Resistance of Alkylene-Oxide-Modified Southern Pine To Attack by Subterranean Termites

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ABSTRACT. Dry southern pine sapwood reacted to 34 weight percent gain with propylene oxide and 27 and 34 weight percent gain with butylene oxide was found to be resistant to attack by subterranean termites. In a 2-week laboratory test with *Reticulitermes flavipes* the butylene oxide samples lost about 5 percent weight while the untreated control lost 30. Large modified blocks were cut into smaller surface and interior samples. Both seta gave good termite resistance showing that no significant chemical gradient existed between the outside of the modified wood and interior. Red color in dead termites and on treated wood blocks at the end of the test indicated the presence of the pathogenic bacterium *Serratia marcesens.* The resistance of modified wood seems attributable primarily to unpalatability and not repellency or toxicity.

WHEN ALKYLENE OXIDES (AO) such as propylene (PO) and butylene oxide (BO) react with wood, permanent ether bonds are formed with hydroxyl groups of the cell wall components (7). Wood chemically modified with AO has been found to be resistant to attack by wooddestroying fungi (5, 6). This resistance does not seem to be due to any toxic effects of the reacted chemicals, but rather modification of the cell wall polymers in such a way that the modified wood becomes undigestible in the fungi's very specific enzyme-substrate system.

Because of the effectiveness of AO-treated wood against fungi, testa were conducted to determine the effectiveness, if any, this chemically modified wood might have in preventing attack by termites. The objective of this research was to test the resistance of AO-modified wood to subterranean termite attack under laboratory conditions.

Experimental

Blocks of southern pine, 4.5 by 4.5 by 15 cm (tangential by radial by longitudinal), were prepared from one freshly cut board. After being ovendried and weighed, these samples were treated with PO-triethylamine (PO-TEA) (95/5 vol/vol) or BO-triethylamine (BO-TEA) (95/5 vol/vol) as previously described (6). Five pieces were prepared. PO-TEA at weight percent gains (WPG) of 9, 17, and 34; BO-TEA at 27 and 34 WPG. A sixth piece from the same board was used untreated as a control.

Block Preparation

The control and treated pieces were sawed into seven smooth-faced 0.4- by 4.5- by 15-cm strips. Two blocks, 0.4 by 2.5 by 2.5 cm, were cut from the middle of each of the three central strips. Five of these, designated interior blocks, were randomly selected for testing. Four blocks of the same dimensions were cut from the two strips initially on the surface of the starting piece. Five of these, designated surface blocks, were randomly selected for testing.

Individual seta of five interior and five surface blocks from each treatment, and the control, were leached in a Soxhlet extractor for 2 hours with benzene/ethanol (2/1 vol/vol) and, after drying, for another 2 hours with water. The leaching process was designed to remove any toxic residual unreacted reagents. The leached blocks were dried overnight in a 105°C oven.

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Termites

Reticulitermes flavipes (Kollar), subterranean termites, were collected at Janesville, Wisconsin, and maintained in a 20-gallon metal container prior to use (2). In a preliminary test, approximately 87 percent of the termites placed in containers with control blocks survived over a 4-week period, indicating that the termites would be acceptable for further experimental usage.

Exposure

An exposure method was selected (1) wherein treated wood was the only source of nutrients for the termites because this would reveal whether undigestibility might be an antitermitic property of the AO-treated wood. Dry, washed sand (10 ml) was poured into a cylindrical, clear plastic container (inside dimensions, 5 cm diameter and 3.5 cm deep). It was wetted with 2.5 ml distilled water, and a leached, ovendry block was placed on the sand (with the 2.5- by 2.5-cm surface in contact with the sand). Each of the 55 experimental blocks (25 interior, 25 surface, and 5 controls) were placed in such units — one per unit. Five sand-filled containers without wood blocks were also prepared for starvation datum. One-gram groups of termites (mixed caste forms) were placed in each unit. The number of termites in various caste forms (workers, nymphs, and soldiers) were counted in three out of every five replicate containers. The termite groups consisted mainly of the worker form, the form that actually attacks wood. The average number of termites in 1-gram groups was 323—89.5 percent workers, 9 percent nymphs, and 1.5 percent soldiers. The units, with lids, were stored in a 25°C incubator.

Inspection

Units were inspected 4, 10, and 13 days after setup to determine if the experiment was proceeding normally. The experiment was terminated at the end of 2 weeks because the earlywood from the control samples was almost completely gone. To continue the experiment would have introduced a starvation condition in this control set. Termites counted previously in units were recounted and reweighed. The percentage survival of the different termite forms and the total group, as well as final percentage group weight, were calculated. After being brushed free of debris, the individual wood blocks were ovendried (105°C), weighed, and percentage weight loss of the block sets was calculated.

TABLE 1. — *Percent weight loss in control and modified southern pine blocks after 2 weeks' exposure to subterranean termites.*

Treatment	Retention of chemicals, WPG[a]	Block location[b]	Wood weight loss (%)
Control	0	—	31
Propylene oxide (PO)	9	Interior	24
		Surface	19
	17	Interior	15
		Surface	13
	34	Interior	5
		Surface	8
Butylene oxide (BO)	27	Interior	4
		Surface	4
	34	Interior	3
		Surface	3

[a]Weight percent gain.
[b]In piece of wood after treatment.

Results

In a preliminary termite exposure of AO-modified wood—PO or BO or both—not leached previously, the termites moved as far from the blocks as possible. Apparently, unreacted monomers vaporized causing lethal fumigation of the termites in the small containers within 1 day. Those blocks were then extracted with benzene-ethanol followed by water and the units reset with fresh termites. This time the termites exhibited no abnormal behavior. Because of these findings, subsequent termite tests were conducted only on extracted blocks.

The average percent weight losses from corresponding interior and surface block seta differed by 5 percent or less (Table 1), demonstrating the uniformity of resistance at both the surface and the interior of the treated wood. This agrees with information (4) that wood treated with epichlorohydrin is modified evenly throughout the wood up to 2 by 4 inches in cross section. Figure 1 illustrates that weight loss in BO blocks (A) was due to slight termite attack.

Table 2 shows that the PO seta at 9 and 17 WPG and all of the BO sets had final percentages of termites generally lower but within 20 percent of the final termites in the starved set (71% survival and 64% group weight). This indicates that the energy expended to eat the treated wood was not balanced by nutritional energy from that wood, thereby having a

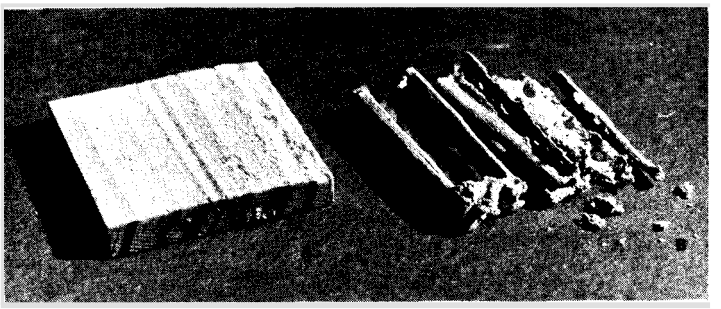

Figure 1 — Butylene-xoide-modified (34 WPG) block (A) and control (B) after termite attack.

TABLE 2. - *Average termite survival and group weight after 2 weeks' attack on control and modified southern pine blocks.*

Treatment	WPG[a]	Wood block	Termite survival (%)	Termite group weight (%)
Control	0	——	8584	
Starved	0	—[b]——	71	64
Propylene oxide (PO)	9	Interior	71	71
		Surface	49	54
	17	Interior	67	64
		Surface	57	64
	34	Interior	7	14
		Surface	32	22
Butylene oxide (BO)	27	Interior	55	55
		Surface	50	51
	34	Interior	51	46
		Surface	52	48

[a]Weight percent gain.
[b]Starved, had no wood block in units.

slightly harsher starvation effect than the mere absence of wood in the starved set.

The survival of the various termite forms differed in the sets. In the control set, the worker, nymph, and soldier survivals were 84 percent, 93 percent, and 100 percent, respectively. The matching percentages in the starved set were 71 percent, 86 percent, and 33 percent, and in the BO seta 50 percent, 76 percent, and 75 percent. This shows that the starvation condition and, more severely, the BO treatment caused greater mortality of both worker and nonworker forms. The mortality was not notable until the 10-day inspection, indicating that the BO treatment may have merely enhanced the starvation effect. Some contribution to mortality by a slow-acting toxic action also remains as a possibility.

Red color in dead termites and on wood blocks at later inspections indicated that the pathogenic bacterium *Serratia marcesens* had proliferated in AO-treated-wood sets. It was noted after the 10-day inspection of one PO 17 WPG interior block unit and in all of the PO 34 WPG and BO block sets. This pathogen is frequently present in termite colonies, but normally does not have a noticeable effect on the termites until they are weakened by other conditions.

Discussion and Conclusions

Propylene and butylene oxide treatments made southern pine sapwood resistant to subterranean termite attack. Chemical modification of wood at levels of 34 WPG for PO and 27 and 34 WPG for BO virtually eliminated Reticulitermes attack under laboratory conditions.

The mode of action for this termite resistance in modified wood has not been established. Others (3) found termite resistance in southern pine acetylated with acetic anhydride. Theoretically, neither the epoxides nor the acetate group that reacted with the wood should be toxic to termites, but chemical weight gains of about 25 percent appeared to render the wood resistant to attack.

Possible explanations for the observed resistance to subterranean termite damage are numerous; AO-modified wood can be: a) toxic, b) repellent, c) distasteful, d) undigestible and, therefore, unsuitable as food, or, e) AO-modified wood fibers are stiffer and physically more difficult to eat. Explanations c), d), and e) are aspects of unpalatability.

Ethylene and propylene oxides are used as biological sterilants so any free unreacted oxide remaining in the treated wood might be toxic or repellent to termites. Repellency and lethal fumigation occurred in the preliminary study with AO-treated wood. After solvent extraction of this wood, neither repellency nor fast-acting toxicity were noted.

The resistance of the modified wood seems attributable primarily to ita unpalatability. Up to 39 percent WPG, the higher weight gains

from AO treatments virtually eliminated attack on the wood by termites. A delayed mortality of termites occurred; although it was greater than that occurring in groups of starved termites, it was similar except for 34 percent BO. Nevertheless, that greater mortality may be attributable to either an enhanced starvation effect or a slow-acting toxic effect. These two options will remain difficult to assess because proliferation of pathogenic microbes in groups of starvationally weakened termites will confound interpretation of results.

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