

Research Article

Excito-repellency and fumigation potentials of chlorpyrifos and cypermethrin against the American cockroach, *Periplaneta americana* (L) (Dictyoptera: Blattodea)

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Abstract

The repellence and fumigation properties of two insecticidal agents, chlorpyrifos and cypermethrin, were tested against the American cockroach, *Periplaneta americana*, in laboratory assays. The insecticides were diluted in acetone and tested against the roaches in predetermined concentrations and in an untreated control. The experimental cages were choice chambers and a non-choice chamber for repellency and fumigation assays, respectively. Both tested insecticides repelled cockroaches in a dose-dependent manner. Chlorpyrifos induced a significantly higher $P < 0.05$ repellence under concentrations 5.0 and 10.0 mg/ml in both sexes of cockroaches. The repellency indexes range between 0.22-0.63 and 0.11-0.66 for male and female, respectively. Chlorpyrifos had moderate repellence indexes (0.50-0.66) while cypermethrin showed lower repellency indexes (0.11-0.36). Cypermethrin induced faster knockdown of KT_{50} and KT_{100} in both sexes of cockroach in the fumigation assay. However, chlorpyrifos produced faster mortality MT_{50} and MT_{100} in both sexes. It was concluded that both insecticides were effective in the control of *P. americana*. However, while chlorpyrifos could double as a repellent and a fumigant, cypermethrin was only effective as a fumigant. Therefore, the modes of application of these insecticides relatively dictate the levels of control they exhibit against this insect pest.

Keywords: Chlorpyrifos, Cypermethrin, Repellency, American Cockroach, Fumigation

1. Introduction

The American cockroach, *Periplaneta americana* (L), is one of the common household cockroach species worldwide and can be found in many human abodes. Originally believed to be a native of Africa, but later introduced to the Americans through human activities in the early 16th century and since then, spread throughout the world (Lin *et al*, 2022). They prefer to live in shady and moist environments, such as urban sewers, where they will gain access to food sources (Bell and Adiyodi, 1982). The spread of cockroach populations in human spaces has resulted in a number of medical and economic issues. Cockroaches are known to be important disseminators of a wide range of infections across geographical boundaries (Qurratul and Abdul Hafiz, 2021). Various pathogenic bacterial, fungi and helminthic worm species have been isolated from cockroaches (Pai *et al*, 2003; Fotedar and Banerjee, 1992; Oriolowo *et al*, 2025). They are linked to respiratory diseases like asthma in humans due to allergies and accidental ingestion or inhalation in children (Stohr *et al*, 2008; Do *et al*, 2016; Celmeli *et al*, 2016).

In Nigeria, the American cockroach is the most common species found in kitchens, restaurants, food preparation areas and living rooms (Maigoro *et al*, 2026). They contaminate human dwellings by defecating and regurgitating partially digested food while feeding. As a result, their presence in hotel kitchens, restaurants and food outlets arouses human disgust and consequently affects the value and revenue of those establishments (Qurratul and Abdul Hafiz, 2021). Apart from this, cockroaches are nuisance pests, and people living or working in cockroach-infested structures do experience psychological stress and social stigma (Brenner, 1995). Personal and public hygiene are the best approaches to limiting cockroach infestation in homes and public places. However, in places where infestation had already occurred, application of insecticides will complement good hygiene practices in eradicating cockroach infestations.

Chemical insecticides remain the most used in the control of cockroach infestation due to their ease of application and effectiveness despite reports of resistance

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development. Several synthetic insecticides have been used in the control of cockroaches; among these are cypermethrin, a pyrethroid, and chlorpyrifos, an organophosphate (Gaire *et al*, 2023; Kemabonta *et al*, 2014). The effectiveness of these chemicals against insect pests is largely determined by their formulation and methods of application, either as contact, residual, aerosols, fumigants or as baits. Despite varying contact/residual potencies, many of them have been reported to possess repellent and fumigatory properties against a variety of insects, including cockroach (Wu and Appel, 2018).

Repellence is a complex phenomenon, as it describes how an insect interacts with chemicals and how it responds after interaction (Gaire *et al*, 2023). Repellency can be classified into five categories (Deletre *et al*, 2016), and the insect physiological detection mechanisms, chemical concentrations, experimental conditions and other variables contribute to the insect's response, making repellence tests unique for every insect (Syed and O'dell, 2022; Deletre *et al*, 2016). Chlorpyrifos and cypermethrin have proved effective as contact, residual or as bait against cockroaches; however, the potencies as repellent and fumigant have not been so much established. Therefore, this study was aimed at testing and comparing the repellence and fumigant potencies of chlorpyrifos and cypermethrin against *P. americana*.

2. Materials and Methods

2.1. Site of the experiment

The culture of the American cockroach, *P. americana*, was maintained in the Zoology Department laboratory, University of Ilorin, Nigeria, where all bioassays were also carried out.

2.2. Insecticides used

The insecticides used, chlorpyrifos under the trade name Pyrinex (480g/litre), and Cypermethrin under the trade name Superthrin (100/litre), were purchased from a registered agrochemical retail store along Murtala Mohammed road, Ilorin, Nigeria. The choice of diluent was water. The concentrations of solutions used were determined by the pesticide manufacturer's labels.

2.3. Insect culture

Adult cockroaches were collected from a residential apartment in Tanke, Ilorin, Kwara State, Nigeria. They were transported to the zoology department of the University of Ilorin. They were reared in a paper carton of dimensions 40 cm x 40 cm x 40 cm at a temperature of 25-28 °C and a relative humidity of 70-80%. The cockroaches were fed with biscuits and water. Newly emerged nymphs were isolated from the colonies and placed in a separate rearing carton, allowed to grow into adults. The experiment was conducted on one-week-old adults of the F1 generation that had been bred under these laboratory conditions. The rearing cage was regularly cleaned by removing cockroach frass and faeces.

2.4. Excito-Repellency Test Chamber

The Excito-Repellency Test Chamber is a choice chamber of dimensions 30 cm x 28 cm x 25 cm with a tightly fitted door of dimensions 15 cm x 10 cm constructed using transparent glass. The chamber was slightly modified from the one described by Luker (2024). At the base of the chamber is a transparent escape passage made of a transparent cylindrical tube of length 50 cm and radius of 2.5 cm connected to a transparent escape chamber of dimensions 20 cm x 15 cm x 10 cm. The escape passage allows irritant cockroaches to exit the repellency chamber into the escape chamber.

2.5. Fumigation Chamber

The fumigant toxicity test reported in this study was carried out as described by Zibae *et al* (2016) with little modifications. A Peety-Grady-like chamber of dimension 40 cm x 40 cm x 40 cm constructed with transparent glass was used. The chamber is a non-choice chamber which allows the insects to be exposed to the insecticide fumes over a period of 90 hours. One side chamber has a tightly fitted door of dimensions 10 cm x 5 cm for introducing the cockroaches into it.

2.5. Repellency Assay

Twenty sexed (10 males and 10 females) randomly selected from the F1 generation adults were introduced into the repellence chamber. 1 ml of acetone containing 10 mg of active insecticide ingredient was subsequently introduced on a cotton wool ball hung within the chamber. 1 ml of acetone was introduced the cotton wool was used for the control experiment. The door of the chamber was immediately shut, and the escape outlet opened. Four replicates were observed for each experiment. The average numbers of cockroaches that escaped the treated chamber through the escape route were recorded after 30 minutes. The percentage repellency was calculated as described by Skeltenkamp *et al* (1992) using the formula:

$$100 - [100 \times (\frac{N_t}{N_t + N_c})]$$

Where N_t is the number of cockroaches in the treated chamber, and N_c is the number in the escape chamber.

Repellency index was determined as described by Ande (2004) using the formula:

$$\frac{N_t - N_c}{N_t + N_c} \times 100$$

The RI value was classified as follows: RI = 1 neutral effect, RI > 1 attracting effect, RI < 1 repellent effect (Ail-Catzim *et al*, 2015)

2.5. Fumigation Assay

One-centimetre cotton ball placed in a petri dish was treated with 1 ml of acetone containing 10 mg of the active insecticide ingredient. To avoid direct contact of the cockroach with the insecticide, it was injected into the centre of the cotton ball using a syringe. Each insecticide-impregnated cotton ball was separately introduced into the fumigation chamber. The control group cotton ball was

injected with 1 ml of acetone. Four replicates were tested for both treatment and control groups. Twenty sexed cockroaches were introduced into the fume chamber. Knockdown and mortality were monitored through the transparent chamber for 90 hours. Mean 100% knockdown time KT_{100} and mean 100% mortality time MT_{100} were recorded for each sex under each insecticide treatment.

2.6. Statistical Analysis

Repelency rate of all treatments, mean knockdown time and mean mortality time were compared using Analysis of Variance (ANOVA) and the means were separated using Fisher's Least Significant Difference (LSD) at $p < 0.05$.

Table 1: Mean Percentage repellence of male cockroaches exposed to insecticides

Insecticides	Conc.(mg/ml)	N	No Repelled	% Repelled	RI
Chlorpyrifos	5.0	20	10.75 ± 1.48^a	53.25 ± 7.36^a	0.51
	10.0	20	15.25 ± 1.30^b	76.25 ± 6.50^b	0.63
Cypermethrin	5.0	20	5.50 ± 1.11^c	27.50 ± 5.59^c	0.22
	10.0	20	7.50 ± 1.12^d	37.50 ± 5.56^d	0.36
Control	-	20	3.50 ± 0.83^e	17.50 ± 5.50^e	-

Values are the mean $\pm$ SD of three observations Means in the same column with the same superscript are not significantly different (ANOVA, $P < 0.05$)

Cypermethrin elicited a relatively lower repellence in cockroaches at both concentrations. However, there was a significant difference ($P < 0.05$) in the number of cockroaches escaping the treated chamber under concentrations of 5.0 and 10.0 mg/ml. All treatments had a repellence index (RI) of less than one ($RI < 1$), which implied both chemicals had repellent properties.

Female cockroaches were also repelled by the two tested insecticide diluents. There was a significant difference ($P < 0.05$) in the number of insects escaping the treated chamber to the untreated chamber under 5.0 and 10.0mg/ml concentrations of chlorpyrifos (Table 2). However, female

3. Results

3.1. Repellence Toxicity

Male American Cockroaches displayed strong directional repellence towards chlorpyrifos and cypermethrin, both in a dose-dependent manner (Table 1). Chlorpyrifos induced a significantly higher number of cockroaches escaping the treatment chamber to the untreated zone of the repellency chambers. There was a significant difference ($P < 0.05$) in the number of male cockroaches repelled towards the untreated chamber under concentrations of 5.0 and 10.0 mg/ml.

cockroaches exposed to 5.0 and 10.0 mg/ml concentrations of cypermethrin did not exhibit any significant difference ($P > 0.05$) in percentage escape from the treated chamber. Generally, male cockroaches were more susceptible to the insecticides. More males escaped the treated chamber under all treatments and concentrations. All treatments had a repellence index of less than one ($RI < 1$). This implies that both chemicals possess repellent properties. Chlorpyrifos had moderate repellence (0.50-0.66) for both sexes and concentrations. Cypermethrin, however, had a lower repellence (0.11-0.36) against both male and female *P. americana*.

Table 2: Mean Percentage repellence of female cockroaches exposed to insecticides

Insecticides	Conc.(mg/ml)	N	No Repelled	% Repelled	RI
Chlorpyrifos	5.0	20	8.00 ± 1.84^a	40.00 ± 9.35^a	0.50
	10.0	20	12.75 ± 1.48^b	63.75 ± 7.34^b	0.66
Cypermethrin	5.0	20	3.25 ± 1.15^c	16.25 ± 4.18^c	0.11
	10.0	20	4.50 ± 1.12^c	22.50 ± 5.50^c	0.26
Control	-	20	2.66 ± 0.81^c	13.30 ± 4.15^{cd}	-

Values are the mean $\pm$ SD of three observationsm. Means in the same column with the same superscript are not significantly different (ANOVA, $P < 0.05$)

3.2. Fumigant Toxicity

Knockdown toxicity of chlorpyrifos and cypermethrin fumes is presented in Figure. 1. It took chlorpyrifos 52 and 80 minutes, respectively, to achieve 50% knockdown in male and female cockroaches. While cypermethrin achieved 50% knockdown in males and females, respectively, after 26 and 28 minutes of exposure to its fume. 100% knockdown in male and female cockroaches treated with chlorpyrifos was

achieved after 85 and 188 minutes, respectively. All male and female cypermethrin-treated cockroaches were completely knocked down after 37 and 44 minutes, respectively. It generally took female cockroaches a significantly longer period before they experienced knockdown. Cypermethrin fume is more effective than chlorpyrifos as a knockdown agent against cockroaches, irrespective of sex. In all the tested insecticides, knockdown was usually preceded by agnostic behaviour such as hypersensitivity, wing flecking and grooming.

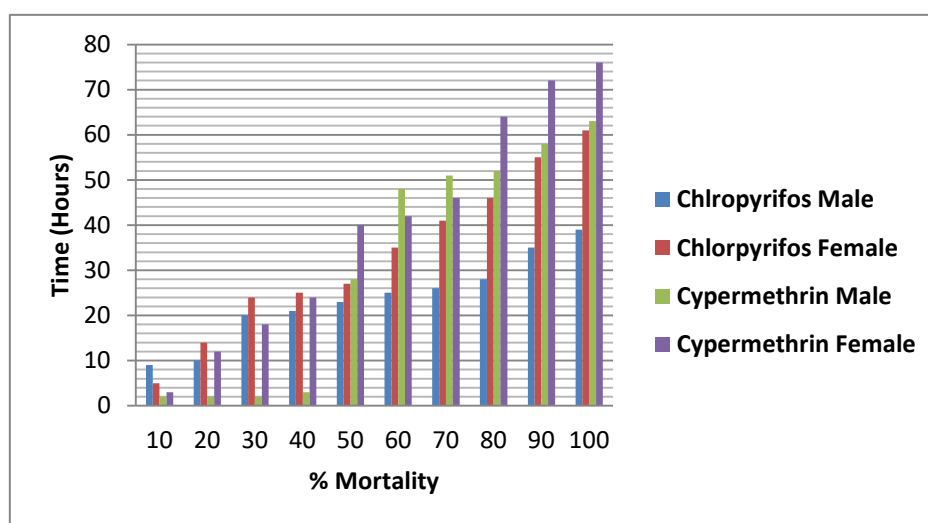


Figure 1. Progressive knockdown time of sexed cockroaches exposed to fumes of chlorpyrifos and cypermethrin.

Figure 2. shows the percentage mortality of cockroaches exposed to fumes of the tested insecticides. It took 23 and 27 hours, respectively, for male and female cockroaches to die under chlorpyrifos treatment. Cypermethrin fume killed 50% of male and female cockroaches, respectively, after 28 and

40 hours. 100% mortality was achieved after 39 and 68 hours, respectively, in males and females of cockroaches treated with chlorpyrifos. However, 100% mortality was achieved after 63 and 76 hours, respectively, in cockroaches treated with cypermethrin fume. Under all treatments, female cockroaches were more tolerant of these insecticide fumes.

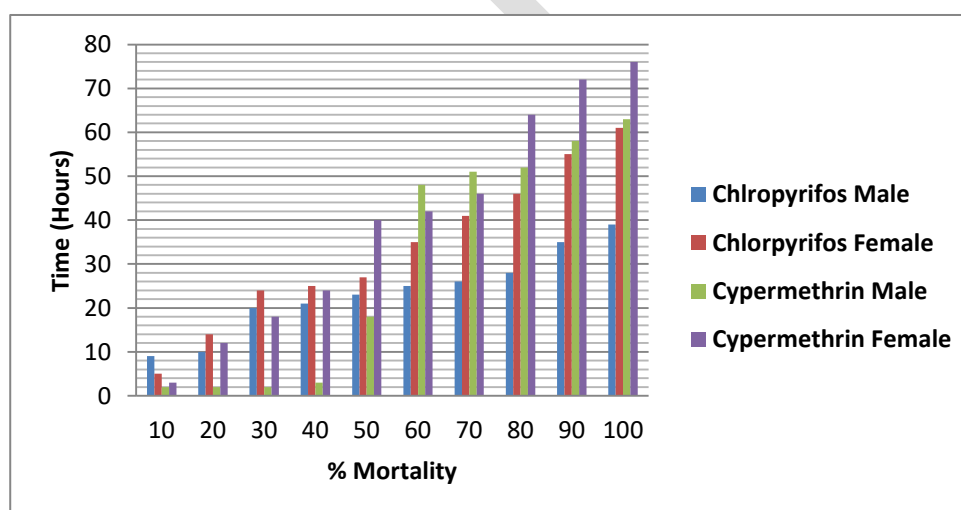


Figure 2. Progressive mortality time of sexed cockroaches exposed to fumes of chlorpyrifos and cypermethrin

4. Discussion

4.1. Repellence Potency

The study evaluated the effectiveness of two insecticides, chlorpyrifos (an organophosphate) and cypermethrin (a pyrethroid) as repellent and fumigant in the control of American cockroach, *P. american*. The experiment shows that chlorpyrifos was more effective than cypermethrin as a repellent. Higher concentrations produce better repellence in both male and female cockroaches. Chlorpyrifos exerts its toxicity notably by entering the insects' tracheal system and across the epithelium to the haemolymph, consequently

blocking the work of acetylcholinesterase (Meenu *et al*, 2023). Chlorpyrifos is therefore effective against roaches hiding in narrow, enclosed crevices where sprays cannot reach directly. The percentage repellence and repellence indexes of both insecticides at the tested concentrations ranged from medium to low. This is in contrast to the finding of Rust and Reiersen (1977), who asserted that insecticide toxicity is directly related to its repellancy. This is because several studies have identified both tested insecticides to be potent when used as contact insecticides against cockroaches (Nazeri *et al*, 2016; Oriolowo and Ande, 2025). It is therefore implied that the

repellence of an insecticide is determined by its commercial formulations and route of entrance into the insect. Female cockroaches were more tolerant of both insecticides than males as repellents. This was in support of the findings of Abd-Elghafar *et al* (1990), where they found adult males to be more susceptible to chlorpyrifos and cypermethrin than gravid and adult females.

4.2. Fumigation in a non-choice chamber

Cockroaches exposed to fumes of chlorpyrifos and cypermethrin exhibit agnostic behaviour like hypersensitivity, wing fletching and grooming. This uncoordinated movement was followed by loss of coordination, knockdown and eventual paralysis. This rigid or flaccid paralysis thus resulted in a complete cessation of movement and eventual death. Similar behaviour was reported in German cockroaches exposed to chlorpyrifos and cypermethrin (Nazari *et al*, 2016).

Cypermethrin produces the shortest period to achieve Kd_{50} and Kd_{100} compared to chlorpyrifos for both sexes of cockroaches. Similar comparison of potency was reported by Sathantriphop *et al* (2019) and Oriolowo and Ande (2025). Cypermethrin acts by disrupting the functioning of the sodium channels in the membrane of the insects' nervous system, which causes instant paralysis and a very quick knockdown. Chlorpyrifos, however, produced MT_{50} and MT_{100} with the shortest period compared to cypermethrin when both sexes of roaches were exposed to its fumes in a non-choice chamber. This corroborated the finding of Nazari *et al* (2016), who reported lower LD_{50} and LD_{90} for chlorpyrifos than cypermethrin in German cockroaches exposed to these insecticides.

5. Conclusion

Both insecticides were found to be efficient against *P. americana*. However, their modes of application relatively dictate the level of control they exhibit. Chlorpyrifos was found to be more effective as a repellent and as a fumigant, while cypermethrin was effective as a fumigant. The implication of this is that chlorpyrifos may not be effective in the control of cockroaches as a fumigant whenever they have an alternative place to move into. However, when quick immobilisation of insect pests is required, cypermethrin is recommended because a quick knockdown could prevent pests from inflicting more damage. It was also noted that repellency of any insecticide does not correlate directly with its effectiveness, but with its formulation and mode of entrance into the insect's body.

Abbreviations

ANOVA Analysis of Variance
LSD Fisher's Least Significant Difference

Author Contributions

Olatayo Bamidele Oriolowo:

Conceptualization, Investigation, Data Curation, Investigation, Formal Analysis, Writing - original draft, Methodology and Visualization.

Adeolu Taiwo Ande: Supervision, Project Administration, Validation, Writing – Review & Editing.

Conflicts of Interest

The author(s) declare that they have no known competing financial interests, professional affiliations or personal relationships that could have appeared to influence the work reported in this paper.

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