Available Online at ESci Journals
International Journal of Entomological Research
ISSN: 2310-3906 (Online), 2310-5119 (Print)
http://www.escijournals.net/IJER

LABORATORY EVALUATION OF TRANSFER EFFECT OF TERMITICIDES AS A SLOW-ACTING TREATMENT AGAINST SUBTERRANEAN TERMITE *COPTOTERMES GESTROI* (ISOPTERA: *RHINOTERMITIDAE*)

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A B S T R A C T

Termiticides containing fipronil, imidacloprid and indoxacarb were examined to cause the mortality among the donor termites (exposed to termiticides) to recipient termites (unexposed to termicides) of *Coptotermes gestroi*. The results showed that fipronil killed the donor termite faster compared to indoxacarb and imidacloprid. At 100 and 1000 ppm, fipronil caused high mortality on termite *C. gestroi* on the third day for both concentrations where the mortality was 100%. The range of the mean percent mortality of recipient termites was different compared to the range of mean mortality of donor termites. The results show that the range of the mean mortality for recipient termites were from 0.35 to 16.05 for imidacloprid, 4.5 to 39.6 for fipronil and 4.2 to 15.75 for indoxacarb. As for the donor termites, the range of the mean mortality was 0.7 to 2.5, 1.8 to 4.75 and 0.85 to 2.95 for imidacloprid, fipronil and indoxacarb respectively.

Keywords: *C. gestroi,* donor, recipient, transfer effect, non- repellent termiticide.

INTRODUCTION

Subterranean termite *C. gestroi* is considered as a pest species in South East Asia and Brazil and causes a lot of damages in these countries (Kirton and Brown 2003; Costa-Leonardo *et al.,* 2004). Presently, new generation of termiticides which contain imidacloprid, fipronil and indoxacarb as their active ingredients are used as soil-applied or by direct injection in the colony and posed lethal effects to subterranean termite (Ramakrishna *et al.,* 2000; Osbrink 2001; Kamble and Davis 2005; Hu *et al.,* 2005). The advantages of these new termiticides are slow-acting and non-repellent. Thus, termites cannot detect these termiticides when applied in to the soil or when used on filter paper in the laboratory. The transfer effect of imidacloprid (Premise 200 SC), fipronil (Agenda 2.5 EC) and indoxacarb (Steward) was studied by researchers and results showed that the termites were able to transfer the termiticides from the treated termites (donors) to the untreated termites (recipients) (Ferster *et al.,* 2001; Kard, 2001; Throne and Berisch, 2001; Delgarde and Lefervre, 2002; Parman and Vargo, 2005; Tomalski and Vargo, 2005; Hu *et al.,* 2005; Shelton *et al.,* 2006). The objective of this study is to evaluate the transfer effect of non-repellent termiticides containting imidacloprid, fipronil and indoxacarb among subterranean termite, *C. gestroi* and to compare the transfer effect of different concentrations from the exposed termites to the unexposed termites.

MATERIALS AND METHODS

Subterranean termite collection: The Subterranean termites *C. gestroi*, were collected from the underground monitoring stations which were established around the Universiti Sains Malaysia (USM) Campus, Penang, Malaysia. Pine stakes (*Pinus caribae)*, (2.5 x 2.5 x 15 cm) were used and placed in the hollow plastic containers (16 x 18 cm) as baits. These plastic containers were buried at a depth of 15cm below the ground. After stakes were infested for 7-14 days (depending on colony activity), infested stakes were brought back to the Entomology laboratory. Termites were removed from stakes as described by Tamashiro *et al.* (1973). Healthy and active third nymph instars of

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C. gestroi were chosen for the study.

Blue termite: Approximately 1000 workers were stained with 0.1 % (wt/wt) Nile Blue A, by forced feeding of stained filter paper (Whatman No.1, 9.0cm diameter) for 4-7days. Termites were removed from the blue filter paper as described by Tamashiro *et al.* (1973). These blue termites were identified as the donors. While approximately 1250 termite workers untreated (unexposed) termites were used as recipient termites for each termiticide. A total 3750 recipient termites were used workers for all termiticides.

The treated filter paper: The filter papers were treated with several concentrations (1, 10, 100 and 1000 ppm) with Premise® SC 200 (active ingredient: imidacloprid 18.3% wt/wt), Agenda™ 2.5 EC (active ingredient: fipronil 2.92%wt/wt) and Steward (active ingredient: indoxacarb 14.5% w/w). Blue termites were directly introduced into a Petri dish and allowed to crawl and feed on to the treated filter paper for 4h under laboratory condition at 28.0-29.0 ± 2.0ºC and 65-70% relative humidity.

Donor and Recipient: Ten blue termites (donor) were removed and reintroduced into a new Petri dish of untreated filter paper containing fifty untreated termite workers (recipient termites), Each concentration was replicated five times. This method was described by Hu *et al.* (2005). Daily observations on % mortality were recorded every 24h for six days. The percentage mortality data were subjected to arc-sine transformation before analysis of variance and means were separated with Tukey HSD test at 95% confidence limit. Recipient (untreated) termite mortality was used as evidence to ascertain that the transfer of lethal concentrations of termiticides occurred among termites.

Analysis of High Performance Liquid Chromatography (HPLC): HPLC (JASCO PU–1580) was used to prove termiticides transfer by using C18 column and mobile phase consisting of an acetonitrile-water mix (80:20) and with different wavelengths of chemical material.

HPLC solutions: After 24h, some donor and recipient termites were taken out of the Petri dish. Then each group of donor and recipient termites were placed in separate test tubes. They were washed by adding 10 ml of distilled water in those test tubes. The water was filtered by using Whatman 0.90mm filter paper which was introduced into glass vial connected to test tube as described by Shelton *et al.* (2006). This solution was transferred to a small bottle (20ml) and then 25 µl of each concentration as well as 25 µl of the standard solution were injected into the HPLC system.

HPLC method analysis: C_{18} column (5µm, 25cm x 4.6mm.i.d.) used was described by Hainzl and Casida (1996). The mobile phase consisted of acetonitrile – water 80:20, v/v at a flow rate of 1.5 ml/min. Sample injection volume was 25µl as described by Baskaran *et al.* (1999). The wavelength used for each termiticide was 270 nm for imidacloprid, (Baskaran *et al.,* 1999), and 290 nm for fipronil (Hainzl and Casida, 1996). Initially, the standard solutions were run in the HPLC system, followed by donor washes and recipient washes respectively. This experiment was replicated three times for each concentration.

RESULTS AND DISCUSSION

Termiticides effects on donor termite: Significantly termite mortality occurred among the donor termites which were directly exposed to the termiticides as compared to unexposed termites (control treatment) (Table 1). The results showed that fipronil (Agenda) termiticide killed the donor termite faster than indoxacarb and imidacloprid. At 100 and 1000 ppm, fipronil caused high mortality on termite *C. gestroi* on the third day for both concentrations where the mortality was 100%. In comparison to imidacloprid and indoxacarb at 100 and 1000ppm, the mean mortality on the third day was 3.2 % and 3.4 % for indoxacarb, respectively and 4.2 % and 0.0 % for imidacloprid, respectively. It was observed that all fipronil concentrations achieved 100% mortality on the fourth day, while for imidacloprid and indoxacarb, the 100% mortality were observed on the sixth day. Thus, imidacloprid and indoxacarb concentrations were slower than fipronil to kill the termites.

The mean mortality of fipronil was significantly different among all concentrations. For 1 ppm the mean mortality was 2.6, 3.2, 4.2, while for 10 ppm was 3.6, 3.4, and 3.0 and for 100 ppm was 5.0, 5.0, and 0.0 for the first three days respectively. At 1000 ppm, it was highly significant for the first and second days. These results showed that fipronil termiticide was quicker in transferring the effect than imidacloprid which the mean mortality of termite at 1000ppm on the first day was 2.8 and 3.2 for indoxacarb. As shown in Table 1, there are significant differences between the means of the donor termite mortality during the first four days for imidacloprid and indoxacarb concentrations.

Table 1. Daily mean mortality of donor termites treated with several termiticides at various concentrations.

Termiticide	Conc.	1				2				3				4				5				6			
Imidacloprid	0	0.0	±	0.00	a	0.4	±	0.24	a	1.4	±	0.24	a	3.4	±	0.2	a	3.0	±	0.4	b	1.8	±	0.37	b
	1	0.0	±	0.00	a	0.6	±	0.24	a	2.6	±	0.24	b	4.0	±	0.3	ab	2.8	±	0.6	b	0.0	±	0.00	a
	10	1.4	±	0.24	b	2.4	±	0.50	b	3.4	±	0.40	bc	2.8	±	0.4	bc	0.0	±	0.0	a	0.0	±	0.00	a
	100	1.8	±	0.48	b	2.6	±	0.24	b	4.2	±	0.37	bc	1.4	±	0.9	c	0.0	±	0.0	a	0.0	±	0.00	a
	1000	2.8	±	0.37	c	4.0	±	0.70	c	0.0	±	0.00	c	0.0	±	0.0	c	0.0	±	0.0	a	0.0	±	0.00	a
Fipronil (A)	0	0.4	±	0.24	a	0.2	±	0.20	a	0.2	±	0.20	a	0.2	±	0.2	a	0.4	±	0.2	a	0.4	±	0.24	a
	1	2.6	±	0.24	b	3.2	±	0.37	bc	4.2	±	0.48	c	0.0	±	0.0	a	0.0	±	0.0	a	0.0	±	0.00	a
	10	3.6	±	0.24	c	3.4	±	0.50	c	3.0	±	0.31	b	0.0	±	0.0	a	0.0	±	0.0	a	0.0	±	0.00	a
	100	5.0	±	0.31	d	5.0	±	0.31	d	0.0	±	0.00	a	0.0	±	0.0	a	0.0	±	0.0	a	0.0	±	0.00	a
	1000	7.8	±	0.37	b	2.2	±	0.37	b	0.0	±	0.00	a	0.0	±	0.0	a	0.0	±	0.0	a	0.0	±	0.00	a
Indoxacarb	0	0.0	±	0.00	a	0.4	±	0.24	a	0.4	±	0.24	a	0.4	±	0.2	a	0.8	±	0.4	b	0.4	±	0.24	a
	1	0.0	±	0.00	a	1.8	±	0.37	b	2.4	±	0.24	b	2.4	±	0.2	c	3.4	±	0.2	c	0.0	±	0.00	a
	10	1.6	±	0.40	b	2.2	±	0.20	b	2.8	±	0.20	bc	3.4	±	0.4	d	0.0	±	0.0	a	0.0	±	0.00	a
	100	2.2	±	0.37	b	3.2	±	0.20	c	3.2	±	0.20	bc	1.4	±	0.4	b	0.0	±	0.0	a	0.0	±	0.00	a
	1000	3.2	±	0.37	c	3.4	±	0.24	c	3.4	±	0.40	c	0.0	±	0.0	a	0.0	±	0.0	a	0.0	±	0.00	a

*Means within each column followed by the same letter are not significantly different (Tukey HSD, $p < 0.05$).

Table 2. Mortality and survival percentages of donor termite.

		Mortality and survive percentage (%)											
Termiticide	Concentration	1day		2 days		3 days		4days		5days		6days	
		M	S	M	S	M	S	M	S	M	S	M	S
Imidacloprd	0	0.0	100	4.0	96	0.0	96	0.0	96	2.0	94	0.0	94
	1	0.0	100	6.0	94	38	56	44	12	12	0.0	100	0.0
	10	14	86	34	52	38	14	14	0.0	100	0.0	100	0.0
	100	18	82	34	48	30	18	18	0.0	100	0.0	100	0.0
	1000	28	72	40	32	32	0.0	100	0.0	100	0.0	100	0.0
Fipronil (A)	0	0.0	100	0.0	100	4.0	96	0.0	96	0.0	96	2.0	94
	1	26		28	46	42	4.0	4.0	0.0	100	0.0	100	0.0
	10	36	64	34	30	30	0.0	100	0.0	100	0.0	100	0.0
	100	50	50	50	0.0	100	0.0	100	0.0	100	0.0	100	0.0
	1000	78	22	22	0.0	100	0.0	100	0.0	100	0.0	100	0.0
Indoxacarb	0	20	98	0.0	98	0.0	98	4.0	94	0.0	94	0.0	94
	1	18	82	24	58	24	34	34	0.0	100	0.0	100	0.0
	10	16	84	22	62	28	34	34	0.0	100	0.0	100	0.0
	100	22	78	32	46	32	14	14	0.0	100	0.0	100	0.0
	1000	32	68	34	34	34	0.0	100	0.0	100	0.0	100	0.0

M = Mortality. S = survival

Generally, the mean mortality of donor termite exposed to the 10 and 100 ppm imidacloprid concentrations were not significantly different in the first three days which were 1.4, 2.4, 3.4 and 1.8, 2.6, 4.2 respectively. However it was significantly different with 1000 ppm on those days. The results obtained for the mean mortality of imidacloprid and indoxacarb at 1 ppm for the first day to the third day were 0.0, 0.6, 2.6 and 0.0, 1.8, 2.4 respectively (Table 1). As a result, at low concentrations of 1 and10 ppm, there were no significant differences between the mean mortality of imidacloprid and indoxacarb. There was a linear correlation between the concentration and termite mortality at low concentrations (1 and 10 ppm). This indicates that the mortality of termite *C. gestroi* consistently increases when concentration increases. While at high concentrations (100 and1000 ppm), the relationship was different; imidacloprid was linear while fipronil and indoxacarb were non-linear correlation.

These results showed that fipronil was more toxic and caused high mortality to termite *C. gestroi* compared to other concentrations. The results in Table 2 show a linear relationship between time and percent mortality of donor termite *C. gestroi*. fipronil concentrations at 100 and 1000ppm have 100% mortality on the second day. For imidacloprid, the termites mortalities were 34% and 40% and indoxacarb have 32% and 34% mortalities for the two concentrations (100 and 1000 ppm). Consequently, the percentage mortality of the donor termite at 10 ppm in the first three days were 14.0, 34.0, 30 for imidacloprid and 16.0, 22.0, 28 for indoxacarb respectively. It was different with fipronil as high percentage of mortality was observed in the first day. The effect of imidacloprid and indoxacarb on donor termite was slower than fipronil, thus the high percentage of mortality was observed in fipronil. The observations on donor termites *C. gestroi,* after treatment indicated that the social behaviour of termite such as feeding, walking, moving, grooming and throphallaxis changed with imidacloprid treatment which was similar to what Rust and Saran (2006) reported for Chlorfenapyr. This change in social behaviour started after 3 to 5h for high concentrations (100 and 1000 ppm). While with low concentrations, the change started after 10 to 20 hours. The change which occurred includes stopped feeding, very slow walking, individual separation, sticky liquid material coming out from the abdomen, and inability of grooming. In some cases, termite workers ate the legs and abdomen or mouth of other termites. However, with fipronil and indoxacarb, these changes in social behavior were not observed

Recipient termite mortality: The range of the mean mortality of recipient termites was different compared to the range of mean mortality of donor termites. The results in Table 3 show that the range of the mean mortality for recipient ranged from 0.35 to 16.05 for Imidacloprid, 4.5 to 39.6 for fipronil and 4.2 to 15.75 for indoxacarb. As for the donor termites, the range of the mean mortality was 0.7 to 2.5, 1.8 to 4.75 and 0.85 to 2.95 for Imidacloprid, fipronil and indoxacarb respectively. The difference in the range of the mean mortality occurred probably due to some factors such as the different number of donor and recipient termites, the method of termiticide exposure and the time of exposure.

Generally, when the treatments were compared with control treatment (untreated), results showed that there were significant differences of recipient termite mortality. This difference in the recipient mean mortality explains that the termiticides were transferred from donor termites to the recipient termites is due to the transfer effect of the termiticides as seen in Shelton *et al.* (2006) when Chlorfenapyr was used in the laboratory to test transfer effect among workers of *Reticulitermes flavipes*. Shelton and Grace (2003) works on imidacloprid and fipronil termiticides also indicated that the transfer of these non-repellent termiticides occurred between the donor and the recipient termites. However, the results of the mean mortality of recipient termite in the first day showed no significant differences between control treatment and 1 ppm for indoxacarb and 1, 10 and 100ppm for imidacloprid. The results of 1ppm for fipronil and imidacloprid concentration was similar to that of Shelton and Grace (2003) which indicated that the donor termites exposed to the 1ppm of either termiticides did not successfully transferred lethal concentration to the recipient termites. In the second day, 1 ppm imidacloprid still did not show any significant different with control treatment. This is probably due to the amount of imidacloprid as the concentration was insufficient to be transferred from donor to recipient termites. Thus, there wasn't high mortality on recipient termite *C. gestroi*. This effect of low concentration of termiticide is beneficial for controlling termites by baiting, but the concentration used must be > 1ppm as Shelton and Grace (2003) indicated. This low concentration is important because

the time which the donor termites take to transfer the termiticide to other termites was long enough. This result was in agreement with Rust and Saran (2006). The longer time increases the chance to contaminate more recipient termites and ultimately eliminate the termite colony in the area.

For fipronil, results showed that there were significant differences among treatment. fipronil concentrations were highly toxic compared to other termiticide concentrations. This is similar to Kaakeh *et al.* (1997) results when fipronil was used to control German cockroach. The high mortality of the recipient termites comes from fipronil termiticide. The other point about this termiticide was the quick transfer effect from the donor termites to the recipient termites. fipronil effect was faster than imidacloprid on the termites mortality and these results were similar to those indicated by Ibrahim *et al.* (2003) for controlling termites. Furthermore, the results were in agreement with Buczkowski and Schal (2001) to control the German cockroach.

The high mortality of recipient termites when mixed with donor termites at 1000 ppm fipronil was 51.2% on the second day (Table 4). This concentration caused the highest mortality for recipient termite and significantly different compared to the other concentrations. This may be due to the high amount of termiticides being transferred compared to the other concentrations. The observation which recorded that the effect of this concentration (1000 ppm) was high for fipronil and indoxacarb was similar to that of Hu (2005). The data in Table 3 show that for high concentrations of imidacloprid, the mean mortality was low for donor and recipient termites compared with fipronil and indoxacarb. This different on the mean mortality may be due to the Imidacloprid toxicity was a slow in effect than other termiticides and termite *C. gestroi* can transfer this termiticide from donor to recipient by contact or by grooming or trophallaxis and this transfer may be take long time. After treatment of the donor and recipient termite, it was observed that the change of the termite social behaviour (feeding, movement, grooming, walking and trophallaxis) was taken a longer time in recipient than donor termite. This is may be due to the recipient termite were exposed indirectly to the termiticides, thus the change in social behavior took a long time to occur specially with low concentration 1ppm.

The relationship between concentrations, mean mortality and time: The relationship between termiticide concentrations and recipient termite mortality can be clearly seen from the data in Table 3. This relationship can be divided into two groups; the low concentrations and high concentrations. With low concentrations, the correlation was almost linear for 1 and 10 ppm for imidacloprid and indoxacarb Table 3. In accordance with Su *et al.* (1987), this linear relationship indicated that the mean mortality of the recipient termites increased when concentrations increased. With fipronil concentrations, the relationship was not linear. Interestingly, there was no difference in the recipient termite mean mortality between 1 ppm and 10 ppm for fipronil. Consequently, any one of the two concentrations gave almost similar results. This means that fipronil concentration can affect at low concentrations and there is no need to use a high concentration to control termites. With high concentrations, the relationship was still linear with imidacloprid and indoxacarb until Day 3 and Day 4, respectively. Thus, higher concentrations led to higher recipient termites mortality as compared to lower concentrations. This is in agreement with Hu (2005). So, when we use any termiticide to control termites, it is important to know the effective concentration which can be transferred from donor termites to recipient termites. The transfer effects were proven by using HPLC technique. The termite, *C. gestroi* has the ability to transfer non-repellent termiticide to the other termite workers and as a result causes mortality. Figures 1 to 5 showed that the rotation time for the peaks of donor termite, recipient termite and the standard solution of the termiticide were almost the same. This means that the transfer effect occurred successfully between donor termites to the recipient termites in this study and as reported by Thorne and Berisch (2001). The percentage of recipient mortality after two days was obvious with all concentrations. At a high concentration (1000 ppm), percentage mortality increased to 22, 37.2 and 51.2 for imidacloprid, indoxacarb and fipronil, respectively on the second (Table 4). Thus, the range of percentage mortality of recipient was different among the termiticides at the same concentration. For imidacloprid (100 ppm), the percentage mortality of recipient ranged from 2 to 35.2% from 1day to the 4day and from 17.6 to 43.6% for fipronil from 1 day to the 3 day at 100 ppm. The result for imidacloprid was different than the result of Shelton and Grace (2003) which was ≈ 29 to 50% for the same concentration. However the result of fipronil was similar to the result of Shelton and Grace (2003) with the same

Table 3. Daily mean mortality of recipient termites mixed with donor termites.

Termiticide	Conc.	1				2				3				4				5				6			
Imidacloprid	0	0.0	±	0.0	a	0.6	±	0.40	a	0.60	±	0.24	a	1.40	±	0.24	a	0.80	±	0.20	a	0.80	±	0.37	a
	1	0.0	±	0.0	a	1.0	±	0.31	a	4.80	±	0.37	b	7.20	±	0.58	b	9.20	±	0.73	b	11.8	±	0.58	b
	10	0.0	±	0.0	a	5.8	±	0.66	b	10.0	±	0.50	c	14.0	±	0.92	c	16.4	±	1.30	d	4.60	±	0.81	c
	100	0.4	±	0.24	a	7.4	±	0.92	b	11.0	±	0.67	c	17.0	±	0.92	d	12.0	±	1.16	c	0.80	±	0.58	a
	1000	1.0	±	0.31	b	7.4	±	0.60	b	15.0	±	0.97	d	26.0	±	0.37	e	0.00	±	0.00	a	0.00	±	0.00	a
Fipronil (A)	0	0.2	±	0.44	a	0.4	±	0.24	a	0.40	±	0.24	a	0.40	±	0.24	a	0.20	±	0.44	b	0.2	±	0.44	b
	1	5.6	±	0.50	b	14.2	±	0.48	b	16.4	±	0.81	c	13.8	±	0.86	c	0.00	±	0.00	a	0.0	±	0.00	a
	10	13.4	±	0.60	c	17.8	±	0.80	c	14.4	±	0.87	c	4.40	±	1.30	b	0.00	±	0.00	a	0.0	±	0.00	a
	100	19.4	±	0.90	d	21.8	±	0.96	d	8.80	±	1.20	b	0.00	±	0.00	a	0.00	±	0.00	a	0.0	±	0.00	a
	1000	24.4	±	0.90	e	25.0	±	0.92	e	0.00	±	0.00	a	0.00	±	0.00	a	0.00	±	0.00	a	0.0	±	0.00	a
Indoxacarb	0	0.0	±	0.0	a	0.2	±	0.20	a	0.60	±	0.24	a	0.20	±	0.20	a	0.60	±	0.4	a	0.6	±	0.24	b
	1	0.0	±	0.0	a	5.8	±	0.86	b	11.6	±	1.00	b	15.8	±	1.10	c	16.8	±	0.2	b	0.0	±	0.00	a
	10	5.60	±	0.67	b	12.0	±	1.40	c	17.2	±	1.30	b	15.4	±	2.10	c	0.00	±	0.0	a	0.0	±	0.00	a
	100	12.4	±	1.0	c	15.0	±	1.60	cd	17.4	±	1.60	b	3.20	±	1.40	b	0.00	±	0.0	a	0.0	±	0.00	a
	1000	14.6	±	2.0	D	18.0	±	1.50	D	16.8	±	3.70	B	0.00	±	0.00	A	0.00	±	0.0	A	0.0	±	0.00	a

* Means within each column followed by the same letter are not significantly different (Tukey HSD, $p < 0.05$).

Table 4: Mortality and survival percentage of recipient termite.

		Mortality and survive percentage (%)											
Termiticide	Concentration	1day		2 days		3 days		4days		5days		6days	
		M	S	M	S	M	S	M	S	M	S	M	S
Imidacloprd	0	0.0	100	4.0	96	0.0	96	0.0	96	2.0	94	0.0	94
	1	0.0	100	6.0	94	38	56	44	12	12	0.0	100	0.0
	10	14	86	34	52	38	14	14	0.0	100	0.0	100	0.0
	100	18	82	34	48	30	18	18	0.0	100	0.0	100	0.0
	1000	28	72	40	32	32	0.0	100	0.0	100	0.0	100	0.0
Fipronil (A)	0	0.0	100	0.0	100	4.0	96	0.0	96	0.0	96	2.0	94
	1	26		28	46	42	4.0	4.0	0.0	100	0.0	100	0.0
	10	36	64	34	30	30	0.0	100	0.0	100	0.0	100	0.0
	100	50	50	50	0.0	100	0.0	100	0.0	100	0.0	100	0.0
	1000	78	22	22	0.0	100	0.0	100	0.0	100	0.0	100	0.0
Indoxacarb	0	20	98	0.0	98	0.0	98	4.0	94	0.0	94	0.0	94
	1	18	82	24	58	24	34	34	0.0	100	0.0	100	0.0
	10	16	84	22	62	28	34	34	0.0	100	0.0	100	0.0
	100	22	78	32	46	32	14	14	0.0	100	0.0	100	0.0
	1000	32	68	34	34	34	0.0	100	0.0	100	0.0	100	0.0

M = Mortality. S = survival

concentration which was ≈ 21 to 45%. As for indoxacarb termiticide, the percentage mortality for recipient termites ranged from 10.4 to 34.8% and this result was different from Hu (2005) which was 68 to 100% with 100ng indoxacarb. So, the transfer effect of lethal concentration may occur but in a limited area of foraging termites Figure 1 to 5 showed that termiticides were transferred from donor termite to the recipient termite. This was showed from the rotation time of the donor peak and recipient peak at the same concentration. Figure 1 was showed that the rotation time of donor peak of 1000 ppm imidacloprid was 4.375 min and was the same time as the peak of recipient termite (Figure 2). With same concentration (1000 ppm) but with different termiticide, Figure 3 showed the rotation time which standard peak of fipronil termiticide was 4.455 min, while Figure 5.4 showed that the rotation time of the donor peak was 4.375 min and the recipient peak was 4.458 min. This insignificant different on the rotation time of the standard, donor and recipient peaks was not considered, because there were no other materials injected at the same time. indoxacarb peaks (donor + recipient termite) were shown in Figure 5, which described that the rotation time of donor peak was 1.920 min while the recipient peak was 1.908 min. Results of HPLC technique proved that the termiticides were transferred from donor termite to the recipient termite. Generally, the transfer effect or the transfer of lethal concentration occur successfully at 10 and 100 ppm during termite grooming or by trophallaxis in the laboratory in this study and as reported by Shelton and Grace (2003).

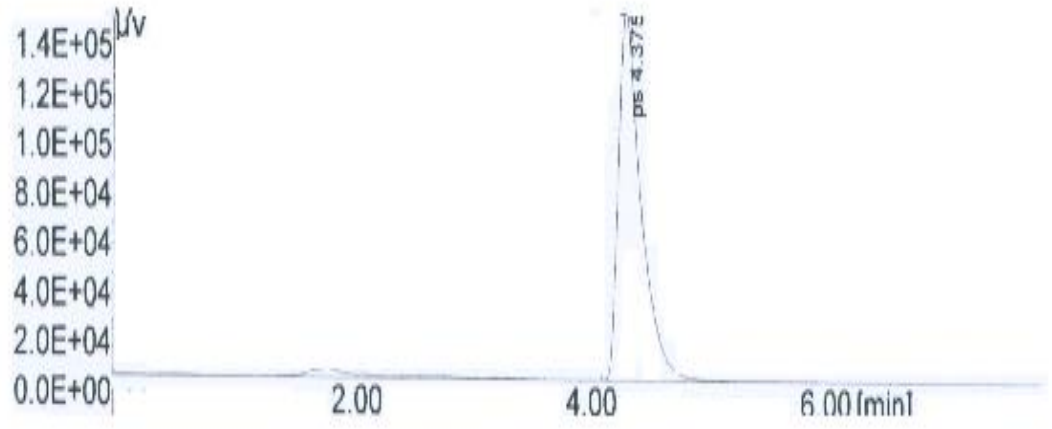

Figure 1. Donor peak of 1000 ppm imidacloprid.

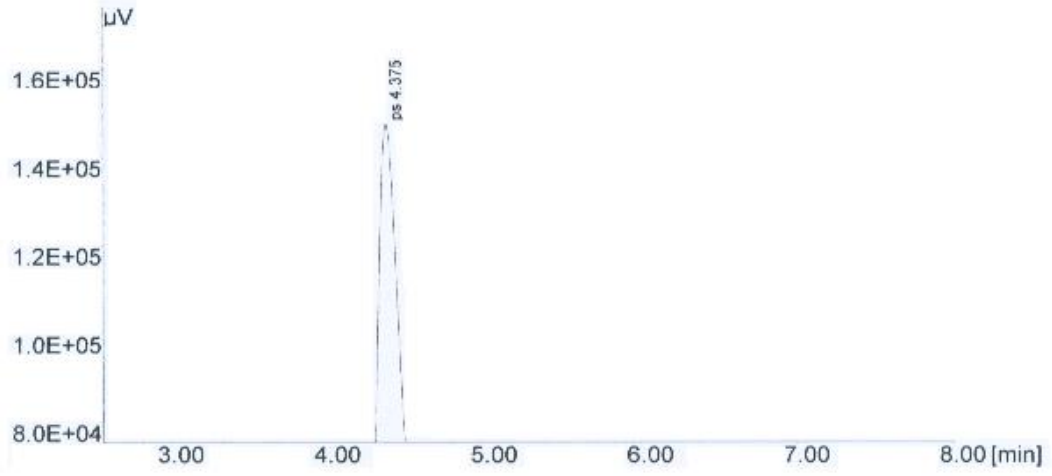

Figure 2. Recipient peak of1000 ppm imidacloprid

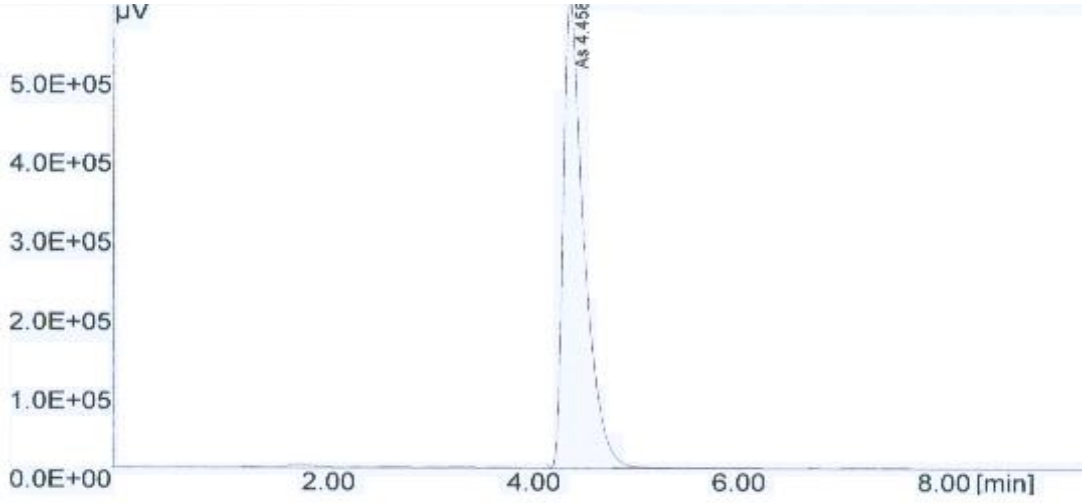

Figure 3. Standard peaks of 1000 ppm fipronil.

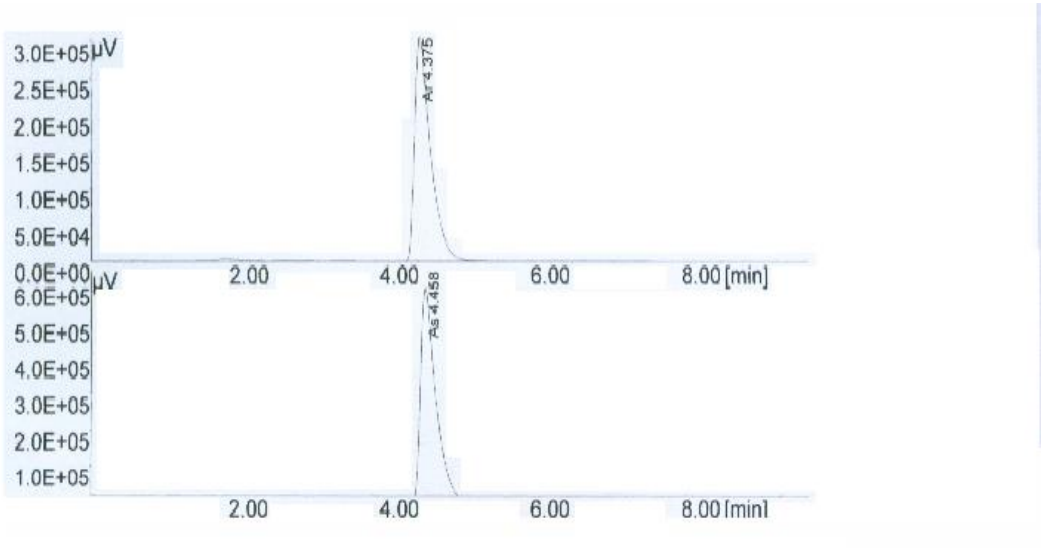

Figure 4. Recipient + donor peaks of 1000 ppm fipronil (A)

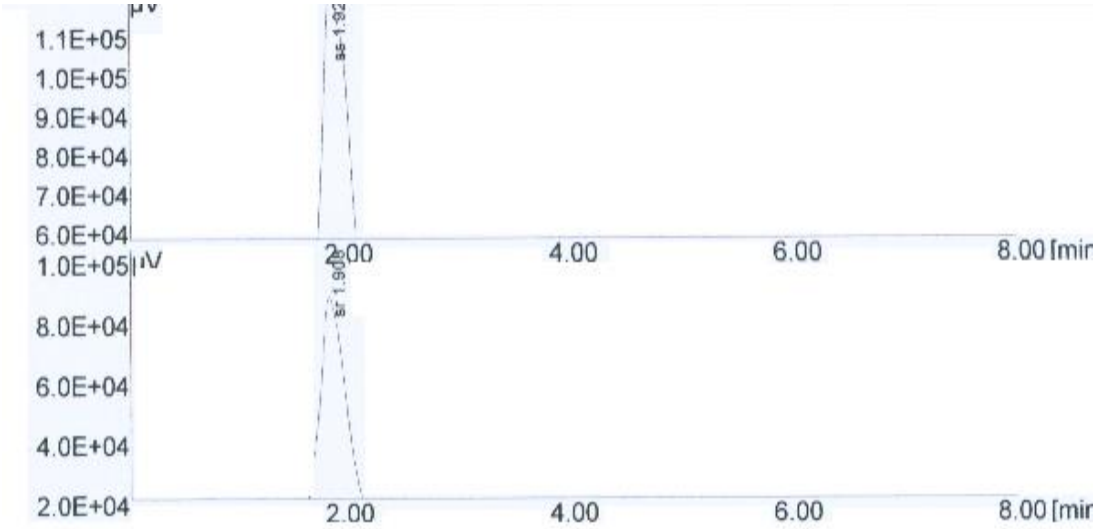

Figure 5. Donor + recipient peaks of 1000 ppm indoxacarb.

In conclusion, the results showed that there were significant differences of recipient termite mortality. These differences implied that the termiticides transferred from donor to the recipient termite. The HPLC results confirmed that assumed hypothesis and the retention time of the recipient peaks were similar to those of the standard and the donor peaks. Additionally, it was concluded that the non-repellent termiticides were transferred successfully from the treated to the untreated termites especially with low concentrations. Thus, it is possible to use low concentrations of the non-repellent termiticide in the field against subterranean termite *C. gestroi.*

ACKNOWLEDGEMENTS

We would like to thank the School of Biological Sciences, Universiti Sains Malaysia (USM) for the facilities provided for doing the research and Bayer Environmental Sciences (Malaysia) for the financial and chemical support. We thank Mr. Hadzri Abdullah for his technical assistance.

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