Resistance of Six Wood Products Used in Paneling to *Reticulitermes jlavipes* (Isoptera: Rhinotermitidae)

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ABSTRACT **Six wood products used in wall paneling were tested for resistance to feeding damage by the eastern subterranean termite, *Reticulitermes flavipes* (Kollar). Alaska-cedar, *Chamaecyparis nootkatensis* (D. Don) Spach, fiber without wax and resin treatments normally used in paneling production was not a preferred food source in choice tests where all 6 wood products plus pine, *Pinus palustris* Mill., were simultaneously provided. However, the same nontreated Alaska-cedar fiber sustained severe damage when provided as the only food source in no-choice tests. Nontreated fiber of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., and hardboard and hardboard paneling made from a mixture of western hemlock and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, sustained significant feeding damage in both choice and no-choice feeding tests. Pressed paneling mats made from Alaska-cedar or western hemlock exhibited antifeedant properties. Waxes, resins, and additives used in manufacturing these mats imparted resistance to *R. flavipes*.**

KEY WORDS *Reticulitermes flavipes*, **antitermitic, termite, wood paneling**

THE EASTERN SUBTERRANEAN TERMITE, *Reticulitermes flavipes* (Kollar), is a widespread pest of wooden structures and products in North America, where it causes hundreds of millions of dollars in damage annually (Sharma 1993). Wooden paneling and composite wood products used extensively in building construction are found in millions of homes in the United States and abroad. Wood from hardwood and softwood trees is often used in paneling that is subsequently damaged by termites. However, wood products used in paneling are seldom tested for resistance to attack by subterranean termites or other wood-destroying insects.

Natural resistance of wood to termite attack is caused in part by chemicals deposited in wood during heartwood formation (Kumar 1971), and several tree species yield wood that is resistant to insect attack (Beal et al. 1974, Carter and Smythe 1974, McDaniel 1989). Concentrations of biologically active chemicals usually differ among trees within a species and vary among locations in individual trees. A chemical that causes resistance to insects may occur only in wood of one tree species (Rudman and Gay 1967). Different woods contain different insecticidal chemicals and can be expected to vary in their resistance to wood-destroying insects (Carter and Smythe 1974, Carter and Mauldin 1981).

Sapwood and heartwood also differ in resistance to insects. Termites may survive on sapwood but not on heartwood cut from the same tree. Differences have also been observed in survival and feeding responses of *R. flavipes* exposed to wood samples removed from different radial and height positions in the same tree species (Carter et al. 1975, 1983). Thus, different panels made with wood from the same tree or different trees of the same species could differ in their resistance to termite feeding.

Various termiticidal components of hardwoods and softwoods have been extracted and identified (Saeki et al. 1971, Lenz and Becker 1972, Saeki 1973, French et al. 1979, Jurd and Manners 1980, Jones et al. 1983, McDaniel et al. 1989). Chemicals in termite resistant woods may be contact toxic to termites or act as antifeedants, repellents, or protozoacides (Carter 1979, Carter and Mauldin 1981, Carter et al. 1983). Carter and Beal (1982) showed that susceptible pine wood treated with extracts from naturally resistant woods acquired antitermitic properties, and was protected against feeding by termites. Their results indicated a potential use for antitermitic wood extractives as treatments to wood to impart resistance to subterranean termites.

Of 11 North American conifers and their extractives that were tested for susceptibility to ***R. flavipes***, heartwood of Port-Orford cedar, ***Chamaecyparis lawsoniana*** (A. Murr.) Parl.; eastern redcedar, ***Juniperus virginiana*** L.; western redcedar, *Thuja plicata* Donn ex D. Don; baldcypress, ***Taxodium distichum*** (L.) Rich.; redwood, ***Sequoia sempervirens*** (D. Don) Endl.; and Ponderosa pine, *Pinus ponderosa* Dougl. ex Laws., were not favorable to termite feeding and survival (Carter and

Smytbe 1974). One source of western hemlock, *heterophylla* (Raf.) Sarg., was resistant to termites in choice tests; this wood contains oils toxic to termites. Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, western redcedar, and a 2nd source of western hemlock were susceptible to termite feeding (Carter and Smythe 1974). Other researchers demonstrated that the antitermitic properties of *Chamaecyparis* sp. are attributable to essential oils (Saeki et al. 1971).

A tropolone, nootkatin ($C_{15}H_{20}O_2$), the sesquiterpene nootkatene ($C_{15}H_{22}$), chamic acid ($C_{10}H_{14}O_2$), carvacrol ($C_{10}H_{14}O$), and several other chemicals occur in Alaska-cedar. Nootkatin is toxic to several wood-decay fungi (Carlsson et al. 1952, Rennerfelt and Nacht 1955, Erdtman and Topliss 1957, Smith and Csejesi 1970). Because fungal decay can cause wood to become more palatable *to* termites, decay-inhibiting chemicals may reduce wood palatability.

In this study, 6 wood products used extensively in the paneling industry were tested for resistance to feeding damage by *R. flavipes.* Woods used in these products are known to differ in their resistance to termite attack. When wood products are processed for paneling, the use of adhesives, waxes, phenolic resins, solvents, coatings, and heat treatments are part of the manufacturing requirements. These requirements may degrade or increase resistance of panels to termites.

Materials and Methods

Bioassays. *R. flavipes* were collected from 3 field colonies infesting fallen southern yellow pine (*Pinus* sp.) logs in the Harrison Experimental Forest, 32 km north of Gulfport, MS. Colonies were maintained in the laboratory in 75-liter containers provisioned with moistened southern yellow pine sapwood boards. Separate groups of 100 and 1,000 termites were drawn from each colony for use in no-choice and choice tests, respectively. Only workers of the 3rd instar or older were used. No-choice and choice tests were conducted 3 times for each colony and ran for 4 wk in bioclimatic rooms at 24 ± 1°C and 60% RH under no-light conditions.

Foraging Substrate. The substrate was clean, sterile sand and vermiculite in a 10:1 ratio (wt:wt) homogeneous mixture. Sterile deionized water was added at the rate of 450 ml/1,000 g of dry mixture to yield a moisture content of 31% by weight.

Wood Products. For no-choice and choice feeding bioassays, a total of 36 samples from each of 6 commercially produced wood products used in paneling were cut into rectangular blocks (2.5 by 2.5 by 0.5 cm). Thirty-six longleaf pine, *Pinus palustris* Mill., sapwood blocks of the same dimensions were used as controls. All blocks were oven dried at 105°C for 24 h and then weighed. They were then allowed to absorb moisture from the air for 7 d at 20°C and 50% RH before being placed in test units.

The following 6 products were tested: (1) pressed composite mat consisting of 79% wood fiber of Alaska-cedar, ***Chamaecyparis nootkutensis*** (D. Don) Spach, 10% synthetic textile fiber, 10% phenyl formaldehyde resin, and 1% paraffin wax; (2) pure Alaska-cedar fiber pressed mat (without textile fiber, resin, or wax); (3) pressed composite mat consisting of 79% western hemlock wood fiber, 10% synthetic textile fiber, 10% phenyl formaldehyde resin, and 1% paraffin wax; (4) pure western hemlock fiber pressed mat (without textile fiber, resin, or wax); (5) hardboard, 98.8% by weight in equal quantities of western hemlock and Douglas-fir plus small amounts of other unidentified western Canadian softwoods, 1% phenyl formaldehyde, and 0.2% alum; and (6) hardboard paneling of the same composition as hardboard but covered with smooth, paper-thin vinyl on one side.

No-Choice Test Units. Each no-choice test unit consisted of a cylindrical clear-plastic container (5.3 cm diameter by 4.0 cm high), with a removable cap, partially filled with 35 g of substrate tamped down to form a level surface. A single block of 1 of the 6 wood products, or pine sapwood, was placed on top of the substrate in the center of each container and was the only food source. Each container then received 100 worker termites. A double layer of filter paper (1 by 2 cm) was folded over a l-cm length along the container lip to allow air exchange and the container was capped. Each bioassay was replicated 6 times per colony and wood product, resulting in 18 replicates per product.

Choice Test Units. Each choice test unit consisted of a cylindrical clear-plastic container (15.2 cm diameter by 6.3 cm high), with a removable cap, partially filled with 307 g of substrate. The substrate was tamped gently down to form a level surface. A pine sapwood block and 1 block of each of the 6 wood products were placed on top of the substrate and at equal spacing around the inside of the container wall. Each container then received 1,000 worker termites. A double layer of filter paper (2 by 4 cm) was then folded over a 2-cm length along the container lip to allow air exchange and the container was capped. Each bioassay was replicated 6 times per colony, resulting in 18 replicates per product.

Damage Assessment. After termites were introduced into the test units, leach unit was observed daily. Mortality and erratic termite behavior during each 4-wk bioassay was noted. After final observations, damage to blocks was assessed by cleaning substrate and debris off each block and then drying and weighing each block to determine its weight loss. Each block was then graded by the amount of termite damage by using a damage rating index of 04: 0, no damage or weight loss; 1, superficial damage, surface etching, ≤5.0% weight **loss;** 2, moderate penetration into wood, >5.0–10.0%

Table 1. Mean resistance ± SEM of 6 wood-paneling products to attack by *R. flavipes* in a no-choice feeding test

Product	Final weight, g	Weight loss, g (%)	Termite survival, %	Damage rating index
Alaska-cedar composite mat[a]	1.49 ± 0.04	0.00 ± 0.00a (0.0)	0.0 ± 0.0a	1.0 ± 0.1e
Western hemlock composite mat[a]	1.45 ± 0.02	0.00 ± 0.00a (0.0)	0.0 ± 0.0a	1.0 ± 0.1e
Pure Alaska-cedar fiber (no wax; no resin)	0.95 ± 0.08	0.14 ± 0.01b (-12.8)	79.0 ± 1.7b	3.0 ± 0.2f
Pure Western hemlock fibers (no wax; no resin)	0.55 ± 0.08	0.35 ± 0.04d (-39.3)	91.7 ± 1.5c	4.0 ± 0.2g
Hardboard	2.36 ± 0.04	0.28 ± 0.01c (-10.4)	85.3 ± 2.1d	3.0 ± 0.2f
Hardboard paneling	3.52 ± 0.03	0.22 ± 0.01c (-5.9)	83.0 ± 4.0d	3.0 ± 0.3f
Southern pine sapwood (control)	1.22 ± 0.06	0.31 ± 0.03d (-20.3)	83.0 ± 2.0d	4.0 ± 0.2g

Means within columns followed by the same letter are not significantly different ($P \geq 0.05$); letters a, b, c, d, ANCOVA and Tukey Studentized range test (SAS Institute 1987) for weight loss and termite survival; letters e, f, g, nonparametric multiple comparison procedure (Hollander and Wolfe 1973) for damage rating indices (n = 18). 0, no damage, resistant: 1, superficial damage, surface chewed and etched, ≤5.0% weight loss; 2, moderate penetration into wood, >5.0%–10.0% weight loss; 3, severe, extensive feeding, >10.0–50.0% weight loss; 4, destroyed, not resistant, ≥50.0% weight loss.

[a] Slight surface chewing and etching only.

weight loss; 3, severe, extensive feeding and penetration into wood, >10.0–50.0% weight loss; 4, destroyed, wood disintegrated and collapsing, >50.0% weight loss.

Differences in weight loss among wood products were evaluated by analysis of covariance (ANCOVA; covariate = initial weight; Steel and Torrie 1980). Means of block weight loss and termite mortality were separated by the Tukey studentized range test (SAS Institute 1987). A Kruskal–Wallis test was used to evaluate damage rating index data, with products compared by an additional nonparametric multiple comparison procedure based on Friedman rank sums (Hollander and Wolfe 1973).

Results

No-Choice Tests. Termites that were offered Alaska-cedar or western hemlock composite mats did not survive (Table 1). Although termites did not consume any of the Alaska-cedar or western hemlock mats, some mechanical damage and excrement contamination occurred as foraging termites chewed on the mat surfaces. However, termites consumed 12.8% of the pure Alaska-cedar fiber by weight, ingesting enough nutrients for 79% of the termites to survive. When alternate foods were not available, pure Alaska-cedar fiber was significantly more susceptible to attack than were composite mats of Alaska-cedar or western hemlock (Table 1). Pure Alaska-cedar or western hemlock fiber, hardboard, hardboard paneling, and pine sapwood were all significantly more susceptible to termite attack than were Alaska-cedar or western hemlock composite mats. Termite survival in these tests (excluding mats) ranged from 79.0–91.7%, demonstrating susceptibility of the western hemlock and Douglas-fir in these products, even after these woods are processed into hardboard. Although the percentage weight loss for pine was less than that for pure western hemlock fiber, their damage rating indices were the same because a larger proportion of sapwood was present and consumed in pine blocks (Table 1).

Choice Tests. Alaska-cedar and western hemlock mats were resistant to termite attack and received no feeding damage as termites preferred the alternative food sources (Table 2). Also, pure Alaska-cedar fiber that did not receive the adhesive, wax, and resin treatments normally used in the production of panels was not preferred, but surface mechanical damage and contamination with soil and excrement occurred as the termites chewed on and crawled over the fiber (Table 2). Pure western hemlock fiber, hardboard, and hard-

Table 2. Mean resistance ± SEM of 6 wood-paneling products to damage by *R. flavipes* (Kollar) in a choice feeding test

Product	Final weight, g	Weight loss, g (%)	Damage rating index[a]
Alaska-cedar composite mat	1.51 ± 0.04	0.00 ± 0.00a (0.0)	0.0 ± 0.0f
Western hemlock composite mat	1.44 ± 0.01	0.00 ± 0.00a (0.0)	0.0 ± 0.0f
Pure Alaska-cedar fiber[a] (no wax; no resin)	0.98 ± 0.08	+0.09 ± 0.02b (+ 10.0)	0.0 ± 0.0f
Pure Western hemlock fibers (no wax; no resin)	0.63 ± 0.06	0.41 ± 0.13c (-38.8)	3.0 ± 0.0g
Hardboard	1.79 ± 0.04	0.76 ± 0.01d (-29.8)	3.0 ± 0.0g
Hardboard paneling	2.92 ± 0.11	0.83 ± 0.10d (-21.9)	2.7 ± 0.3g
Southern pine sapwood (control)	0.25 ± 0.10	1.19 ± 0.04e (-82.6)	4.0 ± 0.0h

Means within columns followed by the same letter are not significantly different ($P > 0.05$); letters a, b, c, d, e; ANCOVA and Tukey Studentized range test (SAS Institute 1987) for weight loss; letters f, g, h, nonparametric multiple comparison procedure (Hollander and Wolfe 1973) for damage rating indices (n = 18). 0, no damage, resistant; 1, superficial damage, surface chewed and etched, ≤5.0% weight loss; 2, moderate penetration into wood, >5.0–10.0% weight loss; 3, severe, extensive feeding, >10.0–50.0% weight loss; 4, destroyed, not resistant, >50.0% weight loss. Mean termite survival in all choice test units ± SEM, 87.2 ± 1.2%.

[a] Surface etching only; weight gain caused by soil and excrement deposited by foraging termites.

board paneling were significantly more susceptible than was pure Alaska-cedar fiber, sustaining 21.9-38.8% weight loss as a result of termite feeding. Southern yellow pine sapwood sustained significantly more damage than any of the 6 wood products tested. Termites consumed almost all of the soft sapwood between the dense rings of latewood.

Discussion

Incorporation of insect-resistant wood in paneling may reduce the risk of termite damage to the final product. However, if susceptible woods are used in paneling, it should be possible to protect panels by adding phenyl formaldehyde resin to their components. Additionally, adhesives, waxes, resins, solvents, heat treatments, coatings, and drying requirements are part of various wood paneling manufacturing processes. These additives and processes may change the resistance of paneling to termite attack.

Paneling that incorporates Alaska-cedar may be less preferred by *R. flavipes* than paneling made from more palatable woods or when other more preferred woods are present. However, because pure Alaska-cedar fiber was damaged in no-choice tests, it may be susceptible to damage in structures under certain conditions. When western hemlock and Alaska-cedar were treated with various compounds and chemicals during composite mat manufacturing, they became resistant to *R. flavipes.*

Antitermitic properties of several conifer species are related to their insecticidal chemicals (Carter et al. 1983, Adams et al. 1988, Scheffrahn et al. 1988, McDaniel 1989, McDaniel et al. 1989). For example, the antitermitic properties of *Chamaecyparis* sp. are attributable to essential oils, and Port-&ford-cedar was found to be resistant to termites (Saeki et al. 1971). Sesquiterpenes and their alcohols are components of eastern redcedar, which provide some protection against subterranean termites (McDaniel 1989). Redcedar species contain cedarwood oil, which contains the terpenoids cedrene and cedrol. These compounds are toxic to termites (Guenther 1943, McDaniel 1989). Baldcypress, redwood, and ponderosa pine also contain antifeedant chemicals that reduce termite survival (Garter and Smythe 1974). Therefore, one approach to improve paneling resistance to termites would be to use mixtures of non- or moderately termite-resistant wood with very resistant wood in the manufacturing process. Resistance would improve, and strength, durability, and finishing of such panels also would be upgraded, while controlling costs and enhancing marketability. Such new composite panels and their resultant susceptibility or resistance to termites would require further investigation.

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