Potential of Kaolin-based Particle Film Barriers for Formosan Subterranean Termite (Isoptera: Rhinotermitidae) Control

by

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ABSTRACT

Effects of three particle film products on Formosan subterranean termites, *Coptotermes formosanus* Shiraki, were evaluated in feeding, tunneling, and contact assays. The particle films, hydrophobic M96-018 and hydrophilic Surround and Surround WP are based on the inert clay mineral kaolin. In 2-week long no-choice feeding tests, significant mortality occurred only with M96-018-coated wood. When a choice was provided, M96-018 and Surround were consumed at higher rates than untreated wood. Surround WP did not differ from controls in either test. In the tunneling assay termites were given the option of crossing a kaolin-sand mixture to reach an alternate food source. After 3-weeks, rates of 1% and 5% M96-018 provided an effective barrier to Formosan termite tunneling, while termites were not stopped by rates as high as 20% Surround and Surround WP. Dust treatments of all three formulations caused significant increases in mortality within 24 h, with mortality rates ranging from 72.0 – 97.3% within 72 h of treatment. The particle films were most effective when moisture levels were low, suggesting that desiccation was the mechanism for mortality. All particle films showed potential for use in above ground applications while hydrophobic M06-018 has the most potential as a soil barrier to subterranean termites.

Key words: *Coptotermes formosanus*, kaolin, particle film, barrier

INTRODUCTION

Soil insecticide barriers were long considered the main method of preventing subterranean termite infestations. The withdrawal of chlorinated hydrocarbons from the market in the mid-1980's left a void in persistent treatment

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options, resulting in an increase in the frequency of insecticide applications. Treatment failure and concern over increasing insecticide usage have renewed interest in developing alternative methods for subterranean termite control. A treatment option that has been gaining popularity worldwide is the use of inert particle barriers.

Effective particle barriers have been found in two individual particle size ranges. Particles of 1-3 mm in diameter provide a physical barrier because the particles are too large for individual termites to move and pack too tightly for the termites to walk through. These larger mineral particles include crushed basalt (Tamashiro *et al.* 1991), sand (Ebeling and Pence 1957, Su *et al.* 1991, Su and Scheffrahn 1992), granite (Smith and Rust 1990, French 1994), and limestone (Myles 1997). Smaller particles that desiccate insects have been tested extensively against stored product pests (Alexander *et al.* 1944a and 1944b, David and Gardiner 1950) and to a lesser extent, subterranean (Grace and Yamamoto 1993) and drywood (Ebeling and Wagner 1959, 1961) termites. The most effective particles are hard nonsorptive particles that work by abrading the insect's epicuticle (Wigglesworth 1944, David and Gardiner 1950), or porous sorptive particles that disrupt the structure of the cuticle by adsorption to epicuticular lipids (Alexander *et al.* 1944a, Ebeling and Wagner 1959, 1961). Since both mechanisms cause rapid water loss, resulting in death by desiccation, particle films are most effective when moisture levels are low. Smaller particles are generally the most effective, and range in size from about 1-2μm (Chiu 1939, Alexander *et al.* 1944b).

Kaolin is a nonadsorptive, nonabrasive fine grained aluminosilicate mineral ($Al_4Si_4O_{10}(OH)_8$), used in the manufacture of pharmaceuticals, cosmetics, paints, and porcelain. In general, the types of kaolin available in early studies were ineffective desiccating agents against stored product pest insects and termites. Advances in engineering can produce particles of various sizes, shapes, and degrees of hydrophobicity that have opened new possibilities for use in pest control. Particle films based on surface modified kaolin have been shown effective as barriers against agricultural pests including the pear psylla, *Cacopsylla pyricola* Foerster (Puterka *et al.* 2000, 2005), codling moth, *Cydia pomonella* (L.) (Unruh *et al.* 2000), black pecan aphid, *Melanocallis caryaefoliae* (Davis) (Cottrell *et al.* 2002), boll weevil, *Anthonomus grandis grandis* Boheman, (Showler 2002), and Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Mazor and Erez 2004). In this study, we evaluated three kaolin-based materials against the Formosan subterranean termite, *Coptotermes formosanus* Shiraki.

MATERIALS AND METHODS

Materials

Three particle film materials were evaluated. All were composed of kaolin particles, >85% sized to ≤ 2μm. Surround (Engelhard, Iselin, NJ), the parent material of the other two products, is a hydrophilic formulation used in combination with a spreader-sticker, M03. Surround WP is essentially Surround coated with MO3 spreader-sticker to make a single component package. M96-018 is composed of the kaolin based Surround, made hydrophobic by coating with a synthetic hydrocarbon.

Formosan subterranean termites were collected from field colonies in City Park, New Orleans, LA, using traps made from 7" cylindrical irrigation valve boxes (NDS, Inc. Lindsay, CA) containing rolled corrugated cardboard and buried with the lids at ground level. The termites were maintained at room temperature on stacked, moistened pine blocks in covered plastic containers (16.5 x 11.5 x 6 cm) and were used within two weeks of collection. Four colonies were used for each experiment.

Wood preparation

A 6% suspension was prepared from each of the particle film formulations. M96-018 was first pre-mixed into methanol (4 ml MeOH / 6 g M96-018) to form a slurry before adding water. Surround was prepared by adding 6 g to 125 μl M03 and 100 ml water. Surround WP has spreader sticker incorporated into the powder and was mixed directly into water at 6 g / 100 ml water.

Thin slices of pine (3.8 cm x 3.0 cm x 0.7 cm), weighing approximately 0.4 g each, were oven-dried at 100° C for 24 h, cooled 1h at room temperature under ambient conditions, and weighed. A hand-held mister was used to coat both sides of the wood with one of the kaolin suspensions or water and the wood was dried, cooled, and weighed again to determine the amount of particle film applied. The final rates of kaolin, by weight, were 7% for M96-018, 4% for Surround, and 5% for Surround WP.

No-choice feeding test

One of the treated pieces of wood was placed in the bottom of a round plastic dish 8.5 cm diameter and 3.5 cm high. Controls received wood treated with water. One hundred grams of fine blasting sand (Quikrete, Atlanta, GA) and 10 ml water were then added to the dish. Finally, 250 termites (225 workers + 25 soldiers) were added to each, the dishes covered, and placed in unlighted incubators at 28°C. Twenty replicates, five from each of four colonies, were tested. After two weeks the dishes were dismantled and the surviving termites removed. Sand was brushed from the wood slices, which were then oven-dried, cooled, and weighed. Mortality and wood consumption data were analyzed by ANOVA, and Tukey's means comparison test.

Choice test

Two pieces of wood were placed in the bottom of an 8.5 cm x 3.5 cm round plastic dish: one treated with only water and the other treated with either one of the kaolin formulations or water. One hundred grams of fine blasting sand, 10 ml water, and 250 termites (225 workers + 25 soldiers) were added to each, the dishes covered, and placed in unlighted incubators at 28°C. For each of the three formulations, 20 replicates were tested, five from each of four colonies. After two weeks, the dishes were dismantled. The wood was cleaned, oven dried and weighed, as previously described. Paired t-tests were used to compare the consumption of treated and untreated wood.

Tunneling bioassay

Termites were provided with a food source, with the option of traveling through treated sand to reach a second food source. To evaluate the use of these products as a barrier we exposed termites to sand treated with kaolin in an assay that was similar to that described by Grace (1991). The assay apparatus consisted of three compartments: (1) a nest container; (2) a tunneling arena; and (3) a dish containing an additional food source. The three 8.5 x 3.5 cm round plastic dishes were connected linearly by 1-cm pieces of Tygon tubing. Each of the end compartments contained 100 g sand, 10 ml water, and a 4 g pine block. The tunneling arena contained sand mixed with one of the kaolin products or untreated sand as a control.

Rates of each kaolin material to be incorporated into sand were determined by preliminary experiments. M96-018 was evaluated at 0.1%, 1%, and 5% (dry weight of compound per dry weight of sand), while Surround and Surround WP were evaluated at 5%, 10%, and 20%. One gram of Formosan subterranean termites (10% soldiers, by weight) was added to each nest container, the dishes covered, and kept at 28°C in dark incubators for 3 weeks. Each treatment was replicated twenty times (five replicates from each of four colonies).

The bottoms of containers were scanned every 2-3 days. Tunnel areas were measured using SigmaScan software (SPSS Inc., Chicago, IL). When containers were dismantled at the end of 3 weeks, termites in each compartment were weighed to determine mortality and termite location. Wood blocks were removed cleaned, dried, and weighed. ANOVA and Tukey's means comparison tests were used to compare between-rate differences in mortality, tunnel area, and wood consumption.

Dust treatment

C. formosanus workers were dusted with Surround, Surround WP, or M96-018 by placing 2g of one of the products in a plastic vial, adding 20 workers, capping, and rolling the vial for 20 sec. Control termites were placed in empty vials, and then rolled. The termites were then emptied onto a piece of filter paper in a glass Petri dish. After the termites crawled off the filter paper, the paper was removed. Dishes were covered and placed in plastic sweater boxes containing wet paper towels. For each treatment, twenty replicates were tested, five from each of four colonies. Mortality was recorded after 1, 2, 4, 8, 24, 48, and 72 hours. For each time period, mortality data were analyzed by ANOVA and Tukey's means comparison test.

RESULTS AND DISCUSSION

In 2-week no-choice tests, none of the coatings provided significant reduction in the amount of wood consumed ($F = 1.80$; df = 3, 76; $P = 0.1542$) (Table 1). Mortality of termites provided wood coated with M96-018 was greater than that of termites provided untreated control wood ($F = 3.14$; df = 3, 76; $P = 0.0303$). In Surround and Surround WP treatments, mortality did not differ from that in M96-018 or control treatments. With a maximum mortality rate of 26.05% (M96-018), none of these results suggest a meaningful level of protection against FST.

When an untreated alternate food source was provided, particle film coatings did not deter feeding. In choice tests, consumption of wood coated with M96-018 (mean ± SEM, 0.18 ± 0.01g) was greater than that of the paired

Table 1. Mortality and wood consumption in a no-choice test of *C. formosanus* feeding on kaolin-coated wood.

Treatment	Mortality	Wood Consumption (g)
M96-018	26.05 ± 2.55a	0.24 ± 0.02a
Surround	20.02 ± 1.96ab	0.24 ± 0.02a
Surround WP	22.28 ± 2.59ab	0.23 ± 0.02a
Control	16.79 ± 1.85b	0.29 ± 0.02a

Mean ± SEM of 20 groups of 250 termites. Means within each column followed by the same letter are not significantly different (α ≤ 0.05, ANOVA, Tukey's Studentized Range Test).

Table 2. *C. formosanus* mortality, tunneling, and wood consumption after 3-week tunneling bioassay.

Treatment	Mortality	Tunnel area (sq. cm)	Wood consumption (g)	Barrier Crossed (# of reps.)
M96-018				
0%	34.4 ± 2.6a	12.1 ± 1.5a	0.25 ± 0.04a	19
0.1	39.9 ± 3.8a	9.2 ± 1.1a	0.32 ± 0.03a	15
1	42.8 ± 2.9a	0.5 ± 0.2b	0.04 ± 0.01b	3
5	44.8 ± 5.2a	0.0 ± 0.0b	0.00 ± 0.00b	0
Surround				
0	29.1 ± 4.6a	9.8 ± 1.0a	0.17 ± 0.03a	18
5	22.8 ± 1.7a	7.6 ± 1.2ab	0.12 ± 0.03ab	12
10	22.0 ± 2.8a	5.9 ± 0.9bc	0.10 ± 0.02ab	11
20	20.7 ± 1.9a	3.8 ± 0.9c	0.04 ± 0.02b	8
Surround WP				
0	37.2 ± 7.0a	8.6 ± 1.4a	0.19 ± 0.03a	16
5	31.5 ± 4.0a	11.5 ± 1.3a	0.12 ± 0.03a	12
10	23.7 ± 2.9a	10.8 ± 1.1a	0.19 ± 0.04a	18
20	30.1 ± 5.3a	9.2 ± 1.1a	0.10 ± 0.03a	19

Mean ± SEM of 20 groups of termites. Within a formulation, means within each column followed by the same letter are not significantly different (α ≤ 0.05, ANOVA, Tukey's Studentized Range Test).

Table 3. Mortality of *C. formosanus* workers after coating with kaolin particle films.

	% Mortality			
Treatment	8h	24h	48h	72h
M96-018	6.5 ± 3.2ab	43.3 ± 7.3a	82.8 ± 5.1a	97.3 ± 1.6a
Surround	14.3 ± 3.7a	30.3 ± 6.8a	67.0 ± 8.0a	83.5 ± 5.7ab
Surround WP	9.3 ± 2.6ab	26.0 ± 4.9a	63.5 ± 8.9a	72.0 ± 8.2b
Control	0.3 ± 0.3b	2.0 ± 0.8b	4.5 ± 1.5b	5.0 ± 1.6c

Mean ± SEM of 20 groups of 20 termite workers. Means within each column followed by the same letter are not significantly different (α ≤ 0.05, ANOVA, Tukey's Studentized Range Test).

untreated wood (0.13 ± 0.01g) ($t(19) = 4.28, P = 0.00017$). Greater consumption of Surround-coated wood (0.18 ± 0.01g) versus untreated wood (0.14 ± 0.01g) was also found ($t(19) = 2.70, P = 0.00711$). There was no difference between Surround WP (0.15 ± 0.01g) and the control (0.16 ± 0.01g) ($t(19) = 0.82, P = 0.37964$). In control-control pairings, there was no difference in consumption of the two pieces of wood (0.17± 0.01g, 0.17± 0.01g) ($t(19) = 0.82, P = 0.39114$). These results suggest that the slight, but insignificant differences in wood consumption in no-choice tests were due to mortality rather than reduced feeding by individual termites.

Only M96-018 provided an effective barrier to Formosan termite tunneling. In 5% M96-018, no tunneling occurred. Termites failed to cross the treated sand in all of the 5% M96-018 replicates and 85% of the 1% M96-018 replicates, while termites did not cross control sand only 5% of the time (Table 2). In comparison to controls (0%) and 0.1% M96-018, the 1% and 5% rates had less consumption of wood in the destination container and tunneling in the barrier compartment. While a significant reduction in tunnel area and wood consumption occurred with 20% Surround, the barrier was penetrated in 40% the replicates, versus 90% of control replicates. Surround WP did not affect termite tunneling or wood consumption. No increase in termite mortality was found in any of the treatments.

When applied directly to the termites, M96-018 coated the termites' bodies uniformly and little was removed by grooming. Coverage of termite bodies by Surround and Surround WP was uneven and most of the particle film was removed by grooming within 24h. In the first four hours after dusting, treated termite mortality did not differ from that of controls. After 8h, only Surround produced a significantly higher mortality rate than the control, ($F = 4.48$; df = 3,76; $P = 0.0060$) (Table 3). After 24h, all treatments had substantially higher mortality than that of the controls (F = 9.55, df = 3,76; $P < 0.001$). By 72h, >70% of termites were dead in all kaolin treatments, with the highest rate occurring with M96-018 (97.25 ± 1.58%).

Particle films act by desiccation. Other studies have found that the desiccants boric acid and diatomaceous earth cause subterranean termite mortality, but are ineffective as soil barriers (Grace 1991, Grace and Yamamoto 1993). Likewise, all kaolin formulations killed *C. formosanus* when applied directly to the termites. In high moisture environments, Surround and Surround WP failed to impact mortality or provide a barrier to tunneling. The hydrophobic formulation M96-018 was more successful in the tests described in this paper. However, in preliminary experiments where there was direct contact with wet sand, all kaolin treatments failed to block tunneling. Even in dry habitats, as termites import soil into the treated area, contact with soil and the termites themselves would likely increase the moisture content of the kaolin to the point of interfering with its desiccant action. Other desiccants have been effective at preventing the founding of drywood colonies in attics and other enclosed spaces (Wagner and Ebeling 1959). When applied as a contact treatment, all three kaolin particle films caused increased termite mortality within 8h, and caused mortality rates of 72-97% after 72h. These results suggest that these materials did not provide an effective barrier to subterranean termites, but they may have a potential use against drywood termites.

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