Residual Efficacy of Chlorpyrifos and Diazinon Formulations for German Cockroaches (Orthoptera: Blattellidae) on Panels Placed in Commercial Food Preparation Areas[1, 2]

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ABSTRACT Ceramic and stainless steel panels were treated with chlorpyrifos (Dursban LO or ME) or diazinon (Knox Out 2FM) and aged in a commercial kitchen. Type of surface (ceramic tile or stainless steel) did not significantly affect residual performance of formulations used for control of adult male German cockroaches, *Blattella germanica* (L.). Microencapsulation stabilized the residues of both chlorpyrifos and diazinon and caused 100% mortality of susceptible German cockroaches for 8 weeks and resistant cockroaches for 4 weeks. The emulsifiable formulation provided only 0-67% mortality after 1-2 weeks.

KEY WORDS Insecta, *Blattella germanica*, chlorpyrifos, diazinon, microencapsulation.

Suppression of the German cockroach, *Blattella germanica* (L.) in commercial food preparation areas is essential because infestations can result in closing the facility by the local health department. Control is difficult because most pesticides are either not registered for use in exposed food areas or are ineffective in commercial kitchens. High humidities and temperatures in these areas accelerate hydrolysis of synthetic organic insecticides (Cornwell 1976). Nonporous surfaces, such as stainless steel and ceramic tile, offer minimal protection to insecticide residues and expose them to relatively rapid degradation.

It is difficult to evaluate new formulations of insecticides against German cockroaches in restaurants and cafeterias. Consequently, much of the information concerning cockroach control has been obtained from studies in low income apartments where average populations of 13,000 German cockroaches per apartment have been reported (Koehler et al. 1987, Rust and Reierson 1981). These data may not be relevant to food handling establishments.

Strains of cockroaches encountered in commercial kitchens are often resistant to insecticides (Cochran 1989). A multiresistant German cockroach strain has been developed and mass-reared by scientists in Gainesville, FL. (Milio et al. 1987). This strain has ca. 14-fold resistance to chlorpyrifos at the LT_{50} and new chemcials or new formulations of pesticides can be evaluated and the results compared to data on mass-reared, susceptible cockroaches (Smittle 1966, Cornwell 1976).

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[2] This article reports the results only. Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by USDA or the University of Florida.

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Our objective was to determine whether a diazinon formulation and two chlorpyrifos formulations applied to two nonporous surfaces and aged in a commercial food preparation area would provide mortality of susceptible and resistant cockroaches for up to 8 weeks after application. The formulations tested are the most commonly used chemicals for pest control in commercial kitchens and are considered superior formulations because of their safety, low odor, timed-release microencapsulation technology, or residual properties (Koehler and Patterson 1988).

Materials and Methds

Cockroach Strains. Two strains of German cockroach reared at the USDA-ARS Insects Affecting Man and Animals Laboratory, Gainesville, FL were used in this study. The Orlando normal is a susceptible strain (Koehler and Patterson 1986) obtained in Orlando, Florida about 40 years ago and has been continuously mass-reared without exposure to insecticide. The HRDC is an insecticide resistant strain with documented resistance to chlorpyrifos, diazinon, bendiocarb, fenvalerate, and cypermethrin (Milio et al. 1987, Wadleigh et al. 1989). The strain originated from cockroaches collected at the U.S. House of Representatives in 1980 and crossed in 1982 with a field strain collected from a Gainesville apartment complex. In the laboratory, selection pressure was initially applied to the HRDC colony by placing a water source on two plywood panels (15 by 15 cm) treated with propoxur (0.11 mg/cm^2) and diazinon (0.11 mg/cm^2) in the rearing tubs during the cockroaches' third, fourth, and fifth instars. Cockroaches had to cross the treated surface in order to obtain water. Currently, the colony is pressured with the same chemicals applied at 0.22 mg/cm^2.

Adult males that had eclosed three days previously were used for the bioassay. They were removed from the colony by lightly anesthetizing the colony with CO_2.

Chemicals and Surfaces. Chlorpyrifos formulations used were Dursban LO, a 4EC, low-odor formulation, and Dursban ME (Dow Chemical, Midland, MI), a 1EC, microencapsulated formulation. The diazinon formulation used was Knox Out 2FM (Pennwalt Corp., Philadelphia, PA), a 2EC, microencapsulated formulation. The surfaces were 225 cm^2 (15 by 15 cm) panels of ceramic tile and stainless steel. Prior to treatment, panels were cleaned with acetone, washed with soap and water, and air dried.

Each treatment of 0.5% water-based formulation was applied at the labelled rate for field use to 60 ceramic and 60 stainless steel panels with a hand-compressed air sprayer (B & G Equipment Co., Plumsteadville, PA) to the point of run-off (approximately 4.07 ul/cm^2). Controls were treated in the same manner with water. The spray residue was allowed to dry for 2 hours. The experiment was designed to have three treatments plus the control, two types of surfaces, and five weekly sampling intervals. Treatments were replicated three times.

The test site was a hospital kitchen in Gainesville, FL. For each treatment, panels were attached to the ceramic tile walls directly behind the dishwasher using Velcro strips adhered to the back of the panel and the wall. Panels were subjected to normal cleaning and environmental conditions (25 - 30°C and 85 - 100% RH) found in most commercial kitchens. Panels were bioassayed at 0, 2, 4, 6, and 8 wk after treatment.

Bioassay Method. Panels were removed from the food preparation area and returned to the laboratory for bioassay at five biweekly intervals. Ten male German cockroaches from each laboratory strain were confined on the treated panels for 24 hours using an inverted pyrophyllite-dusted, clear, plastic cup (247 ml). Both strains were bioassayed on the same panel using two locations, and different panels were used for each time after treatment.

Percent mortality was recorded for each panel, and the data were analyzed by analysis of variance and means were separated by the Waller-Duncan method (SAS Institute 1988) after arcsine square root transformation.

Results and Discussion

Surface (stainless steel or ceramic) did not significantly affect mortality of cockroaches (Table 1). Because both surfaces were nonporous, all insecticide on the surface was available for cockroach contact. Therefore, the assays provided a good indication of formulation performance in areas of high humidity, temperature, and frequent sanitation.

Table 1. Mortality of insecticide-susceptible and multiresistant German cockroaches exposed to surfaces treated with insecticide and aged in a commercial kitchen.

		Percent mortality at week after treatment				
Treatment	Surface	0	2	4	6	8
SUSCEPTIBLE (Orlando Normal)						
Dursban ME	Ceramic	100a	100a	100a	100a	100a
	Stainless	100a	100a	100a	100a	100a
Dursban LO	Ceramic	100a	37bc	0b	——	——
	Stainless	100a	67ab	0b	——	——
Knox-out 2FM	Ceramic	100a	100a	100a	100a	100a
	Stainless	100a	100a	100a	100a	100a
Control	Ceramic	0c	0c	0b	0c	0c
	Stainless	0c	0c	0b	0c	0c
MULTIRESISTANT (HRDC)						
Dursban ME	Ceramic	100a	80a	100a	30b	0c
	Stainless	100a	100a	100a	50b	3c
Dursban LO	Ceramic	100a	3c	0b	——	——
	Stainless	97b	0c	0b	——	——
Knox-out 2FM	Ceramic	100a	100a	100a	90a	33bc
	Stainless	100a	100a	100a	80a	50b
Control	Ceramic	0c	0c	0b	0c	0c
	Stainless	0c	0c	0b	0c	0c

Means within a column followed by the same letter are not significantly different ($P > 0.05$; Waller-Duncan method [SAS Institute 1988]).

The microencapsulated formulations (Dursban ME and Knox-out 2FM) provided longer residual effectiveness than the emulsifiable formulation (Dursban LO). Both microencapsulated formulations killed 100% of the susceptible cockroaches on both surfaces for 8 weeks after treatment. Dursban LO killed 100% of the susceptibles only after the initial application. Koehler and Patterson (1988) treated plywood panels with Dursban LO and ME, aged them in the laboratory, and determined that Dursban ME provided 100% mortality of susceptible cockroaches for 4 weeks after treatment compared to 2 weeks for Dursban LO. In this test, Dursban LO's residual efficacy was greatly reduced on ceramic and stainless steel surfaces subjected to frequent cleaning, high humidity, and high temperatures.

Multiresistant cockroaches had significantly lower mortality (<80%) than susceptible cockroaches placed on surfaces treated with microencapsulated formulations and aged more than 4 weeks. Knox-out 2FM and Dursban ME treatments killed 100% of the multiresistant cockroaches up to 4 weeks after treatment; whereas Dursban LO killed only 0-3% of the multiresistant cockroaches after residues were aged one week. After 4 weeks, the efficacy of the microencapsulated formulations declined markedly. These data on ceramic and stainless steel sufaces were less erratic than the results reported by Koehler and Patterson (1988) for the microencapsulated formulations applied to plywood. Rust and Reierson (1978) demonstrated that microencapsulated diazinon formulations increase the availability of the active ingredient compared to water emulsions of diazinon, and consequently, result in improved control of resistant German cockroaches. The microencapsulated insecticides appear to be more stable on ceramic and stainless steel surfaces in food handling establishments and cause higher mortality of insecticide resistant cockroaches than the water emulsion formulation.

Microencapsulated chlorpyrifos and diazinon formulations are safe to use in commercial kitchens. Diazinon has an acute oral LD_{50} of 300-400 mg/kg before microencapsulation, but the LD_{50} of Knox Out is >21,000 mg/kg (Anonymous 1988). Similarly, chlorpyrifos has an acute oral LD_{50} 96-270 mg/kg (Anonymous 1988), but Dursban ME's LD_{50} is >25,000 mg/kg (Dow Chemical, Midland, MI).

Chlorpyrifos and diazinon effectively kill German cockroaches (Kenaga et al. 1965, Grayson 1966, Whitney et al. 1967, and Burden et al. 1972) and have been used in commercial kitchens by the pest control industry for more than 20 years. Rust and Reierson (1978, 1979) and Koehler and Patterson (1988) have reported improved stability and German cockroach control with microencapsulated formulations of diazinon and chlorpyrifos. Our data substantiate that microencapsulated insecticide residues are more persistent on ceramic and stainless steel surfaces frequently encountered in food preparation areas.

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