TECHNICAL NOTE

Residual Extractives in Western Red Cedar Shakes and Shingles after Long-Term Field Testing

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Abstract

Western red cedar shakes and shingles were analyzed for extractives after 25 and 33 years of exposure in a field test to better understand the extractives associated with long-term durability. Only minimal concentrations of thujaplicins were found, but plicatic acid was still present in significant quantities. Plicatic acid or other uncharacterized compounds that remain in the wood may play a more important role in the durability of shakes and shingles than previously thought.

Western red cedar (WRC; *Thuja plicata* Donn) is commonly used to make shakes and shingles because of its straight grain, low density, dimensional stability, and natural durability (Gonzalez 2004). In many places, WRC shakes and shingles can perform well without preservative treatment. However, where regional or site-specific decay hazards are high or where sapwood or low durability heartwood is used, preservative treatment should be applied (DeGroot and Nesenson 1995).

WRC's natural durability comes from its heartwood extractives. These include the thujaplicins, which are known to inhibit the growth of many decay fungi (Rennerfelt 1948), and the lignans (Roff and Atkinson 1954). Johnson and Cserjesi (1980) reported that thujaplicins were almost entirely depleted from the butt ends of WRC shakes after 5 years' exposure on a test rack in Haney, British Columbia. Despite this early depletion, the shakes remained viable for many years. After 20 years in test, these shakes had a mean decay rating of 1.7 on a scale of 0 to 4 (in between ''trace'' and moderate'') and if in service the roof would have needed to be replaced (Morris et al. 1995). At a test site in Vancouver with lower rainfall, shakes installed in 1980 showed only early signs of decay, with two panels having mean ratings of 0.1 and 0.2 after 25 years (Morris and Ingram 2006). Shingles installed at the same time had moderate decay, with two panels having mean ratings of 1.2 and 1.3. The early losses of thujaplicins suggest that other extractives may contribute to the natural durability of the shakes. The presence of other extractives could also explain the variable decay resistance of WRC containing low levels of thujaplicins (DeBell et al. 1999).

Advances in the analysis of extractives have led to a method capable of measuring a broader range of extractives, including thujaplicins, terpenes, and lignans (Daniels and Russell 2007). The present work reports the concentration of extractives in these shakes after 33 years in test as well as extractives data from other WRC shakes and shingles after 25 years in test.

Materials and Methods

An untreated experimental shake roof panel was set up in 1973 at the University of British Columbia's Malcolm Knapp Research Forest in Haney, British Columbia, as a control for experiments on preservative treatments of shakes (Johnson and Cserjesi 1980, Morris et al. 1995, Morris and Ingram 2006). Two additional untreated shake roof panels and four untreated shingle roof panels were set up in 1980 at Haney with matching material at Westham Island. In 1991, the material at Westham Island was moved to an area with a similar climate at the rear of the new FPInnovations laboratory in Vancouver, British Columbia. Shakes and shingles were nailed into 19-mm plywood panels using a building paper interlayment according to procedures recommended by the Council of Forest Industries of British Columbia (1972; see also Morris et al. 1995).

All the test sites are in the greater Vancouver area. The Scheffer index is a climate index based on mean monthly temperature and number of days with precipitation that is used to evaluate above-ground decay hazards (Scheffer 1971). Vancouver International Airport, which is close to both the Westham Island and FPInnovations test sites, has an updated Scheffer index of 50 (Morris and Wang 2008). The test site in Haney receives more frequent rainfall and

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therefore has a higher Scheffer index. This resulted in a 10-point difference between Westham Island/FPInnovations and Haney based on climate data from the original Scheffer index calculations for Canada (Setliff 1986, Morris et al. 1995). Both sites fall within the moderate decay hazard zone.

Six shakes and six shingles from the FPInnovations test site were sampled for extractives analysis on August 30, 2005. Two shakes and four shingles from the Haney test site were sampled on April 25, 2006. Samples from the Haney test site were taken from shakes and shingles on the top and bottom, while samples from FPInnovations test site were taken from the top, middle, and bottom of the test panels. One 5-cm-long by 3-cm-wide sample was taken from each of three locations on each shake/shingle: the butt (excluding the bottom 5 mm, which was often heavily eroded and colonized by lichens), the middle at 5 mm under the overlap, and the top. Sample thickness at the butt had been reduced by erosion and was approximately 15 mm for shakes and 8 mm for shingles. Wood samples were lightly brushed to remove some of the dirt and lichen from the surface of the samples. Samples were taken through the entire depth of the shake or shingle.

Samples were milled to pass through a 20-mesh screen, and moisture contents were determined. Approximately 0.5 g of each sample was extracted in ethanol containing the *para*-bromophenacyl ester of crotonic acid as an internal standard and analyzed by high-performance liquid chromatography according to the methods of Daniels and Russell (2007). Plicatic acid, thujaplicatin methyl ether, gamma thujaplicin, beta-thujaplicin, beta-thujaplicinol, thujic acid, and methyl thujate were quantified.

Results and Discussion

All extractives in shake samples were much less abundant than would be expected in unexposed WRC heartwood, though comparable unexposed samples were not available for analysis. Typical WRC heartwood extractive concentrations are reported by Daniels and Russell (2007). Plicatic acid, which is usually the most abundant extractive in WRC, was by far the most abundant in the exposed samples (Table 1). The concentration tended to be lower in the butts than in the protected middle and upper sections. Thujic acid and methyl thujate were also relatively abundant in some of the samples. The highly variable concentration of methyl thujate is attributed to its frequent association with fungal colonization (Daniels and Russell 2007). The thujaplicins were found only in very low quantities, with the exception of one sample.

The thujaplicin content in the 1973 shake samples can be compared with the data from Johnson and Cserjesi (1980), though they used a different technique (gas chromatography) for analysis. Differences in thujaplicin content between the top, middle, and butt of each shake were reported after 5 years. After 33 years, this difference had disappeared, as there were very few extractives remaining anywhere on the shakes.

Table 2 shows the extractive concentrations in shingle samples. Plicatic acid was the most abundant extractive in these samples. As in shakes, its concentration tended to be lower in exposed sections. The thujaplicins and thujic acid were present only in very low quantities.

When shake and shingle data were considered together, the type of roofing material (shake vs. shingle) had a major impact on the concentration of plicatic acid and thujaplicatin methyl ether, with shakes having higher extractives

Table 1.—Extractives found in western red cedar shakes after long-term field testing.[a]

Panel	Sample[b]	Plicatic acid	Thujaplicatin methyl ether	Gamma-thujaplicin	Beta-thujaplicin	Beta-thujaplicinol	Thujic acid	Methyl thujate
Haney-1 (1973)	U/A	0.160	0.020	0.006	0.005	0.012	0.063	0.058
	U/B	0.067	0.017	0.005	0.005	0.010	0.043	0.029
	U/C	0.027	0.015	0.003	0.004	0.009	0.038	0.029
	L/A	0.023	0.017	0	0.003	0.011	0.054	0.045
	L/B	0.027	0.011	0.004	0.003	0.010	0.044	0
	L/C	0.019	0.019	0	0	0.013	0.050	0
FPI-1 (1980)	U/A	0.468	0.012	0.001	0.002	0.002	0.008	0
	U/B	0.467	0.016	0.003	0.002	0.002	0.006	0
	U/C	0.160	0.010	0.001	0.002	0.002	0	0
	M/A	1.089	0.027	0.132	0.085	0	0.369	0.002
	M/B	0.290	0.022	0.001	0.005	0	0.012	0.002
	M/C	0.174	0.017	0.002	0.005	0	0.004	0
	L/A	1.070	0.035	0.004	0.002	0	0.005	0.008
	L/B	1.079	0.049	0.002	0.002	0	0.007	0.044
	L/C	0.139	0.019	0.001	0.002	0	0	0.002
FPI-2 (1980)	U/A	0.431	0.038	0.001	0	0	0.004	0.003
	U/B	0.383	0.036	0.002	0.002	0	0	0
	U/C	0.298	0.025	0.001	0.002	0	0	0
	M/A	0.714	0.040	0.004	0.003	0.002	0.008	0.040
	M/B	1.146	0.021	0	0.003	0	0.006	0.043
	M/C	0.294	0.010	0	0.002	0	0	0
	L/A	1.304	0.038	0	0.003	0	0.115	0.156
	L/B	1.790	0.031	0.009	0.004	0.002	0.110	0.163
	L/C	0.713	0.019	0.006	0.003	0	0.006	0.028

[a] Extractive concentrations are presented as percentages.
[b] The first letter indicates the location of the shake on the panel (U = upper, M = middle, L = bottom). The second letter indicates where the sample was taken on each shake (A = top, B = middle, C = butt).

Table 2.—Extractives found in western red cedar shingles after long-term field testing.[a]

Panel	Sample[b]	Plicatic acid	Thujaplicatin methyl ether	Gamma-thujaplicin	Beta-thujaplicin	Beta-thujaplicinol	Thujic acid	Methyl thujate
FPI-1 (1980)	U/A	0.085	0.005	0.001	0.002	0	0	0
	U/B	0.064	0.004	0.001	0.002	0	0	0
	U/C	0.044	0.004	0.001	0	0	0	0
	M/A	0.311	0.005	0.001	0.002	0	0	0
	M/B	0.045	0.006	0.001	0	0	0	0
	M/C	0.010	0.004	0.001	0.001	0	0	0
	L/A	0.152	0.005	0.001	0.001	0	0	0
	L/B	0.047	0.004	0.001	0.001	0	0	0
	L/C	0.037	0.003	0.001	0.001	0	0	0
FPI-2 (1980)	U/A	0.159	0.050	0.001	0	0.002	0.008	0.001
	U/B	0.101	0.033	0.001	0	0	0.004	0
	U/C	0.075	0.032	0.002	0.003	0	0.003	0
	M/A	0.015	0	0	0.002	0.002	0	0
	M/B	0.018	0	0	0.002	0.002	0	0
	M/C	0.023	0.004	0.002	0.002	0.002	0	0
	L/A	0.063	0.006	0.002	0	0	0	0
	L/B	0.091	0.004	0.001	0	0	0	0
	L/C	0.014	0.007	0.001	0	0	0	0
Haney-1 (1980)	U/A	0.028	0.030	0.005	0.006	0	0.121	0.016
	U/B	0.011	0.008	0.002	0.002	0.003	0.038	0.007
	U/C	0.025	0.021	0.003	0.003	0.003	0.028	0.005
	L/A	0.016	0.005	0.001	0	0	0.009	0.003
	L/B	0.019	0.015	0.004	0.002	0	0	0.006
	L/C	0.030	0.012	0.002	0.003	0.016	0.053	0.011
Haney-2 (1980)	U/A	0.033	0.007	0.002	0.003	0.004	0.036	0.007
	U/B	0.025	0.018	0.004	0.005	0.023	0.057	0.008
	U/C	0.017	0.025	0.006	0.006	0	0.091	0
	L/A	0.015	0.017	0.004	0.003	0.005	0.017	0
	L/B	0.039	0.009	0.003	0.003	0.007	0.022	0
	L/C	0.037	0	0.002	0.003	0.007	0.018	0.011

[a] Extractive concentrations are presented as percentages.
[b] The first letter indicates the location of the shingle on the panel (U = upper, M = middle, L = bottom). The second letter indicates where the sample was taken on each shingle (A = top, B = middle, C = butt).

concentrations. This correlates with the decay ratings for the two types of roofing material (Morris and Ingram 2006). The difference could be due to differences in the material these products were manufactured from or to differences in the depletion rate, possibly due to the higher amount of end grain exposed in sawn shingles compared with split shakes. Sawn shingles would be expected to wet up more easily but also to dry faster after rain. Consequently, leaching might be expected to be greater from shingles, but biodegradation of extractives might be expected to be faster in shakes where slower drying would create a longer-lasting moist environment more suitable for the growth of microorganisms.

Of the compounds measured, only plicatic acid was consistently found in appreciable quantities. Plicatic acid or other uncharacterized compounds that remain in the wood may play a more important role in the durability of shakes and shingles than previously thought. Plicatic acid is known to have mild activity against fungi (Roff and Atkinson 1954). It is an antioxidant and a metal chelator (Gardner et al. 1959, Stirling et al. 2007) and may indirectly inhibit decay fungi by interfering with Fenton-type reactions associated with brown-rot decay (Schultz et al. 2005). Plicatic acid is also associated with low equilibrium moisture content (Stirling and Morris 2006), which may be a critical factor in the durability of shakes and shingles where wetting and drying occur frequently.

Conclusion

Plicatic acid was the most abundant and consistently found extractive in shakes and shingles after 25 and 33 years of exposure. Other extractives, including the thujaplicins, were found only at very low levels in most samples.

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