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Laboratory and field evaluations of lithium perfluorooctane sulfonate baits against domiciliary and peridomestic cockroaches in Penang, Malaysia

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Abstract: Laboratory and field performance of a bait toxicant, lithium perfluorooctane sulfonate (Sulfotine™) [LPOS] in bait station (1% LPOS) in comparison with a commercially available bait station (containing 0.5% chlorpyrifos) were tested against the American cockroach, *Periplaneta americana* (Linnaeus) and other peridomestic cockroach species in low-income houses and apartments in Penang Island, Malaysia. Laboratory evaluation indicated that there was minimal difference between the performance of LPOS baits and that of the chlorpyrifos bait, when tested against *P. americana*, *P. brunnea* and *P. australasiae*. In field studies, LPOS- and chlorpyrifos-based bait stations reduced trapped domiciliary and peridomestic cockroaches by 95% and >85% within the first two weeks following treatment, respectively. At the 12th week post-treatment, LPOS still provided >99% reduction in cockroach trap counts. Further studies were executed to evaluate the effects of bait numbers on the performance of LPOS baits against the American cockroach in suburban apartments (35.8 m^2). It was demonstrated that 4-8 baits were needed to achieve good control of the cockroach population (i.e. about 90% reduction within 1 week post-treatment). Sanitation levels were positively correlated with percentage reduction in trap counts in houses treated with lower bait numbers; however, when higher number of baits were used, the role of sanitation on reduction of cockroach numbers was lessened.

Key words: cockroaches, baiting, lithium perfluorooctane sulfonate, bait placement number, sanitation

INTRODUCTION

The American cockroach, *Periplaneta americana* (Linnaeus), is a major household pest in Southeast Asia and many tropical countries (Lee et al., 1999; Lee and Robinson, 2001). In certain regions of the world such as southeastern U.S.A., this species commonly occurs as a peridomestic pest (Mampe, 1972; Wright et al., 1986; Appel, 1986; Appel and Smith, 1996). Several field surveys had found that this species is the most dominant species in Malaysia (Oothuman et al., 1984; Yap et al., 1991; Lee et al., 1993; Yap et al., 1997; Lee and Lee, 2000a) where it is regularly found in kitchens, bathrooms and old cabinets, as well as in outdoor sewage tanks.

Chemical control has thus far remained the most popular method for cockroach control (Lee and Robinson, 2001). Residual insecticides in many different formulations are often considered the most effective control. The use of baits for cockroach control is a better alternative to residual insecticides because it reduces

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the likelihood of pesticide misapplication (Robinson, 1988). Recent advances in bait formulation and active ingredients have resulted in many fast-acting bait products that provide comparable action times as those of contact insecticides. Most baiting studies have concentrated on efficacy of toxicants against *Blattella germanica* (Appel, 1990, 1992; Appel and Benson, 1995; Ogg and Gold, 1993; Lee, 1998). Reports on American cockroaches however, have been limited, especially against those inhabiting residential premises (Lee and Lee, 2000b).

Lithium perfluorooctane sulfonate (LPOS), a relatively new active ingredient, is an isomeric mixture of 70% linear isomers and 30% branched isomers with molecular formula $C_8F_{17}LiO_3S$. Its acute mammalian oral toxicity is >5,000 mg/kg, yet this toxicant was reported to demonstrate excellent oral toxicity against cockroaches and ants (Rettich, 1999).

It had been reported earlier that better sanitation improved residual insecticide treatment efficacy (Gupta et al., 1973, 1975; Schal, 1988), including bait performance (Reierson, 1995; Lee and Lee, 2002b). It has remained unknown however, how this factor interacts with bait numbers in apartments with varying sanitary conditions. The purpose of this study is to evaluate the performance of a bait formulation of LPOS against the American cockroach and peridomestic cockroach species in low-income houses in Penang Island, Malaysia. In addition, the effects of bait placement numbers and role of sanitation were also examined. A standard bait (0.5% chlorpyrifos) was used for comparison.

Materials and Methods

Insects

Laboratory-cultured cockroaches (*P. americana*, *P. brunnea* and *P. australasiae*) were used in the laboratory evaluation. They were from established colonies, previously originated from wild populations collected in Penang Island, Malaysia. The cockroaches were reared under environmental conditions on a 12-hour photoperiod, 25+2℃ and 50+5% relative humidity. Food and water were provided *ad libitum*.

Baits tested

Two bait formulations in the form of containerized bait, containing 1% LPOS, and 0.5% chlorpyrifos, respectively were used in this study. Blank baits (without active ingredient) were used as control baits. All formulations were supplied by S. C. Johnson Inc., Racine, WI, U.S.A.

Laboratory test

For laboratory evaluation, a total of 10 males, 10 females, and 20 mid-instar nymphs were introduced into a test arena (45×30×20 cm) with two harborages (rolled corrugated cardboard) on one side of the arena. A watering device was provided close to the harborage. A total amount of 5 g of non-toxic food (dog pellet) was placed at one corner of the arena, facing the harborage. Following a 24-hour acclimatization period, a containerized bait (3 g) was introduced into the arena and placed on the corner adjacent to where the non-toxic food was located. Mortality of the cockroaches was assessed daily up to 14 days. The experiment was replicated 5 times.

Field trial I

Field studies on the LPOS baits were evaluated in Teluk Kumbar, a suburban area located at southwestern side of Penang Island, Malaysia. Environmental conditions recorded during the studies were 30+2℃ and 80+5% relative humidity. The first trial was done to evaluate the performance of LPOS-based baits against the American cockroach and other peridomestic cockroach species. This was conducted in low-income houses with poor drainage and sanitation. These houses were different in size. Prior to the trial, pre-sampling was performed to identify houses with high cockroach infestations.

Five-0.45 *l* glass jars baited with beer-soaked white bread were placed overnight in the kitchen of sampled houses. Houses with >8 cockroaches trapped per night in 5 jars were chosen for the trial. A total of 12 houses were allocated for each bait formulation and six houses were chosen as control. For each house, a total of 8 containerized baits were placed; mostly in the kitchen, dining and bathroom areas. The baits were left throughout the entire experimental period. Post-treatment sampling was conducted at 1, 2, 6 and 12 weeks.

Field trial II

The second trial was done to determine the effect of bait numbers and sanitation on the performance of LPOS containerized baits against the American cockroach. A low-income apartment blocks located in Sg Batu, Penang Island, Malaysia with standardized living area sizes (35.8 m^2) were chosen. Houses with >8 cockroaches trapped per night in 5 jars were included in the trial. Treatments consisted of different number of bait placements (0, 2, 4 and 8 bait stations) and 9 houses were assigned for each treatment. In order to avoid possible mixed effects between different treatments, the treatments were assigned to houses in clusters, rather than at random. This was done by choosing the houses within the same apartment block for the same type of treatment. Bait stations were placed mainly in the kitchen, dining and bathroom areas. At each sampling date, all bait stations were inspected and missing baits were replaced. No replacement was made for baits that had been completely consumed. Post-treatment sampling was done at 1, 2, 6 and 12 weeks. Each premise chosen for this trial was also rated for sanitation as described by Lee and Lee (2000b): 1=poor (extreme clutter, always with damp or wet floor, leaking pipe and food debris on the floor), 2=moderate (less clutter, less food debris on floor, no leaking pipe, sometimes with damp or wet floor), 3=good (no clutter, no visible food debris, floor always dry, no leaking pipe).

Data analysis

Laboratory bioassay data were pooled and subjected to probit analysis according to procedures described by Robertson and Preistler (1992) using the POLO-PC program (LeOra Software, 1997). Percentage reduction (PR) based on trap counts before and after bait application was calculated for field bait treatments. Data were subjected to Kruskal–Wallis (KW) one-way analysis of variance by rank, and the KW multiple comparison test (Siegel and Castellan, 1988). Correlation between percentage reduction on cockroach trap counts and bait numbers, and between sanitary condition and bait performance were performed with regression analysis using the Statistix Version 7.0 statistical package.

Results and Discussion

Laboratory evaluation of 1% LPOS- and 0.5% chlorpyrifos-based baits against three species of *Periplaneta* indicated excellent performance of both toxicants against the tested insects (Table 1). Both baits showed LT_{50} values of ≤ 2 days when tested against all adult stages. Based on LT_{50} values obtained, chlorpyrifos baits showed a relatively faster action against LPOS baits, however, all test insects were killed within the 14-day experimental period. Rettich (1999) reported the laboratory efficacy of LPOS baits and secondary poisoning effects when tested against three species of cockroaches (*Blattella germanica*, *Blatta orientalis* and *P. americana*).

During the first field trial, a total of 816 cockroaches were trapped and composed of seven species: *P. americana*, *P. brunnea* (Brown cockroach), *P. australasiae* (Australian cockroach), *Neostylopyga rhombifolia* (Harlequin cockroach), *Supella longipalpa* (Brown-banded cockroach), *Nauphoeta cinerea* (Lobster cockroach) and *Symploce pallens* (Smooth cockroach) (Table 2).

Table 1. Laboratory performance of 1% lithium perfluorooctane sulfonate (LPOS) and 0.5% chlorpyrifos in bait stations against three *Periplaneta* species.

Active ingredient	Species	Stage/sex	*n*	LT_{50} (95% CI)	Slope±SE	χ^2 (df)
1% LPOS	*P. americana*	male	50	1.9 (1.5–2.3)	2.6±0.4	1.1 (5)
		female	50	1.2 (0.6–1.8)	1.3±0.3	1.4 (7)
		nymph	100	4.4 (3.6–5.2)	1.3±0.2	1.1 (9)
	P. brunnea	male	50	1.5 (0.9–2.0)	1.9±0.3	0.7 (6)
		female	50	2.0 (1.2–2.5)	2.7±0.6	1.3 (4)
		nymph	100	1.4 (0.9–1.9)	1.3±0.2	3.4 (8)
	P. australasiae	male	50	1.0 (0.6–1.3)	2.9±0.6	0.3 (3)
		female	50	0.7 (0.4–0.9)	3.6±0.6	4.5 (4)
		nymph	100	1.4 (0.7–1.9)	2.3±0.3	6.9 (4)
0.5% chlorpyrifos	*P. americana*	male	50	0.7 (0.5–0.9)	3.0±0.5	0.2 (3)
		female	50	0.9 (0.7–1.2)	3.1±0.5	1.2 (3)
		nymph	100	1.2 (1.0–1.3)	3.6±0.3	2.8 (4)
	P. brunnea	male	50	0.8 (0.7–1.0)	3.5±0.6	0.6 (3)
		female	50	1.2 (0.9–1.4)	3.1±0.4	1.3 (3)
		nymph	100	1.8 (1.6–2.1)	2.9±0.2	1.6 (5)
	P. australasiae	male	50	0.7 (0.6–0.9)	3.7±0.5	1.2 (6)
		female	50	1.0 (0.7–1.2)	2.5±0.3	2.2 (5)
		nymph	100	1.6 (1.3–1.9)	3.0±0.4	1.3 (8)

Table 2. Species composition of cockroaches trapped in low-income suburban homes and apartments.

Species sex/stage	No. cockroaches trapped (%)	
	Low-income houses	Low-income apartments
Periplaneta americana (total)	657 (80.5)	996 (92.0)
Males	94	141
Females	89	110
Nymphs	474	745
Periplaneta brunnea (total)	33 (4.0)	60 (5.6)
Males	4	7
Females	11	10
Nymphs	18	43
Periplaneta australasiae (total)	53 (6.5)	—
Males	11	—
Females	5	—
Nymphs	37	—
Neostylopyga rhombifolia	21 (2.6)	5 (<0.3)
Males	2	1
Females	6	—
Nymphs	13	4
Supella longipalpa	40 (4.9)	22 (2.1)
Nauphoeta cinerea	1 (<0.01)	—
Symploce pallens	11 (1.4)	—
Total	816 (100)	1,083 (100)

The American and the Australian cockroaches were the predominant species (about 87% of total cockroaches trapped). Trapped nymphs (overall) were higher than the adults, with an adult to nymph ratio of 1 : 2.6 in the American cockroach. In the second trial (apartment units), a total of 1,083 cockroaches were trapped. The American cockroach was the predominant species encountered (about 92% of the trap catch). The Australian cockroach, which was commonly found in the first site was not present in the second study, possibly due to lack of vegetation in the study site. The results obtained corresponded well with those reported by Lee et al. (1993) and Lee and Lee (2000a).

Field efficacy studies on LPOS baits demonstrated that LPOS- and chlorpyrifos baits reduced >85% of cockroach trap counts within the first two weeks post-treatment. At the 12th week post-treatment, LPOS still provided >95% reduction of cockroach trap counts; however in houses treated with chlorpyrifos baits, a reduction of 75% was achieved. The results obtained were far superior than those reported earlier by Milio et al. (1986)

Table 3. Percentage reduction of cockroach trap counts upon treatment with 8 LPOS or chlorpyrifos-based bait stations in the field.

Active ingredient	Mean pre-treatment count[1]±SEM	*n*	% reduction±SEM at n^{th} weeks after bait treatment[2]			
			1	2	6	12
1% LPOS	19±4	12	97.0± 1.9a	95.3± 2.4a	98.6± 1.0a	99.2± 0.8a
0.5% chlorpyrifos	13±2	12	88.3± 5.0ab	86.9± 6.3a	95.2± 2.6ab	75.4± 9.6ab
Blank (control)	11±1	6	31.0±20.6b	6.0±30.4a	6.3±30.4a	−76.6±59.8b

[1] There is no significant difference between pre-treatment counts in houses chosen for LPOS, chlorpyrifos and control treatments.

[2] Mean values followed by different letters within the same column are significantly different ($P<0.05$; Kruskal-Wallis multiple comparison).

Table 4. Percentage reduction of cockroach trap counts upon introduction of different bait numbers of LPOS bait station.

Bait number	Mean pre-treatment count[1]±SEM	*n*	% reduction±SEM at n^{th} weeks after bait treatment[2]			
			1	2	6	12
0 (control)	13±1	9	42.2±13.0a	29.4±12.3a	32.8±17.0a	−4.3±13.3a
2	15±3	9	59.5±10.2abc	85.4± 4.4ab	71.7± 8.2ab	33.2± 8.2ab
4	19±4	9	94.2± 3.0bc	95.1± 2.3ab	76.0± 8.7ab	61.3±12.6b
8	12±1	5	97.6± 1.7c	99.3± 0.7b	91.0± 3.4b	74.5± 9.9bc

[1] There is no significant difference between pre-treatment counts in houses chosen for LPOS, chlorpyrifos and control treatments.

[2] Mean values followed by different letters within the same column are significantly different ($P<0.05$; Kruskal-Wallis multiple comparison).

for hydramethylnon bait performance. Alternatively, Patterson and Koehler (1989) demonstrated excellent efficacy of two hydramethylnon formulations against *Periplaneta fuliginosa* and other peridomestic species in Florida (>90% suppression at 12 weeks post-treatment). In houses baited with blank baits (control), a 30% increase in cockroach numbers was observed during the first week post-treatment, but the trap counts gradually decreased. At the 12th week post-treatment, an increase of 77% in trap counts was recorded (Table 3).

At the tenth week post-treatment, four and three bait stations in each treatment and control houses, respectively, were inspected to determine bait consumption and to inspect for the presence of decay organisms on the bait. A total of 33 LPOS, 37 chlorpyrifos and 18 control bait stations were inspected, sealed and then placed back to their original locations. Chlorpyrifos baits were consumed more than the LPOS baits, however LPOS can generally qualify as a better active ingredient in baits because it gave a higher reduction in trap counts than chlorpyrifos up to 12 weeks post-treatment. Control baits were well-consumed by the cockroaches (about 72% of the baits inspected were completely consumed). More than 70% of both LPOS- and chlorpyrifos baits inspected were observed to have mold growth, under these very high humidity conditions. The presence of mold/fungus could reduce bait palatability and even repel cockroach feeding, thus reducing the performance of the bait (Reierson and Rust, 1992).

In field studies examining the effects of bait numbers and sanitation, pre-treatment trap counts in apartments with different treatments assigned did not differ significantly among the different levels of bait treatment. Mean pre-treatment trap

Table 5. Relationship between LPOS bait performance against *P. americana* at 1-week post-treatment and sanitary rating under different bait numbers.

Bait number	$y = mx + c$ (= % reduction)[1]		p	r^2
	m	c		
2	36.1±3.0	−24.8±7.3	0.005	0.694
4	8.7±0.8	74.8±1.8	0.008	0.664
8	1.9±1.4	93.5±1.8	0.453	0.083

[1] y, % reduction; x, sanitary rating ($1 \leq x \leq 3$).

counts ranged from 12.0 to 18.3 cockroaches per night. At day 1 and 2 post-treatment, visual counts of dead and moribund cockroaches were positively correlated with bait placement numbers. At 1 week post-treatment, houses treated with 4 and 8 bait stations showed significant decline ($P < 0.05$) in trap counts as compared to those of the control (Table 4). Although good control was achieved with more than 85%, there was no significant difference ($P > 0.05$) in trap counts in houses treated with 2 and 4 bait stations versus that of the control at the 2nd week post-treatment. This may indicate that more bait numbers were needed to achieve a longer period of control. Houses treated with 8 bait stations still showed a reduction of >70% in trap counts after the 12th week post-treatment. In addition, we also found that both 4 and 8 bait stations provided good performance against adult cockroaches; however, eight bait stations per house was needed to achieve acceptable control of nymphs. Houses treated with 2 bait stations showed reductions in cockroach counts up to 1 week post-treatment only; shortly thereafter, reduction in trap counts gradually decreased.

Sanitation ratings in apartments were found to be moderately, but positively correlated with % reduction in trap counts at 1-week post-treatment in houses treated with 2 and 4 baits ($r^2 = 0.66$ to 0.69; Table 5). However, a significant correlation between the two parameters was not observed in apartments treated with 8 bait stations ($r^2 = 0.083$; Table 5). This may imply that in order to achieve good control with lower bait numbers, good sanitation levels are required; however, more baits can negate the effects of poor sanitation on bait performance. Similar observation had been reported when baiting populations of household ants, *Monomorium* spp. (Lee, 2002).

Summary

Lithium perfluorooctane sulfonate baits are effective against the American cockroach and other peridomestic species tested in this study. Laboratory evaluations of the bait demonstrated superb efficacy against three species of *Periplaneta* (LT_{50} of ≤2 days, with exception to American cockroach nymphs). Excellent control of cockroaches (>95% reduction) was achieved up to 12th week post-treatment in low-income houses and >70% reduction in low-income apartments. Four to eight baits were needed to achieve quick control of cockroach populations (usually about 90% within the first week of post-treatment), and the effects of sanitary condition can be negated by higher numbers of bait placement.

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