EVALUATION OF MOLD AND TERMITE RESISTANCE OF INCLUDED SAPWOOD IN EASTERN REDCEDAR

*Coşkun Köse**†

Assistant Professor
Faculty of Forestry
Istanbul University
34473 Bahcekoy Istanbul, Turkey
E-mail: ckose@istanbul.edu.tr

Adam. M. Taylor†

Associate Professor
Center for Renewable Carbon
University of Tennessee
Knoxville, TN 37996
E-mail: adamtaylor@utk.edu

(Received January 2012)

Abstract. The heartwood of eastern redcedar (*Juniperus virginiana*) frequently contains areas of light-colored wood. This "included sapwood" is considered to be a defect by some manufacturers. In this study, sapwood, included sapwood, and heartwood samples from five eastern redcedar trees were exposed to mold fungi or subterranean termites in a no-choice feeding test. Specific gravity, extractives content, and total volumetric shrinkage were also measured. The extractive content, specific gravity, and volumetric shrinkage values of sapwood and included sapwood were equivalent. Greater extractive content in heartwood blocks was associated with less volumetric shrinkage and greater specific gravity. Included sapwood showed the same resistance to mold growth as heartwood, which was more mold-resistant that the sapwood. Included sapwood, heartwood, and sapwood of redcedar all exhibited resistance to termite attack compared with pine wood controls.

Keywords: Eastern redcedar, included sapwood, mold resistance, termite resistance, wood properties.

INTRODUCTION

Eastern redcedar (*Juniperus virginiana* L.) is a commercially important juniper species in the eastern US. It has many uses because of its beauty, durability, and pleasant odor. It is used for fence posts, garden furniture, clothes chests and closet liners, and animal bedding (Hemmerly 1970; Lawson 1985). Eastern redcedar has whitish sapwood and reddish violet heartwood. The transition between the sapwood and heartwood is abrupt, but there may be light-colored wood—"included sapwood"—within the heartwood. Included sapwood is considered to be a defect by some manufacturers.

The cause of included sapwood formation is uncertain. McGinnes et al (1969) reported that included sapwood is a discolored wood often associated with wounds. Shigo and Hillis (1973) explained the differences between discolored wood and heartwood and emphasized that the events that follow wounding cause formation of discolored wood. Shortle (2001) discussed included sapwood in the context of the compartmentalization of decay in trees model and suggested that the term wound-initiated discolored wood should be used instead of included sapwood. They argue that this included sapwood is a high-risk material because of its wound-associated origins and suggest that its commercial use be restricted.

However, Bauch et al (2004) argued that included sapwood formations are caused by not only wounds and growth stresses, but also by branch stubs and included bark. They maintain that ray blockage and inhibition of the biosynthesis of reddish violet compounds lead to the formation

* Corresponding author
† SWST member

© 2012 by the Society of Wood Science and Technology

of light-colored included sapwood within the heartwood of eastern redcedar. Therefore, included sapwood is anomalous heartwood that should not limit the commercial use of juniper species.

Extractives in eastern redcedar heartwood have implications for wood properties and can be products in themselves (Adams 1987; Kard et al 2007; Eller et al 2010). Redcedar extractives include natural wood preservatives that contribute to its natural durability. Adams et al (1988) found that hexane and ethanol extracts of eastern redcedar sapwood and heartwood showed high termiticidal activities. Bauch et al (2004) reported that reddish violet compounds were toxic to a brown-rot fungus in a bioassay. Cedar wood oils are isolated from heartwood and used in the cosmetic industry as a source of fragrance for soaps and perfumes. They are also used as disinfectants and as a clearing agent for microscope sections and immersion lenses.

In addition to affecting natural durability, some physical properties of wood can be influenced by extractive content levels (Hillis 1987). For example, high extractive content can reduce shrinkage and increase wood density (Panshin and De Zeeuw 1980; Taylor et al 2008).

Shortle et al (2010) showed that included sapwood in eastern redcedar is relatively susceptible to decay compared with normal heartwood. This finding is consistent with the observation that freshly fallen redcedar logs often contain decay pockets associated with included sapwood zones. Comparative studies of these formations have previously not been conducted against mold fungi and termites. The objective of this study was to investigate further the characteristics of included sapwood in eastern redcedar, including mold and termite resistance, extractive content, total volumetric shrinkage and specific gravity.

MATERIALS AND METHODS

Debarked cross-sections (approximately 20 cm in the longitudinal direction) from five trees of *J. virginiana* were provided by a sawmill in Kentucky. All cross-sections contained large areas of included sapwood, as indicated by its light color compared with the surrounding heartwood.

Mold Resistance Test

A mold chamber was constructed according to American Wood Protection Association Standard E24-06 (AWPA 2010). The mold chamber uses a circulating fan above water to provide near 100% humidity and nonsterile soil for a supplemental source of circulating mold spores. A mixed mold spore suspension of the four test fungi, *Aureobasidium pullulans, Aspergillus niger* (2.242), *Trichoderma viride* (ATTC 20476), and *Penicillium chrysogenum* (PH02), was prepared by washing the surface of individual 2-wk-old Petri plate cultures with 10-15 mL of sterile deionized water. The soil was inoculated with mold spore suspensions 2 weeks before placing the test specimens in the chamber. A total of 30 samples (2 specimens per tree, 45×70 mm $\pm$ 12.5 mm thick) were prepared of included sapwood, heartwood, and sapwood replicates. The samples were conditioned at ambient laboratory conditions ($\approx$22°C, 50% RH). The test specimens and controls (green *Pinus strobus* sapwood) were hung from stainless steel rods across the width of the environmental chamber over inoculated soil. Specimens were sprayed with spore suspensions and incubated at 30°C. After 2, 4, 6, and 8 wk incubation, specimens were visually rated for the extent and intensity of mold growth on a scale of 0 to 5, indicating mold covering 5-10%, 10-30%, 30-70%, greater than 70%, and 100% of the sample surface, respectively. The moisture content of samples was measured at the end of the 8-wk test.

Termite Resistance Test

A termite resistance test was carried out according to the AWPA E1-06 standard method (AWPA 2007). *Reticulitermes* spp. were collected from the forest in Tennessee. Glass jars ($80 \times 80 \times 120$ mm) were filled with 150 g sand and 20 mL distilled water. Approximately 280 termites ($\approx$0.85 g) were added to each jar. Wood specimens (50 mm $\times$ 25 mm $\times$ 6 mm in the tangential direction) were prepared from included sapwood, heartwood, and sapwood portions of eastern redcedar and *P. strobus* sapwood (control). Five specimens were tested for each group. Each block was cut into two pieces; one of the blocks was oven-dried to a constant mass and its moisture content determined. The other portion of the sample was placed on the surface of the sand with two corners of the block against the side of the container. After 4 weeks of incubation at 25°C in darkness, the samples were removed and dried at 103°C. The mass losses were determined as percentages of total specimen. For each of the bottles, the remaining live termites were weighed. In addition, each wood block was examined and visually rated using a standard rating system (AWPA 2007).

Total Volumetric Shrinkage and Specific Gravity

A total of 45 cubes (3 samples per tree, approximately 20 mm) were prepared from included sapwood, heartwood, and sapwood portions of the eastern redcedar samples. Each cube was impregnated with water by submerging them in water, applying vacuum (45 min at 60 kPa), and then keeping the cubes submerged for 96 h. The volume of each swollen cube was determined by measuring the mass of water displaced when the sample was submerged in water. The samples were then oven-dried, weighed, and the volume was remeasured by the water displacement method. Total volumetric shrinkage was calculated as the change in volume after drying over the swollen volume. Specific gravity was calculated as the dry mass over the swollen volume.

Extractive Content

Each wood cube used in the shrinkage test was ground in a Retsch MM 400 oscillating mill (Retsch Gmbh, Haan, Germany). Wood powder samples (≈2.5 g oven-dried) were enclosed in heat-sealable polyester filter bags (pore size 25 μm, ANKOM Technology, Macedon, NY). The bags were oven-dried at 103°C for 14 h, weighed, and then extracted according to ASTM D 1105 (ASTM 2007). This test involves successive extraction steps with toluene/ethanol (2:1), 95% ethanol, and hot water. The extracted samples were then oven-dried at 103°C for 24 h and reweighed. The extractive content of each sample was determined as the mass lost from the wood sample and expressed as a percentage of the oven-dry mass.

Data Analyses

Group values for all parameters in the termite resistance, total volumetric shrinkage, specific gravity test, and total extractive content analyses were compared by one-way analyses of variance tests using Duncan's multiple range test (IBM SPSS Statistics Version 19, Chicago, IL).

RESULTS AND DISCUSSION

Eastern redcedar heartwood and included sapwood exhibited more resistance to mold growth (average ratings of 0.1-0.5, respectively) than the redcedar sapwood and pine control samples (average ratings of 4.4-4.8, respectively; Fig 1). After 8-wk exposure, the moisture content of the samples was measured and the average moisture content of all samples were high enough to support fungal growth (>20%).

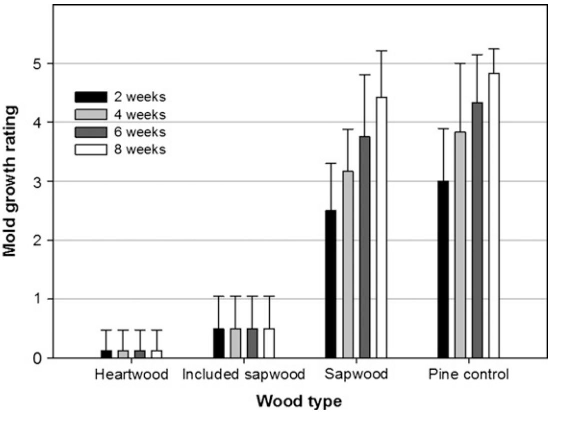

Figure 1. Mold growth rating of eastern redcedar heartwood, including sapwood and sapwood blocks during 8 wk exposure. (Pine sapwood blocks were included as controls. Error bars are one standard deviation.)

The termite resistance tests showed that *P. strobus* control blocks suffered the highest average mass loss (26%) (Fig 2). *Reticulitermes* spp. caused an average of 5% mass loss in the sapwood, 4% in the included sapwood, and only 1% average mass loss in the heartwood of eastern redcedar. All of the termites feeding on sapwood including sapwood and heartwood of the eastern redcedar had died after 2 wk. The mortality of the termites exposed to the pine control blocks was approximately 75%. According to visual evaluation, heartwood was rated as sound (average rating of 9.8), sapwood and sapwood were rated as slight attack (average ratings of 8.8 and 8.6, respectively), and *P. strobus* control samples were rated as very severe attack (average rating of 4.5). Average visual rating of the wood blocks reflected weight losses of all specimens. The high termite mortality in the control samples suggests that there may have been problems with the test or with the vitality of the termites; however, the observed resistance of redcedar wood is consistent with previous research. The mortality was higher than expected in termite tests done at the beginning of spring. According to the ASTM standard, if the termites live longer than 1 wk, their vitality is considered enough to have a valid test (ASTM 1998). The termites had started to die after 3 wk in control blocks. Eastern redcedar heartwood showed resistance against *Reticulitermes flavipes* (Carter and Smythe 1974) and *Coptotermes formosanus* (Morales-Ramos and Rojas 2001). Kard et al (2007) showed that particleboard-chip panels made from eastern redcedar were moderately resistant to *Reticulitermes flavipes*.

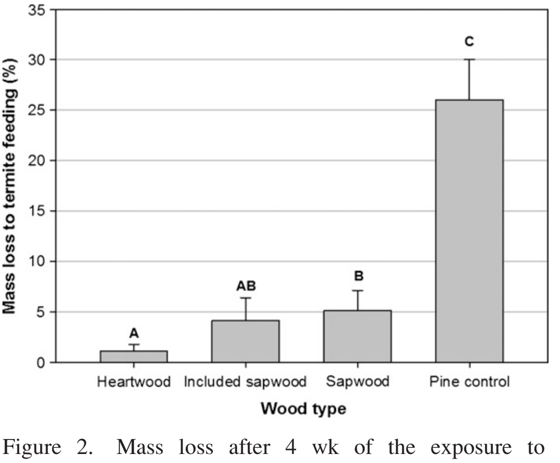

Figure 2. Mass loss after 4 wk of the exposure to *Reticulitermes* spp. of eastern redcedar heartwood, including sapwood and sapwood blocks. (Pine sapwood blocks are included for comparison. Different letters in each column indicate that there is a significant difference [$p \leq 0.05$, Duncan's multiple range test].)

The average amount of extractives was 9.7% in heartwood, 4.9% in included sapwood, and 3.9% in sapwood (Table 1). The relative extractive amounts were comparable to the findings reported by Bauch et al (2004), who reported that the total amount of extractives was 10.3-14.1% in heartwood, 2.7% in included sapwood, and 1.6% in sapwood. In our study, the extractive content, specific gravity, and volumetric shrinkage values of sapwood and included sapwood were not significantly different (Duncan's multiple range test). Increasing extractive content in heartwood blocks was associated with lower volumetric shrinkage levels and higher specific gravity values (Table 1).

While the included sapwood of eastern redcedar does not have the color, fungal decay resistance, and dimensional stability properties of normal heartwood, these data suggest that it has properties that are different from normal sapwood (ie mold resistance). Depending on the application, included sapwood may be a defect or an acceptable anomaly. For example, in exterior furniture products in which the decay hazard may not be high but the risk of mold is significant,

Table 1. Specific gravity, total volumetric shrinkage, and extractives content values of eastern redcedar sapwood, including sapwood and heartwood.

Wood type	Specific gravity	Total volumetric shrinkage (%)	Extractives content (%)
Sapwood	0.36 (0.03) A	8.82 (1.49) A	3.86 (0.93) A
Included sapwood	0.39 (0.03) A	8.69 (1.13) A	4.76 (2.05) A
Heartwood	0.45 (0.05) B	7.63 (0.69) B	9.72 (1.96) B

Each value is the average of 15 replicates. Figures in parentheses are standard deviations. Different letters in each column indicate that there is a significant difference between the specimens ($p \leq 0.05$, Duncan's multiple range test).

included sapwood may not be an important issue; for posts that are in continuous ground contact, the presence of decay-susceptible included sapwood may be a more serious limitation.

Many changes take place during the sapwood to heartwood transition process, including changes in the types and concentration of extractives (Taylor et al 2002). The light color, relatively low extractive content, and decay susceptibility of included sapwood in eastern redcedar are indications that the normal heartwood formation processes have not occurred. However, the mold resistance of included sapwood, in contrast to the susceptibility of the sapwood, suggests that some heartwood-like changes have occurred. Changes could include the depletion of the food reserve materials (free carbohydrates or lipids) that may serve as nutrients for mold fungi. Depletion of these materials has been observed during heartwood formation (Magel et al 1994). Further study of the extractive materials present in included sapwood and sapwood of eastern redcedar would be needed to determine if the absence of food sources in included sapwood is responsible for its relative mold resistance.

CONCLUSIONS

Eastern redcedar frequently contains included sapwood that is a different color than normal heartwood and has relatively low decay resistance. The purpose of this study was to evaluate further the characteristics of included sapwood in eastern redcedar including its mold and termite resistance, extractive content, total volumetric shrinkage, and specific gravity. Our samples of wood from five logs of *J. virginiana* contained large areas of included sapwood. The results of our study show that eastern redcedar including sapwood was relatively resistant to mold growth and termite attack. The extractive content, specific gravity, and volumetric shrinkage values of sapwood and included sapwood were not statistically different. The distinct properties of eastern redcedar including sapwood may affect its suitability for certain applications.

ACKNOWLEDGMENTS

We thank the Council of Higher Education of Turkey for providing a postdoctoral research fellowship to C. Köse. We thank Glasscock Logs and Lumber for supplying the wood samples.

REFERENCES

Adams RP (1987) Investigation of Juniperus species of the United States for new sources of cedarwood oil. Econ Bot 41:48-54.

Adams RP, McDaniel CA, Carter FL (1988) Termiticidal activities in the heartwood, bark/sapwood and leaves of Juniperus species from the United States. Biochem Syst Ecol 16:453-456.

ASTM (1998) D 3345-08. Standard test methods for laboratory evaluation of wood and other cellulosic materials for resistance to termites. American Society for Testing and Materials, West Conshohocken, PA.

ASTM (2007) D 1105-96. Standard test method for preparation of extractive-free wood. American Society for Testing and Materials, West Conshohocken, PA.

AWPA (2007) E-1 06. Standard method of laboratory evaluation to determine resistance to subterranean termites. American Wood-Preservers' Association, Inc., Birmingham, AL.

AWPA (2010) E-24 06. Standard method of evaluating the resistance of wood product surfaces to mold growth. American Wood-Preservers' Association, Inc., Birmingham, AL.

Bauch J, Puls J, Klupsch R, Vogel C (2004) Biological and chemical characteristics of 'included sapwood' of *Juniperis virginiana* L. Holzforschung 58:74-81.

Carter FL, Smythe RV (1974) Feeding and survival responses of *Reticulitermes flavipes* (Kollar) to extractives of wood from 11 coniferous genera. Holzforschung 28:41-45.

Eller FJ, Clausen CA, Green F, Taylor SL (2010) Critical fluid extraction of *Juniperus virginiana* L. and bioactivity of extracts against subterranean termites and wood-rot fungi. Ind Crops Prod 32:481-485.

Hemmerly TE (1970) Economic uses of eastern red cedar. Econ Bot 24(1):39-41.

Hillis W (1987) Heartwood and tree exudates. Springer-Verlag, Berlin, Germany. 268 pp.

Kard B, Hiziroglu S, Payton ME (2007) Resistance of redcedar panels to damage by subterranean termites (Isoptera: Rhinotermitidae). Forest Prod J 57:74-79.

Lawson ER (1985) Eastern redcedar, an American wood. FS-260. USDA For Serv. http://www.fpl.fs.fed.us/documnts/usda/amwood/260eredc.pdf (1 June 2011).

Magel E, Jay-Allemand C, Ziegler H (1994) Formation of heartwood substances in the stemwood of *Robinia pseudoacacia* L. II. Distribution of nonstructural carbohydrates and wood extractives across the trunk. Trees (Berl) 8(4):165-171.

McGinnes EA Jr., Kandeel SA, Szopa PS (1969) Frequency and selected anatomical features of included sapwood in eastern red cedar. Wood Sci 2:100-106.

Morales-Ramos J, Rojas MG (2001) Nutritional ecology of the formosan subterranean termite (Isoptera: Rhinotermitidae): Feeding response to commercial wood species. J Econ Entomol 94:516-523.

Panshin AJ, De Zeeuw C (1980) Textbook of wood technology. McGraw-Hill, Inc., New York, NY. 722 pp.

Shigo AL, Hillis WE (1973) Heartwood, discolored wood, and microorganisms in living trees. Ann Rev Phytopathol 11:197-222.

Shortle WC (2001) CODIT. Pages 233-234 *in* OC Maloy and TD Murray, eds. The encyclopedia of plant pathology. John Wiley & Sons, New York, NY.

Shortle WC, Dudzik KR, Smith KT (2010) Development of wood decay in wound-initiated discolored wood of eastern red cedar. Holzforschung 64:529-536.

Taylor AM, Baek SH, Jeong MK, Nix G (2008) Wood shrinkage prediction using NIR spectroscopy. Wood Fiber Sci 40(2):301-307.

Taylor AM, Gartner BL, Morrell JJ (2002) Heartwood formation and natural durability—A review. Wood Fiber Sci 34(4):587-611.