicated that oxidative stain in both hard and soft maple begins only after the wood becomes heated to a threshold temperature (Rappold and Smith 2004; Wiemann and Knaebe 2008; Wiemann et al. 2009). Wiemann et al. (2011) found this temperature to be about 43 °C in soft maple (*Acer rubrum* L.), but an independent statistical review of our previous experiments suggested that more valid and precise results might be obtained by repeating the experiment using a narrower range of conditioning temperatures. Herein we report on the drying results using the new sampling experiment.

Figure 1 reproduces the results found in Wiemann et al. (2011). This figure shows the rank order of the color score from the least (1) to the most (72) discolored samples of soft maple exposed to temperatures ranging from 41 to 51°C and 75% relative humidity for a period of five days. Half the samples were cut and conditioned at 41, 46, and 51 °C immediately after sawing (first run), and the other half were stored as full length boards at 2 °C for eight days before they were cut and conditioned at 42, 43.5, and 45 °C (second run). For each run, half the samples were wrapped in plastic wrap to prevent drying; the other half were unwrapped. Samples conditioned at temperatures above 43 °C showed the most discoloration. Wrapping had no consistent effect on the degree of discoloration. Storage for eight days at 2 °C resulted in a greater number of very discolored samples (color scores 66–72), although the comparisons are not direct because the two runs were conditioned at different temperatures. Therefore, we repeated the experiment with a more limited temperature range (41–43 °C) without wrapping any samples in plastic wrap, using the same conditioning temperatures for the stored and unstored samples.

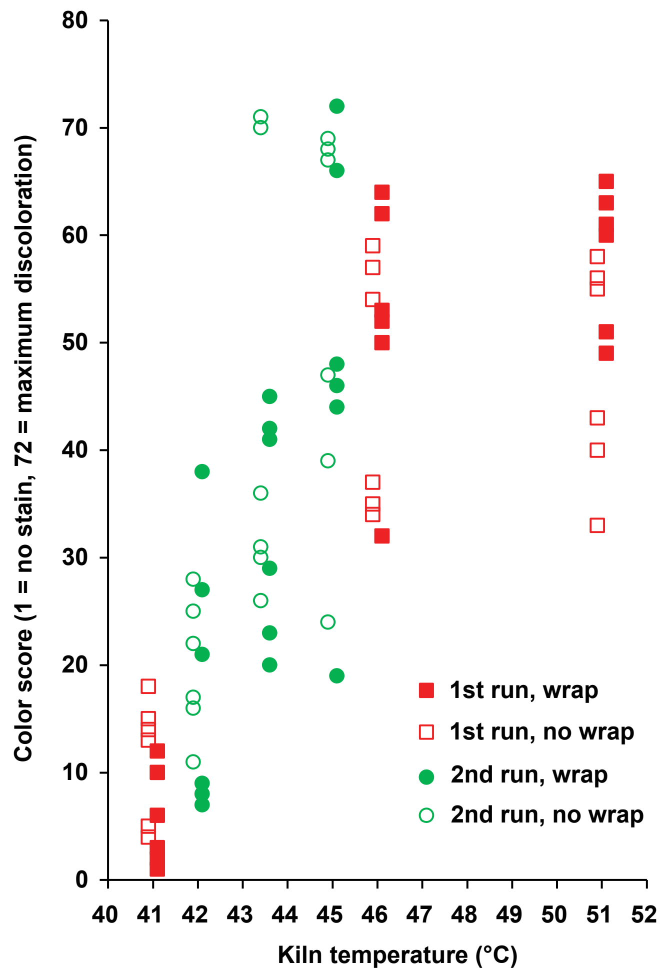

Figure 1. Discoloration of soft maple samples after exposure to the indicated temperatures. Squares represent samples from the first run, circles represent samples from the second run. Closed symbols represent wrapped samples, open symbols represent unwrapped samples. Note the marked increase in discoloration at exposure temperatures above 43 °C.

Figure 2. Conditioning chambers showing incandescent bulbs and fan assemble (a), loaded with samples, with yellow thermometer protruding from a hole in the left side and a data logger on the right side (b), with salt pan installed and with foam spacer to divert air flow (c), and control box showing three control assemblies with temperature readouts visible in front (d).

Procedure

The same conditioning chambers, made from picnic coolers and used by Wiemann et al. (2011), were used in this experiment. As shown in Figure 2, these coolers were rigged with 100-watt incandescent bulbs (to provide heat), fans, thermostats, thermometers, pans containing NaCl to maintain a constant relative humidity of 74%–75%, and data loggers to continuously measure temperature and relative humidity. The wood samples were shielded from direct exposure to radiation from the incandescent bulbs by a thin plywood “floor”.

We obtained 10 sapwood soft maple test boards, at least 8-cm wide and 190-cm long, each one from a different freshly sawn log, from Kretz Lumber company in Antigo, Wisconsin. These boards were transported to the Forest Products Lab in sealed plastic bags, where they were stored at 2 °C until further processing.

Within one day of collecting the test boards, a 90-cm-long segment was cross-cut from each of the 10 boards. The 90-cm segment, to be used in the first run (designated “Fresh”), was set aside for further processing. The remaining portions were re-sealed in the plastic bags and returned to 2 °C storage.

The 90-cm segments were sawn as shown in the top half of Figure 3, labeling the moisture content (MC) samples (1–40) and test samples (1–30). For simplicity of loading, the test samples were also labelled with the conditioning chamber number, C1–C3, and the board number 1–10. The sawing procedure was to rip-saw each 90-cm segment to a uniform width of 7.5 cm without wane or bark and with a maximum of sapwood. Then, beginning at the freshly sawn right end of each ripped segment, a 2-cm MC sample was removed, then a 25-cm test piece, then another 2-cm MC sample, another 25-cm test piece, another MC sample, the third 25-cm test piece, and a final MC sample. The left-most remainder, which was at least 4-cm long (marked x on the top half of Fig. 3), was discarded to eliminate end effects. With allowance for kerf, this resulted in four MC samples and three test samples per board, for a total of 30 test samples. The MC samples and the test samples were immediately weighed. The MC samples were put into a convection oven set at 103 °C, and the test samples were loaded into the conditioning chambers 1, 2, and 3, as indicated in the top half of Figure 4. The chambers were loaded so that all 10 boards were represented in each chamber during each run. The positions of the test samples were selected using the random number generator of Excel (random numbers not shown).

The temperature controllers of chambers C1, C2, and C3 were set to 41, 42, and 43 °C, respectively. The test samples were weighed daily. The MC samples were weighed periodically until they no longer lost weight; their final readings were taken as their ovendry weights. Using their initial and ovendry weights, their moisture contents were calculated, and these moisture contents were used to calculate the theoretical ovendry weights of the test samples. Using the calculated ovendry weights and the daily weighings, the drying progress of the test samples was monitored. After eight days, the test samples were removed, weighed, and sawn in half along their length and evaluated for degree of discoloration by two of the authors. The evaluation was done by separating halves into two matching groups with their sample numbers hidden from view. The amount of discoloration of each half sample was evaluated by two people scoring them independently, and ranked from 1 to 30, where 1 was the least discolored and 30 was the most discolored. The two half-sample scores were compared to arrive at a consensus (average) score for the sample. The 30 samples were also divided into four subjective discoloration groups, in which 1 is no discoloration, 2 is minor discoloration, 3 is moderate discoloration, and 4 is severe discoloration.

The remaining portions of the test boards were removed from 2 °C storage after they had been stored for a total of 20 days. They were prepared for the second run (designated “Aged”) in the same manner as the “Fresh” boards, as shown in the bottom half of Figure 3. To avoid confusion, the MC samples were numbered 41–80, the test samples were numbered 31–60, and the chambers were numbered C4 (41 °C), C5 (42 °C), and C6 (43 °C). The chambers were loaded as before, as shown in the bottom half of Figure 4. The pieces marked x on the bottom half of Figure 3 were discarded. The experiment was repeated for eight days, after which the 30 “Aged” samples were removed from the chambers, sawn open, and evaluated for rank and discoloration group. The discoloration groups of the “Fresh” samples

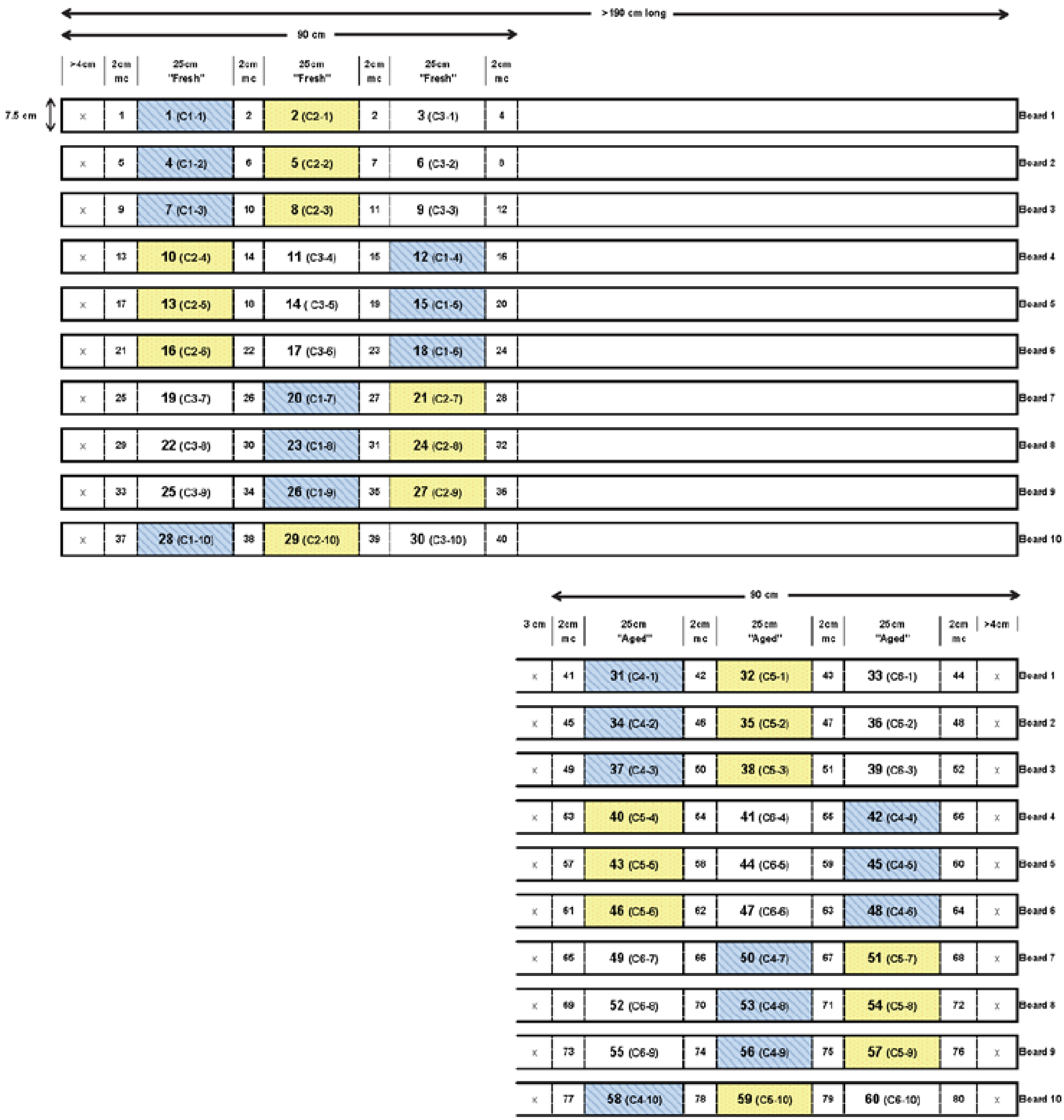

Figure 3. Sample cutting scheme for the 10 sample boards (Board 1 to Board 10). The pieces marked x were discarded to account for possible end drying. 2-cm-long moisture content (MC) samples were numbered as indicated. 25-cm-long test samples, numbered 1–30 for the "Fresh" samples and 31-60 for the "Aged" samples, are marked with piece number (in bold), the conditioning chamber number (C1-C3 for the "Fresh" run and C4-C6 for the "Aged" run), and the board number from which the sample came. For example, 35 (C5-2) is sample 35, cut from Board 2 after the storage of this board for the second run; it was put into chamber 5 with other "Aged" samples; the settings on chamber 5 were maintained the same as those of chamber 2. Samples dried at 41 °C marked with diagonal lines in blue background, those dried at 42 °C marked with dots in yellow background, those dried at 43 °C unmarked.

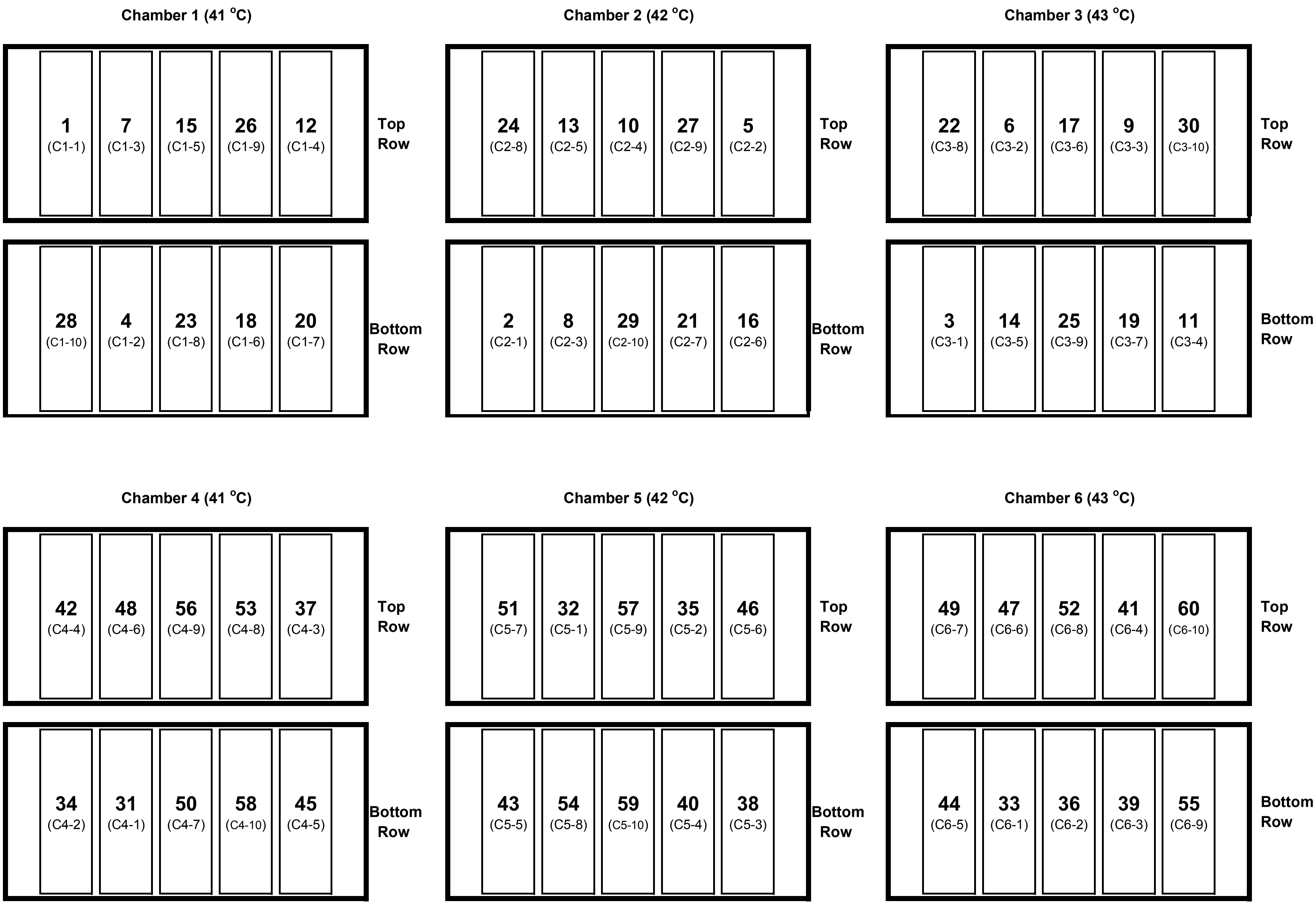

Figure 4. Arrangement of samples in cooler kilns. Air flow was from right to left across the samples. Chambers 1–3 designate "Fresh" samples and 4–6 "Aged" samples.

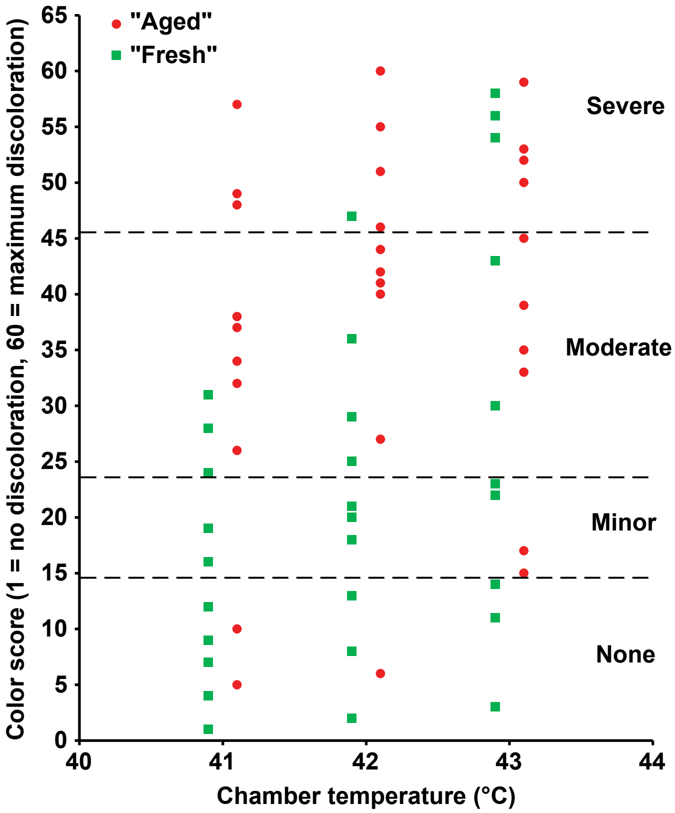

Figure 5. Discoloration of samples after exposure to the indicated temperatures. Squares represent samples from the first run ("Fresh") and circles represent samples from the second run ("Aged"). At each temperature, the least discolored samples are from the "Fresh" group, and the most discolored are from the "Aged" group. The "Fresh" group shows an increased spread in amount of discoloration with increasing temperature. The "Aged" group has a wide spread at the two lowest temperatures, with a smaller spread at the highest temperatures because this group lacked samples that were not discolored. Dashed lines indicate the limits of the subjective discoloration groups, which are labelled on the right.

were re-evaluated to verify that they had not changed color during the processing of the "Aged" samples. Then all 60 samples were combined and ranked from 1–60 as described above, with 1 being least discolored and 60 being most discolored.

Results and Discussion

As measured by the data loggers, chamber temperatures stabilized in an hour and relative humidities stabilized in a day. Temperatures remained constant (within one-half degree centrigrade) throughout the experiments except when the chambers were opened for periodic weighings. Once stabilized, the bulbs flashed on for periods of only a few seconds every few minutes; this could be seen through the holes used for the thermometers. After reaching the target conditions, relative humidities were constant at 75%. At 42 °C, this corresponds to an equilibrium moisture content of 13.4% (Simpson 1991).

Table 1—Initial and final percentage moisture contents of the test samples, based on initial and final weighings and calculated ovendry weights.

Condition	Temperature (°C)	Initial MC (%) Mean	Initial MC (%) Range	Final MC (%) Mean	Final MC (%) Range
Fresh	41	71	63–77	26	19–29
	42	72	64–78	26	23–31
	43	70	59–80	22	19–25
Aged	41	73	63–80	26	20–33
	42	71	61–82	24	19–28
	43	72	63–79	24	20–26

The initial moisture contents of the MC samples varied from 59% to 80% for the first ("Fresh") run, and 61% to 82% for the second ("Aged") run. These moisture values indicate that there was no overall moisture difference between the two runs and that the storage wrapping was effective in preventing drying of the stored samples. The final moisture contents of test samples varied from 19% to 31% for the first ("Fresh") run, and 19% to 33% for the second ("Aged") run, indicating that significant drying took place in the chambers. The initial and final moisture contents, separated by condition and chamber temperature, are given in Table 1.

The color of the samples from the "Fresh" run did not change perceptibly during the time that the "Aged" samples were being conditioned. Figure 5 compares the degree of discoloration of the "Fresh" and "Aged" samples at the three conditioning temperatures. In this figure, the degree of discoloration for all 60 samples is ranked from 1 (minimum discoloration) to 60 (maximum discoloration.) The limits of the four subjective discoloration categories, None, Minor, Moderate and Severe, are marked by dashed lines.

For the "Fresh" samples, the level of discoloration gradually increased with temperature, although all three temperatures had samples with no discoloration. For the lowest temperature (41 °C) half of the samples showed no discoloration, and none had severe discoloration. At higher temperatures, the discoloration was more widely distributed among the categories. For the "Aged" samples, the degree of discoloration was widely distributed among all temperatures, although at the highest temperature (43 °C) no samples were completely free of discolored wood.

Individual board characteristics may cause an effect, although we do not have enough data to make any firm statements. Of the six samples from Board 9, five showed no discoloration even though they were represented at all three temperatures, but the sixth sample showed severe discoloration. None of the other boards showed any notable trends.

One reviewer suggested that ulraviolet radiation might have an effect on discoloration independent of temperature. Standard incandescent blubs of the type used in this experiment produce very little radiation in the ulraviolet range of the spectrum (Maclsaac et al. 1999). In any case, the plywood sheet shielded the samples from direct exposure.

The conventional kiln drying schedule for soft maple heats the wood to a temperature range of 54–77 °C (Boone et al. 1988). The results of our soft maple experiment indicate that a significant amount of discoloration will occur at these temperatures even if the wood enters the kiln soon after it is harvested. Therefore, a low temperature kiln schedule or use of a dehumidifying kiln such as that described by Bergman (2008) may be the best solution to minimize discoloration.

Conclusions

1. Drying soft maple soon after harvest reduces the amount of oxidative stain.
2. Soft maple dried soon after harvest at 41 °C resulted in no to moderate discoloration. Higher drying temperatures increased the severity of discoloration.
3. Soft maple dried after a three-week cold storage period showed moderate to severe color degrade in most samples. At 43 °C, no boards were free of discoloration.
4. Special low-temperature drying schedules may be required to minimize oxidative discoloration in soft maple. The drying temperature should be kept below 41 °C.

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