Biological method to pre-dry lumber with wetwood

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Author: Yang, D.-Q.

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Abstract: Wetwood, or water pocket, has higher moisture content (MC) and lower permeability than normal wood, which cause problems for lumber drying. The high moisture content of wetwood usually requires relatively long periods for adequate drying; consequently, it causes a high risk for developing checks, splits, crook, bow and twist of lumber in kiln drying. These problems have not been solved by any physical, chemical or mechanical methods yet. Using biological method to pre-dry lumber containing wetwood is a new concept introduced in this project. Wetwood is formed by bacteria growth inside normal wood. Some fungi are able to kill bacteria and to utilize foetid liquid produced by these micro-organisms. Consequently, the permeability of wetwood can be increased and the lumber drying rate can be improved. The present project intends a research on biological method to pre-dry lumber containing wetwood, and to evaluate efficacy and economic benefit of such a biological treatment.

Wetwood of balsam fir, sub-alpine fir and aspen was cultured on nutrient media, and several species of bacteria and yeasts were isolated. The bacteria and yeasts were re-inoculated on normal wood of balsam fir. All inoculated micro organisms caused wetwood formation in 2 weeks. The MC of the inoculated wood blocks increased from 41% to 220-240%, whereas the control samples without inoculation reached only 110%. When control samples were dried to a MC of 13%, the inoculated wood samples still had MCs between 80% and 105%. The selection of biological control agents was conducted on both agar plates and on balsam fir wetwood blocks, and 2 fungal candidates demonstrated promising results. The field test showed that pre-treating balsam fir wetwood lumber with the selected best biocontrol candidates, wood stain was reduced by 94%, warping reduced up to 13%, and checking reduced up to 30% compared with untreated controls. Drying time was reduced by

33% (24 hours) compared with drying fresh lumber.

CT scanner was able to detect wetwood locations inside a piece of lumber, and the wetwood was identified in heartwood, sapwood or both wood tissues. After the bio-treatment, the wetwood contents of boards were significantly reduced.

Economical analysis showed that the biological treatment would cost $4-7/Mfbm depending on treating method used. Reduction of 33% of drying time by the treatment in this study could save energy cost by $6-13/Mfbm depending on kiln drying energy used. The treatment could reduce lumber degrading loss by $8.5-37.4/Mfbm base on this study. The benefit of the treatment is significant, but will be affected by pre-drying operation, kiln type, energy use and drying schedule. The biological treated lumber is resistant to fungal infection during pre-drying period, and the lumber products are clean and free of moulds and stain infection.

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Trees of balsam fir, sub-alpine fir and aspen were felled and cut into lumber. Isolation of causal agents was conducted from wet pockets of these wood species by using peptone agar and malt extract agar media. A total of 319 cultures were obtained from the wetwood of these three wood species. Three bacteria and two yeasts were isolated from balsam fir wetwood, 2 bacteria and 1 yeast were more frequently isolated from aspen wetwood, and 2 bacteria and 5 yeasts were obtained from sub-alpine fir. Two bacteria were isolated from the wetwood of all 3 wood species: Shigella sonnei and Pseudomonas fluorescens. Other bacteria and yeasts isolated were identified as Aerococcus viridans, Chryseomonas luteol, Candida boidinli, C. zeylanoides, Cryptococcus albidus, C. laurentii, C. terreus, and Rhodotorula mucileginosa. In addition to these identified bacteria and yeasts, two other yeasts isolated from balsam fir and sub-alpine fir wetwood were unabile to be identified.

Six bacteria and yeast isolates were re-inoculated on normal wood of balsam fir; they were A-a (a bacterium isolated from aspen and identified as Shigella sonnei), A-c (a yeast isolated from aspen and identified as

Cryptococcus laurentii), B-a (a bacterium isolated from balsam fir and identified as Shigella sonnei), B-c (a mixture of 2 bacteria isolated from balsam fir and identified as Shigella sonnei and Aerococcus viridans), Y-2 (an unidentified yeast isolated from balsam fir), and SaB-2 (a bacterium isolated from sub-alpine fir and identified as Shigella sonnei). The result showed that all of these micro-organisms caused wetwood formation on inoculated normal wood samples in 2 weeks. This result indicates that wetwood formation in trees is not caused by only 1 micro-organism but is more likely caused by several species (either bacteria or yeasts) that can colonise well in the wood of trees. The moisture contents (MC) of the inoculated wood blocks increased from 41.2% to 220-240 %, whereas the MCs of the control samples submerged in a liquid culture medium without inoculation reached only 110%. When control samples were dried to a MC of 13%, the inoculated wood samples still had MCs between 80% and 105%. This result indicates that drying lumber containing wetwood will take double the time required to dry normal lumber without wetwood.

An antagonist test using fungal candidates was conducted on agar plates. In this test, 6 potential fungal antagonists and 6 wetwood causal agents (WCA) were used. The six fungal antagonists were Gliocladium roseum (a bioprotectant developed by Forintek), a white isolate of Ophiostoma piliferum (a fungus used in a commercial bioprotectant, Cartapip), a white isolate of Ceratocystis resinifera (an anti-sapstain biological agent used by Chantal Morin at Laval University), Geotrichum sp.A (a white fungus in Deuteromycetes isolated from Jack pine logs, DP3/5B-3a, 1998), Geotrichum sp. B (a white fungus in Deuteromycetes isolated from balsam fir logs, DF3/1B-1b, 1998), and Phaeotheca dimorphospora (a biological control agent of tree disease from Laval University). The six wetwood causal agents were A-a (a bacterium isolated from wetwood of aspen), A-c (a yeast isolated from wetwood of aspen), B-a (a bacterium isolated from wetwood of balsam fir), Y-2 (a yeast isolated from wetwood of balsam fir), SaB-2 (a bacterium isolated from wetwood of sub-alpine fir), and SaY-4 (a mixture of a yeast and a bacterium isolated from wetwood of sub-alpine fir). The results showed that Geotrichum sp.A and Geotrichum sp.B were the most effective against all 6 WCA inoculated; they reduced growth of the WCA in 7 days and completely absorbed colonies of WCA in 11 days. G. roseum, O. piliferum, and C. resinifera were moderately effective against 5 WCAs, but not effective on bacterium A-a that was isolated from aspen wetwood. P. dimorphospora was the least effective against any of these WCA.

The three promising fungal antagonists, Geotrichum sp., G. roseum and the white isolate of O. piliferum, selected from agar plate test were used for an antagonist test on balsam fir wetwood blocks in the laboratory conditions. This test was conducted on small wetwood samples (2 x 4 x 1 inch) in incubators at 25°C and two relative humidity ranges (100% and 75% RH). The results showed that all these three fungi were able to establish on wood surfaces and able to reduce wetwood contents. At 25°C and 75% RH, Geotrichum sp. was the most effective to reduce wetwood content in samples, followed by G. roseum, and then by O. piliferum. G. roseum and Geotrichum sp. not only reduce wetwood content, but also inhibit mold growth and wood stain, compared with untreated control samples. At 25°C and 100% RH, the moisture contents of treated and untreated samples were not changed in any week of the testing period. This result indicates that biological pre-dry wetwood samples should not be conducted at this high relative humidity condition.

A test was conducted to investigate the inhibitory ability of Geotrichum sp., the wetwood control candidate, against sapstaining fungi on wood. The results showed that if balsam fir wood wafers were inoculated with Geotrichum sp. 3 days before the staining fungi, no staining fungi grew on these samples. If wood wafers were inoculated with Geotrichum sp. and staining fungi at the same time, samples were covered by both Geotrichum sp. and the staining fungus Ophiostoma piceae in a ratio of 1:1. If wood wafers were inoculated with the staining fungi 3 days before Geotrichum sp., samples were absolutely covered by the staining fungus and fully stained.

A study on environmental effects on the growth of Geotrichum sp., the wetwood control agent, showed that this fungus started growth at 5°C, had optimal growth between 20-25°C, stopped growth at 30°C, and died at 40°C. Geotrichum sp. had a wide range of pH requirement and grew well in agar medium at pHs between 3 and 10. Geotrichum sp. started to grow at 29% MC, and the speed of the growth increased along with the increase of MC in wood. The best fungal growth of Geotrichum sp. was observed on wood blocks containing 56% MC. Geotrichum sp. was able to grow on wood of jack pine, black spruce, balsam fir, sub-alpine fir and aspen, but it grew better on wood of jack pine, balsam fir and black spruce than on sub-alpine fir and aspen. Geotrichum sp. was able to grow together with an anti-sapstain fungus, Gliocladium roseum, without any antibiotic or incompatible growth reaction.

In the laboratory conditions, the biological treated boards reduced wood MC by 22-37% more than untreated boards. Untreated boards were fully covered by molds and stain after 8 weeks in storage, and 0% of boards was acceptable for use. The biological treated boards were less affected, with 35-75% of pieces acceptable. The time required for drying biological treated boards was estimated reducing by 10.5 hours compared with untreated controls. After drying, the biological treated boards reduced the rate of crook, bow and twist by 5-20%, but increased the rate of split and check by 5-12%, compared with untreated controls. The total deformation rate was reduced up to 5% by the best biological treatment.

In the field conditions, untreated boards were 100% affected by molds and stain after 8 weeks in storage, whereas the best biological treated boards were only affected by 6%. Drying biological treated and untreated boards took similar times, but it was estimated reducing drying time by 48 hours compared with fresh boards. Compared with untreated controls, the biological treated boards reduced the rate of crook, bow and twist by 2-13%, and reduced the rate of split and check by 3-30%. The total deformation rate was reduced by 5-22%, depending on the treatments.

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A test was conducted to investigate the ability of Oidium sp., the wetwood control candidate, against sapstaining fungi on wood. The results showed that if balsam fir wood wafers were inoculated with Oidium sp. 3 days before the staining fungi, no staining fungi grew on these samples. If wood wafers were inoculated with Oidium sp. and staining fungi at the same time, samples were covered by both Oidium sp. and the staining fungus Ophiostoma piceae in a ratio of 50 to 50%. If wood wafers were inoculated with the staining fungi 3 days before Oidium sp., samples were absolutely covered by the staining fungus and fully stained.

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