Oral Toxicity of Barium Metaborate to the Eastern Subterranean Termite (Isoptera: Rhinotermitidae)[1]

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ABSTRACT The oral toxicity of barium metaborate monohydrate (Busan 11-M1) to *Reticulitermes flavipes* (Kollar) was evaluated in no-choice assays by feeding termite workers for 15 and 30 days on filter papers treated with concentrations of 500-40,000 ppm (weight/weight). In the 15 day assay, 30,000 ppm resulted in 92 ± 17% termite mortality and a concomitant 86% reduction in paper consumption. Feeding for 30 days on 1,500 ppm resulted in 100% mortality. Reduced paper consumption was associated with termite mortality, and feeding on low concentrations did not differ from that on control papers. Concentrations ≥ 20,000 ppm provided protection from termite feeding, while concentrations ≤ 5,000 ppm may be applicable in developing baits for subterranean termite control.

KEY WORDS *Reticulitermes flavipes,* wood preservative, termite bait, borate insecticide.

Control of subterranean termites (Rhinotermitidae) has relied for many years upon the application of persistent organochlorine, and more recently organophosphate and pyrethroid insecticides to the soil around infested or threatened structures. When properly applied, these pesticides create a barrier to termite infestation. However, relatively large quantities of pesticide solution are needed, and termite populations persisting in adjacent untreated soil are apparently unaffected. In urban Florida, Su and Scheffrahn (1988a) found Formosan subterranean termite, *Coptotermes formosanus* Shiraki, colonies foraging over areas as large as 3,571 m^2. The widely distributed eastern subterranean termite, *Reticulitermes flavipes* (Kollar), is also capable of foraging over large territories. In Toronto, Ontario, foraging by one *R. flavipes* colony extended over an area of 1,091 m^2 (Grace et al. 1989).

The use of toxic baits to contaminate foraging termites offers an alternative to establishing barriers by soil treatment with persistent insecticides. Esenther and Gray (1968) first reported successful control using baits impregnated with the slow-acting and non-repellent insecticide dechlorane (mirex), and development of baiting techniques using this compound has continued in China (Gao 1987) and Australia (French 1988). However, dechlorane is no longer available for use in many parts of the world, including North America. Investigations of replacement bait toxicants include reports by Prestwich et al. (1983), Jones (1984, 1988), Esenther (1985), Su and Scheffrahn (1988b, 1988c), and others.

A successful bait toxicant must be both nonrepellent to promote feeding, and slow acting to permit distribution through the colony by trophallaxis and other social contacts (Su et al. 1987). Boric acid and boron salts are slow acting

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insecticides effective against *Reticulitermes* spp. (Randall et al. 1934; Becker 1966), with potential applicability in cellulosic baits (D'Orazio 1982; Mori 1987). This paper reports a laboratory evaluation of Busan 11-M1, a commercial form of modified barium metaborate monohydrate ($BaB_2O_4 \bullet H_2O$), as a dietary toxin for *R. flavipes.* This compound is used in coatings as a microbicide, corrosion inhibitor, and flame retardant. It has a maximum solubility of 0.4% in boiling water. Barium is an acute toxicant, and Busan 11-M1 exhibits moderate mamalian toxicity: acute oral LD_{50} 850 mg/kg, acute dermal LD_{50} > 2,000 mg/kg (Buckman Laboratories 1983).

Materials and Methods

Eastern subterranean termites, *R. flavipes,* were collected from Scarborough, Ontario, in traps consisting of rolls of corrugated cardboard within capped plastic (ABS) pipes placed on top of an infested maple stump (La Fage et al. 1983) and in the adjacent soil (Grace 1989). These termites were maintained on moist sand, corrugated cardboard, Whatman No. 1 filter paper, and cotton in plastic containers kept in an unlighted incubator ($27 \pm 0.5°C$, $90 \pm 5\%$ RH). Bioassays were also conducted in this incubator.

Busan 11-M1 (Buckman Laboratories of Canada, Ltd., Dorval, Quebec), a commercial formulation of modified barium metaborate monohydrate 90+% active calculated as $BaB_2O_4 \bullet H_2O$ (Buckman Laboratories 1983), was agitated in methanol, and equivalent amounts of the agitated solution pipetted onto both sides of weighed 9 cm Whatman No. 1 filter papers to obtain precise deposits by weight. Treated papers, and a methanol-treated control paper, were cut into strips 2 × 6 cm (ca. 69 mg), oven-dried (2 hours, 75°C), weighed, and placed along one side of polystyrene vials (44.8 ml, 60 × 35 mm Diam) containing 7 ml (ca. 10 g) oven-dried brick sand, 4 ml perlite, and 2 ml deionized water. An additional 1 ml of water was added at 10 day intervals. Thirty *R. flavipes* workers (externally undifferentiated individuals older than the third instar as determined by size) were deposited in each vial, and the vials (four per treatment) capped with polyurethane foam plugs and placed in the incubator.

In these no-choice assays, termites were fed 15 days on papers containing 500, 750, 1,000, 2,500, 5,000, 7,500, 10,000, 20,000, 30,000 or 40,000 ppm (wt/wt) barium metaborate monohydrate, and 30 days on papers containing 750, 1,000, 1,500, or 2,000 ppm. Feeding and mortality were evaluated by counting surviving termites and weighing the oven-dried papers. Papers were carefully brushed free of sand, oven-dried (2 hours, 75°C) and placed in a desiccator for 1 hour to equilibrate to room temperature, then removed singly and rapidly weighed at a precision of 0.1 mg to minimize effects of ambient humidity on paper weights. Each treatment was repeated with four experimental units, and results subjected to analysis of variance (ANOVA, one-way layout) and the Ryan-Einot-Gabriel-Welsch (REGW) Multiple F Test, $\alpha=0.05$ (SAS Institute 1987).

Results and Discussion

Significant termite mortality resulted from feeding for 15 days on barium metaborate monohydrate concentrations of 10,000-40,000 ppm (1-4% wt/wt), with a concomitant decrease in paper consumption (Table 1). In the 30 day assays, lesser concentrations elicited high mortality, with exposure to a concentration of 1,500 ppm resulting in 100% mortality within the 30 day interval (Table 2).

Table 1. Feeding and mortality of *R. flavipes* workers fed for 15 days on filter papers treated with barium metaborate monohydrate.

Concentration (ppm)	Percent Mortality (Mean ± SD)*	Paper Consumption	
		Actual (mg ± SD)*	Percent of Control
Control	15 ± 2a	24 ± 3a	100
500	9 ± 4a	24 ± 2a	100
750	13 ± 6a	25 ± 2a	100
1,000	18 ± 4ab	20 ± 2a	84
2,500	19 ± 3ab	20 ± 1a	84
5,000	18 ± 6ab	20 ± 3a	85
7,500	33 ± 9ab	14 ± 4b	57
10,000	43 ± 21b	13 ± 4b	53
20,000	68 ± 29c	4 ± 5c	18
30,000	92 ± 17cd	3 ± 1c	14
40,000	97 ± 7d	2 ± 0c	8

* N = 4 groups of 30 termite workers. Means in each column followed by different letters are significantly different (ANOVA, REGW Multiple F Test, $\alpha = 0.05$).

Table 2. Feeding and mortality of *R. flavipes* workers fed for 30 days on filter papers treated with barium metaborate monohydrate.

Concentration (ppm)	Percent Mortality (Mean ± SD)*	Paper Consumption	
		Actual (mg ± SD)*	Percent of Control
Control	40 ± 26a	34±13a	100
750	89 ± 11b	23± 6a	68
1,000	94 ± 8b	29± 5a	85
1,500	100 ± 0b	27± 6a	79
2,000	100 ± 0b	25± 5a	74

* N = 4 groups of 30 termite workers. Means in each column followed by different letters are significantly different (ANOVA, REGW Multiple F Test, $\alpha = 0.05$).

Concentrations of 30,000 and 40,000 ppm resulted in greater than 90% *R. flavipes* mortality within 15 days, and termite consumption of the test papers was reduced by 82-92% at concentations ≥20,000 ppm. However, no disproportionate reduction in paper consumption indicative of feeding deterrence, rather than toxicity, was noted at lower concentrations.

Feeding in a no-choice assay does not guarantee acceptability under free-choice conditions, and additional investigations are needed to determine the applicability of low concentrations of barium metaborate in termite bait development. Termite collection units such as that described by Grace (1989) offer a means of performing multiple-choice feeding assays under field conditions. An additional consideration, also beyond the scope of the present study, is the very broad distribution of *R. flavipes* throughout eastern North America and several European cities. In terms of general applicability, toxicity and feeding behavior should be assessed with termite colonies from different geographic locales to allow for possible variations in response.

Since barium metaborate is relatively insoluable in water, and no information is available on the termiticidal activity of barium, it is possible that toxicity may reflect the amount of boron made available in methanol solution. However, assays with borate dusts as tracking powders have demonstrated that a brief exposure to dry barium metaborate powder results in both high mortality among exposed *R. flavipes* workers and mortality among unexposed group members contacting them (Grace and Abdallay, in preparation), suggesting that the toxic effects observed here were not dependent upon dissolution of the compound in methanol.

At concentrations ≥20,000 ppm (2%), barium metaborate monohydrate may provide protection from termite feeding. Recommended rates for incorporation into paint coatings are 4.5-17% (Buckman Laboratories 1983). Insect repellency, however, may be more desirable than toxicity in a protective coating (Grace 1988). The results also indicate that concentrations ≤ 5,000 ppm may be applicable in developing baits to control *R. flavipes* colonies. In such a bait, slow toxic action and nonrepellence are advantageous.

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