Bleaching treatments for blue-stained mountain pine beetle lodgepole pine

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Abstract

The study compared the ability of seven bleaching agents to remove the blue colour from blue-stained lodgepole pine without adversely affecting the colour of unstained heartwood. A 10% solution of sodium hypochlorite was effective at removing the blue colour from blue-stained lodgepole pine sapwood. Sodium hypochlorite did not adversely affect the colour of heartwood, whereas three other bleaches initially caused a pronounced yellowing of heartwood, which faded over time.

Key words: mountain pine beetle, *Dendroctonus ponderosae*, blue stain, bleaching, lodgepole pine, *Pinus contorta,* wood products, sodium hypochlorite

Résumé

La présente étude compare la capacité de sept agents de blanchiment d’éliminer la coloration bleue du bois de pin tordu latifolié bleui sans modifier la coloration naturelle du cœur. Une solution d’hypochlorite de sodium à 10 % a éliminé la coloration bleue de l’aubier du pin tordu latifolié bleui. L’hypochlorite de sodium n’a pas eu d’effet négatif sur la couleur du cœur, tandis que trois autres agents de blanchiment ont d’abord provoqué un jaunissement prononcé du cœur, qui s’est ensuite estompé au fil du temps.

Mots clés : dendroctone du pin ponderosa, *Dendroctonus ponderosae*, bleuissement, blanchiment, pin tordu latifolié, *Pinus contorta,* produits ligneux, hypochlorite de sodium

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Introduction

Lodgepole pine (*Pinus contorta var. latifolia* S. Wats) grows abundantly in the northern and central regions of British Columbia, and sustains a large industry supplying structural lumber for domestic and export markets and, to a lesser extent, wood for appearance-grade products such as furniture. Increasing volumes of lodgepole pine are being cut from trees infected by mountain pine beetle and associated pathogenic fungi that cause the sapwood of newly infected trees to become blue–grey in colour (Langor 2003). Approximately 173 million cubic metres of lodgepole pine is affected by mountain pine beetle, and blue-stained wood from this resource will form a significant proportion of lumber produced in British Columbia for the foreseeable future (COFI 2004). Clearly, in appearance-grade applications such as furniture, the presence of stained wood is undesirable, but in certain grades of structural lumber it is a serious defect. For example, the Japanese Agricultural Service grade for spruce–pine–fir lumber, which includes lodgepole pine, does not allow the presence of any stain on structural lumber. A simple method for removing blue stain or masking its presence on lodgepole pine is required if the wood is to retain its market share for appearance-grade lumber and the higher grades of structural lumber.

The blue colouration of blue-stained wood is produced by melanin in the hyphae of the fungi that colonise wood (Zink and Fengel 1990). Various chemicals, including alkaline solutions of hydrogen peroxide, can bleach melanin and there has been interest in using bleaching agents to remove the blue colouration from blue-stained wood (Lee et al. 1995; Oh et al. 1997). Patent literature also contains a number of references to solutions of bleaching agents said to be effective at removing fungal stains from wood (Deniskin et al. 2000; Hayashi et al. 1974; Okabe 1981; Suzuki and Ihara 1986). There has been no previous research, however, to compare the effectiveness of these bleaching agents at removing blue stain from lodgepole pine.

The specific aims of this study were to compare the ability of various bleaching agents to remove the blue colour from blue-stained lodgepole pine sapwood without adversely affecting the colour of unstained heartwood. The overall aim of the work is to find surface treatments that will remove the blue colour from blue-stained lodgepole pine wood.

Materials and methods

Twenty pieces of lodgepole pine lumber, measuring 244 cm (length) x 5.5 cm (width) x 3.7 cm (thickness), were obtained. Six pieces of lumber were selected from the initial batch of 20 pieces and used for further experimentation. The selected pieces of lumber contained both blue-stained sapwood and unstained heartwood on their wide faces, and numbers of growth rings per centimeter averaged 14. A 30-cm-long piece of wood was cut from each of the six selected pieces of lumber and these were each cut into nine samples, measuring 3.0 cm x 5.5 cm x 3.7 cm, and allocated to nine bleaching treatments.

A range of bleaching solutions were obtained from commercial suppliers or prepared in the laboratory using active bleaching chemicals. The bleaches used were:

1. Two-part commercial hydrogen peroxide bleach (Lite-n-up – WoodKote Products Inc, Portland, Oregon);
2. Sodium hypochlorite (10% aqueous solution);
3. Sodium hypochlorite and sodium hydroxide followed by hydrogen peroxide (aqueous solution of 10% sodium hypochlorite and 5% sodium hydroxide, 1:1 followed by 30% hydrogen peroxide) (Deniskin et al. 2000);
4. Sodium chlorite and urea (aqueous solution composed of 100 g sodium chlorite and 200 g urea per litre) (Hayashi et al. 1974);
5. Hydrogen peroxide and acetic acid (aqueous solution composed of 30% hydrogen peroxide and 10% acetic acid) (Suzuki and Ihara 1986);
6. Sodium phosphate and sodium chlorite (aqueous solution composed of 3% sodium phosphate and 9% sodium chlorite) (Okabe 1981);
7. Hydrogen peroxide (30% aqueous solution);
8. Distilled water.
9. An untreated control represented treatment nine.

These nine treatments were randomly allocated to the nine wood samples cut from each piece of blue-stained lumber. Solutions were brushed on longitudinal faces of blue-stained sapwood and heartwood of samples at a rate of ~0.012 mL/cm^2 (0.2 mL per 16.5 cm^2 except for Treatment 3, which was applied in two steps: a solution of sodium hypochlorite and sodium hydroxide (0.1 mL) was brushed on samples (as above) and, after the surface had air dried for 20 minutes, a second solution (0.1 mL) of hydrogen peroxide was applied.

Samples were left to dry in a conditioning room at 20 $\pm$ 1 ^oC and 65 $\pm$ 5 % r.h. for 1 week and the colour of the blue-stained sapwood and heartwood in treated samples was measured using a spectrophotometer (Minolta CM-2600d). Colour parameters recorded were L* (lightness), a* (red–green) and b* (blue–yellow) of the CIELAB system, but only b* is analysed here as it measures how blue–yellow the samples were.

The bleaching experiment involved two fixed factors—bleaching treatment and wood type (blue-stained sapwood and heartwood)—with random effects associated with wood samples and order in which treatments were applied to samples. A split-plot design was used to model the effects of fixed factors and random effects on the colour of treated samples. Analysis of variance was performed using Genstat. Before the final analysis, diagnostic checks were made to determine whether data conformed to assumptions of analysis of variance, i.e., normality with constant variance. Significant effects are plotted on a graph containing an error bar (Least Significant Difference, $p<0.05$) to allow means to be compared.

Results and discussion

Analysis of variance showed highly significant effects ($p<0.001$) of bleaching treatment and wood type on colour (b*) of treated samples. There was also a highly significant interaction ($p<0.001$) of treatment and wood type on colour. Results are shown in Figure 1, below. The blue-stained sapwood of samples treated with sodium hypochlorite (Treatment 2) became significantly less blue (b parameter increased). None of the other treatments were able to remove the blue colouration from blue-stained sapwood. Three treatments produced a yellow colour on heartwood (b parameter increased), which was vivid after treatment, but faded over time. The treatments that produced this effect were Treatment 3 (sodium hypochlorite/sodium hydroxide and hydrogen peroxide), Treatment 4 (sodium chlorite and urea) and Treatment 6 (sodium phosphate and sodium chlorite).

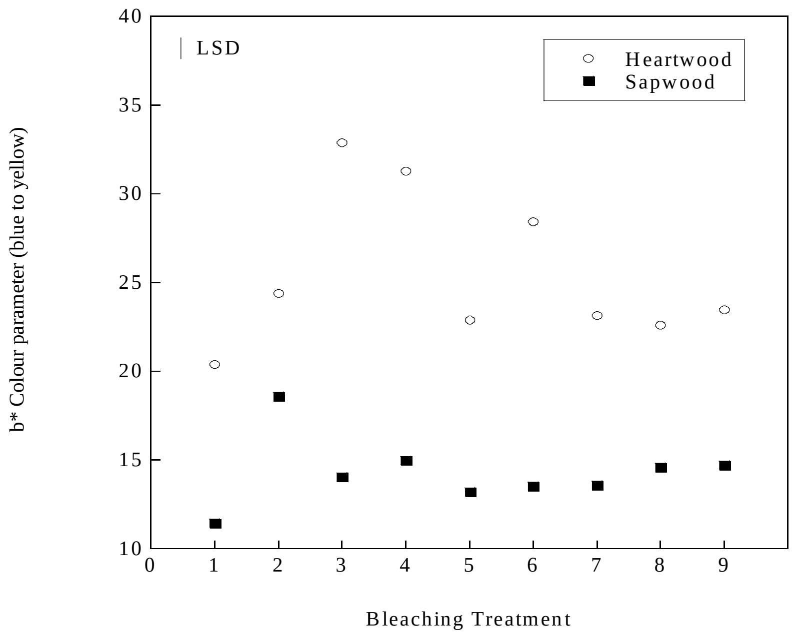

Figure 1. Effect of bleaching treatments on the colour of blue-stained lodgepole pine
Bleaching treatments, by number, are: 1) Two-part hydrogen peroxide bleach; 2) 10% sodium hypochlorite; 3) sodium hypochlorite/sodium hydroxide and hydrogen peroxide; 4) Sodium chlorite and urea; 5) Hydrogen peroxide and acetic acid; 6) Sodium phosphate and sodium chlorite; 7) Hydrogen peroxide; 8) Distilled water, and; 9) untreated control.

The bleaching effect of sodium hypochlorite on blue-stained sapwood was permanent. Figure 2 shows three of the six sets of treated samples, six months after treatment. The lighter blue–green colour of sapwood treated with sodium hypochlorite (Treatment 2) contrasts with blue colour of the other treated samples, including the two controls (Treatment 8, water; Treatment 9, untreated).

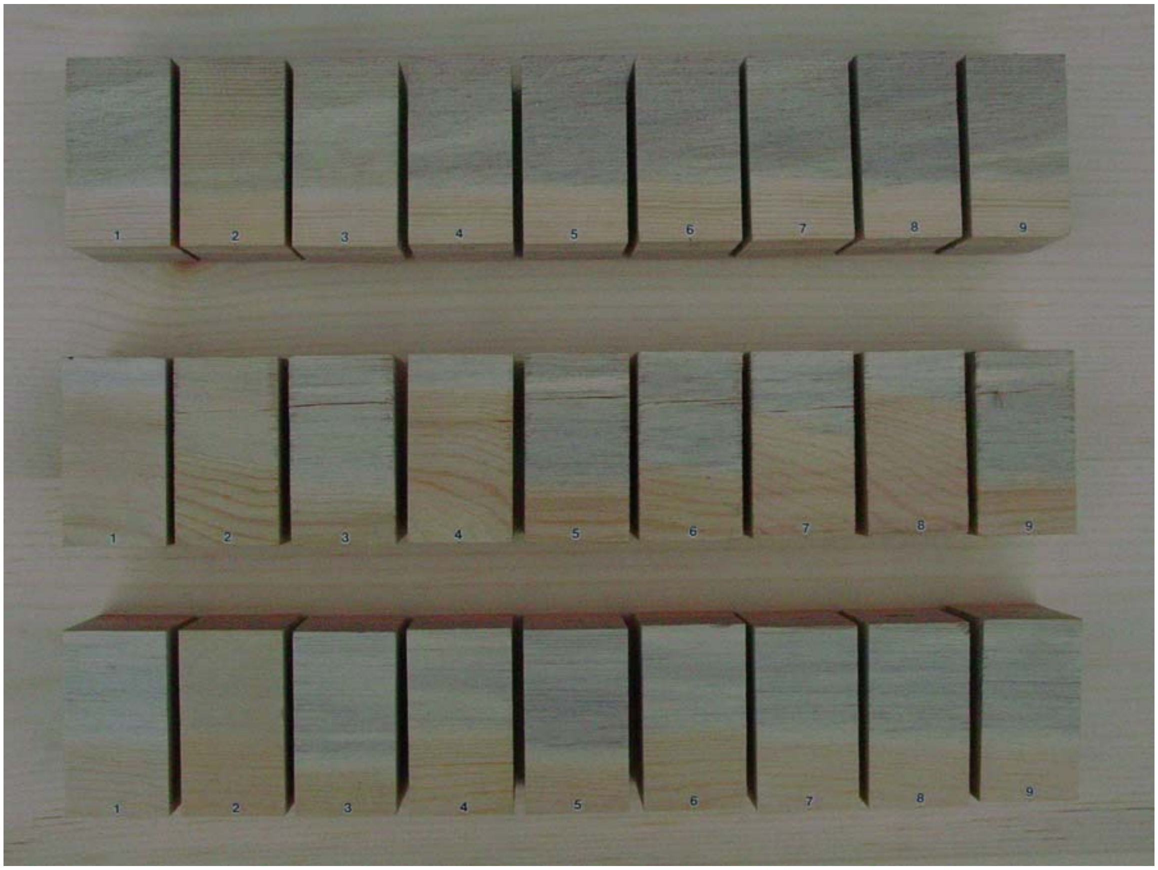

Figure 2. Photograph showing effect of Bleaching Treatments 1 to 9 on the colour of blue-stained sapwood and unstained heartwood.
Treatment numbers on samples refer to the treatments described in the legend for Fig. 1 (Note the bleaching effect of treatment 2 (sodium hypochlorite) on blue-stained sapwood)

These results suggest that chemical treatment of blue-stained wood with a strong (10%) aqueous solution of sodium hypochlorite could be used to remove blue colour from blue-stained lodgepole pine. This finding accords with patent literature containing patents that make claims for the efficacy of sodium hypochlorite as a treatment to remove the colour from wood stained by fungi. Sodium hypochlorite is a common and cheap industrial chemical that is used as a bleaching and anti-microbial agent in a variety of applications. Because the active bleaching agent in solutions of sodium hypochlorite decreases over time, calcium hypochlorite is often employed instead. Further research to develop an industrially effective treatment process to remove blue colouration from blue-stained lodgepole pine should optimize treatment parameters (dipping time and curing temperature), and also examine whether a strong solution of calcium hypochlorite can produce the same bleaching effect as sodium hypochlorite does on lodgepole pine.

Conclusions

A strong (10%) solution of sodium hypochlorite was effective at removing blue colour from blue-stained lodgepole pine sapwood. Sodium hypochlorite did not adversely affect the colour of heartwood, whereas three other bleaches initially caused a pronounced yellowing of heartwood, which faded over time. Further research should be undertaken to investigate whether an effective industrial-scale hypochlorite bleaching process can be developed and used to remove blue colouration from blue-stained lodgepole pine.

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