



Knockdown and Toxicity of Essential Oils from the Rhizome of *Zingiber officinale* (L) and the Bud of *Syzygium aromaticum* (L) to *Periplaneta americana* (L)

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Abstract

The American cockroach (*Periplaneta americana*) is an important peridomestic pest that is responsible for the mechanical transmission of several disease pathogens. This study aimed to evaluate the knockdown and toxicity effects of ginger (*Zingiber officinale*) and cloves (*Syzygium aromaticum*) essential oils against *Periplaneta americana*. Oils were extracted from the rhizomes and buds of ginger and cloves plants respectively. The oils were extracted using the hydrodistillation method and were serially diluted in 20% tween 80 solution to obtain seven concentrations (5, 10, 25, 50, 100, 200 and 400µl/ml). Whatman No.1 filter paper was smeared with 1ml of each concentration of the oil and allowed to dry. Adult *P. americana* were exposed to the treated filter paper in a glass jar. Each experimental set up and the control had 20 adult cockroaches each. The control experiment had the cockroaches exposed to 1ml of 20% tween 80 solution. Each experiment was replicated 4 times. The knockdown effect was observed at 10 minutes intervals for 60 minutes while the mortality count was recorded after 24 and 48 hours. After 20 minutes of exposure to cloves oil, 100% knockdown was observed in the highest concentration (400µl/ml). For ginger oil, complete knockdown was observed in the highest concentration (400µl/ml) after 30 minutes of exposure. Both ginger and clove oil showed increased mortality as the concentration increased. After 48 hours of exposure, 100% mortality of adult *P. americana* were recorded in both oils at the highest concentration of 400µl/ml. While 25% and 40% mortality recorded at the lowest concentration of 5µl/ml for ginger and clove oil respectively at 48 hours. There was no mortality recorded in the control. Clove oil was more potent than ginger oil, this was judged by the 48 hours LC₅₀ value of 7.344µl/ml while the 48 hour LC₅₀ value for ginger oil was 56.564µl/ml. It was concluded from the study that both ginger and clove oils exhibited significant knockdown and toxicity activity against *P. americana*. Thus, it is recommended that the essential oils from these plants should be incorporated in the production of botanical pesticides for the management of *P. americana*, which is a well-known mechanical vector and common household's pest.

Keywords: Knockdown, Toxicity, *Zingiber officinale*, *Syzygium aromaticum*, *Periplaneta americana*.

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INTRODUCTION

Mechanical insect vectors transmit pathogens from one vertebrate host to another without the development of the organisms within the vector (Yusof, 2018). Cockroaches

usually breed in faeces, animal manure, carrion, septic materials and decaying substances and thus live in intimate association with various microorganisms including human pathogens which may cling to the body surfaces of this insect (Basseri *et al.*, 2016). Pathogens are frequently spread to humans and animals by this insect's continual back and forth travel between its breeding grounds and human habitation (Malik *et al.*, 2013). The transmission of these pathogens is mechanical.

The prevalence and persistence of arthropod vector loads, as well as the related direct and indirect consequences that result from these factors are influenced by human-mediated activities and socioeconomic level within communities (Lee *et al.*, 2020; Schrama *et al.*, 2020). For instance, the proliferation of unevacuated waste across macro and microhabitats, poor living conditions, feeding preferences and host availability are key in attracting and influencing population increase of arthropod vectors (Ibrahim *et al.*, 2017). In Uyo, the Akwa Ibom state capital, there are diverse socio-economic lifestyles and livelihoods of people across rural-urban landscapes. These have led to the generation and indiscriminate disposal of domestic waste across the city centers and communities. These wastes may at times be left unevacuated for days or even months. These unevacuated dumpsites serve as excellent breeding sites for insect vectors such as cockroaches. The association of humans, mechanical insect vectors and unevacuated dumpsites is often an important interaction that facilitates the transmission of disease pathogens (Ibrahim *et al.*, 2017; Issa, 2019).

The American cockroach (*Periplaneta americana*) is an insect of public health significance and it is one of the largest common cockroach species (Akbari *et al.*, 2014; Gary, 2015). It survives in warm

weather with high moisture conditions as well as in unfavorable environments such as sewers and other human-made habitats (Jaramillo-Ramirez *et al.*, 2010). *Periplaneta americana* is considered a significant pest species that can be both an annoyance as well as vector harmful to health. It does not only destroy household properties, but also spreads pathogens of various diseases, in some cases cause psychological distress too (Sohn and Kim, 2012; Guzman and Andreas, 2020). *Periplaneta americana* has nocturnal and filthy habits of eating faeces and other waste materials make it an ideal carrier of numerous pathogenic microbes (Guzman and Andreas, 2020). More than 40 pathogenic and nonpathogenic bacterial species have been isolated from cockroaches (Guzman and Andreas, 2020). The Conventional method of controlling insect's pest including cockroaches is the use of chemical insecticides (Levchenko *et al.*, 2018).

However, the effectiveness is no longer tenable due to several reasons, including the development of resistance by these insect vectors against certain frequently used synthetic insecticides (Zhu *et al.*, 2016; Wang *et al.*, 2019). There are also many concerns about the harmful side-effects of these chemical compounds due to their non-ecofriendly attributes. These attributes led to the demand for safer alternatives against insect vectors (Rahayu *et al.*, 2020). Botanicals and their derivatives have proved to be efficient in the management of insect vectors, and they also possess the advantage of being low in toxicity and easily biodegradable (Ubulom *et al.*, 2019; Rahayu *et al.*, 2020; Umohata *et al.*, 2020).

Zingiber officinale commonly known as ginger belongs to the family Zingiberaceae (Kumar *et al.*, 2014). The plant is globally one of the commonly used spices and medicinal agents. It is a tropical plant that needs plenty of heat and humidity to thrive. It is a perennial

rhizomatous plant with pale yellowish colour, a thick lobed rhizome having tuberous joint and on cultivation may grow as high as 24 -39 inches (Ajav and Ogunlade, 2014). The rhizomes of the ginger plant have been used as herbal medicine against muscular pain, inflammation, epilepsy, sore throat, cough, common cold, headache and migraine (Shukula and Singh, 2007). Also, the antibacterial, antiviral and antifungal properties of the essential oil of ginger have been reported (Sivasothy *et al.*, 2011; Madreseh-Ghahfarokhi *et al.*, 2018).

Cloves (*Syzygium aromaticum* L.) is a member of the myrtaceae family which has over 3000 species and more than 130 genera such as the Myrtle, Eucalyptus and Psidium (Tunc and Koca, 2019). Madagascar, Sri Lanka, Indonesia, and China are some of the countries that the aromatic flower (cloves) are known to be grown (Tunc and Koca, 2019). The plant contains a high number of phenolic compounds with several biological activities, including, antibacterial, antifungal and antioxidant properties (Cortes-Rojas *et al.*, 2014). This study aimed to evaluate the knockdown and toxicity effects of essential oils from the rhizome of ginger and buds of cloves to American cockroach (*Periplaneta americana*).

MATERIALS AND METHODS

Collection and Identification of the Experimental Plants

The rhizome of *Zingiber officinale* (ginger) and the flower buds of *Syzygium aromaticum* (clove) used in this study were provided by the Department of Pharmacognosy and Natural Medicine, Faculty of Pharmacy, University of Uyo, Uyo, Nigeria. The plants were earlier identified and authenticated by a plant Taxonomist in the Department of Botany and Ecological Studies, Faculty of Science, University of Uyo, Nigeria, where voucher/herbarium

specimens were prepared and kept for future reference.

Extraction of Oils from the Plant Parts

The essential oils used for this study were obtained by hydrodistillation method using a Clevenger tight apparatus in the laboratory of the Department of Pharmacognosy and Natural Medicine, Faculty of Pharmacy, University of Uyo, Nigeria. The rhizomes of ginger were washed and shade dried for 2 hours on the laboratory benches and later chopped into pieces using a table knife. The chopped material was weighed (1500g) and introduced into a round bottom flask of a Clevenger apparatus. Four litres of ordinary tap water were added to the chopped material in the Clevenger apparatus. The set up was allowed to boil at 70°C for four (4) hours, the oil was thereafter collected through a tap into a glass sample bottle. The oil obtained was dried using sodium sulphate and stored at 4°C for 7 days before use. The same procedure was repeated for cloves but with an extended boiling time of 7 hours at 70°C due to the hard tissues of the cloves buds.

Identification and test of Cockroaches Collected

Males and females of the species *Periplaneta americana* were identified and sorted out from cockroaches' samples collected. The identification authentication was carried out by an Entomologist in the laboratory of the Department of Animal and Environmental Biology, Faculty of Science, University of Uyo, Uyo, Nigeria. Pictorial keys of Ross (1965) and Morphological keys of Barbara (2000), were used for the identification of the cockroaches. The main diagnostic feature used for the identification of the *Periplaneta americana* is reddish brown with a pale yellowish band around the edge of the pronotum (Service, 2012).

Prior to the assay, test specimens were placed in 500ml capacity jars and maintained at a temperature of $30\pm 2^{\circ}\text{C}$ and photoperiod of 12:12 (L:D) h. The upper inner walls of the jars were smeared with a thin layer of Vaseline (blue seal) as described by Thavara *et al.* (2007) and Ubulom *et al.* (2021) to prevent the escape of the cockroaches and keep them entrapped in the lower part of the jar. Considering the nocturnal habits of cockroaches and to provide their preferred hidden places of living, a dark paper was used to cover these containers externally. The test insects (*P. americana*) were maintained in the insectary of the Department of Animal and Environmental Biology, University of Uyo, Uyo. They were fed on wheat flour, biscuits and water as described by Snoody and Appel, (2014).

Preparation of Stock Solution and Test Oil concentration

For each oil, the stock solution was prepared by dissolving 1600 μl of each oil in 4mls of 20% tween-80 solution to obtain 400 $\mu\text{l}/\text{ml}$ of each essential oil. From the stock solution of 400 $\mu\text{l}/\text{ml}$ of each oil, 1.5ml was dissolved in 4ml of tween-80 solution to obtain 400, 200, 100, 50, 25, 10 and 5 $\mu\text{l}/\text{ml}$ by serial dilution.

Determination of Knockdown and Toxicity Effects of the Oils

The knockdown and toxicity of essential oils of the rhizome of *Zingiber officinale* (ginger) and *Syzygium aromaticum* (cloves) against adult *Periplaneta americana* were determined using the method of Manzoor *et al.*, (2012). Whatman No 1 filter paper was separately impregnated with 1ml of the different concentrations of each essential oil which were 5, 10, 25, 50, 100, 200 and 400 $\mu\text{l}/\text{ml}$. Each test concentration had four (4) replicates. Each impregnated filter paper was air dried. Each air-dried filter paper was

introduced into the test jars (500ml capacity). Groups of 20 adult *P. americana* were transferred to jars with treated filter paper and left for continuous exposure. Each test jar was covered with a mesh to allow entry of air but restrict the movement of the cockroaches within the test jar. The control had twenty cockroaches of both sexes exposed to filter paper treated with 1ml of 20% tween – 80 with four replications also. The knockdown effect of each oil against the insects was observed at intervals of 10 minutes for 60 minutes while mortality count was recorded after 24 and 48 hours. Cockroaches were considered dead when they did not move or respond when prodded with a soft brush (Ubulom *et al.*, 2021).

Data Analysis

The data were pooled and percentage knockdown and mortality were calculated. Mortality data were analyzed by standard Probit analysis to obtain the Lethal Concentration (LC_{50}) values. Also, mortality and knockdown data were statistically analyzed using one-way Analyses of Variance (ANOVA). Turkey's mean separation was used to test for significance. Statistical Packages for Social Sciences (SPSS) Version 21 was used for the analysis.

RESULTS

The colour of essential oils obtained from the rhizomes of ginger and buds of dry cloves plants were reddish brown and ash respectively. After 20 minutes of exposure to the highest concentration (400 $\mu\text{l}/\text{ml}$) there was complete knockdown (100%) of *P. americana* to clove oil while the lowest knockdown effect (10%) was recorded in 25 $\mu\text{l}/\text{ml}$ concentration of the oil after 60 minutes exposure period (Table 1). For ginger oil, 100% knockdown was observed after 30 minutes of exposure to the highest

concentration (400µl/ml) of the oil, and the least knockdown effect (37.5%) was recorded in 100µl/ml for the oil after 60 minutes of exposure (Table 2). Also, analysis of variance

revealed significant difference ($p < 0.05$) in knockdown of *P. americana* to both oils (Tables 3 and 4).

Table 1: Percentage Knockdown of *P. americana* to different concentrations of *S. aromaticum*

Conc.	No. of insect	% Knockdown (minutes)					
		10	20	30	40	50	60
5µl/ml	80	0%	0%	0%	0%	0%	0%
10µl/ml	80	0%	0%	0%	0%	0%	0%
25µl/ml	80	0%	0%	0%	0%	0%	10%
50µl/ml	80	0%	0%	0%	30%	50%	50%
100µl/ml	80	0%	0%	40%	62.5%	80%	80%
200µl/ml	80	60%	77.5%	100%	100%	100%	100%
400µl/ml	80	80%	100%	100%	100%	100%	100%
Control	80	0%	0%	0%	0%	0%	0%

Table 2: Percentage Knockdown of *P. americana* to different Concentrations of *Z. officinale*

Conc.	No. of insect	% Knockdown (Minutes)					
		10	20	30	40	50	60
5µl/ml	80	0%	0%	0%	0%	0%	0%
10µl/ml	80	0%	0%	0%	0%	0%	0%
25µl/ml	80	0%	0%	0%	0%	0%	0%
50µl/ml	80	0%	0%	0%	0%	0%	0%
100µl/ml	80	0%	12.5%	37.5%	37.5%	37.5%	37.5%
200µl/ml	80	12.5%	37.5%	75%	75%	75%	75%
400µl/ml	80	50%	80%	100%	100%	100%	100%
Control	80	0%	0%	0%	0%	0%	0%

Table 3: Mean Knockdown Values of *P. americana* Exposed to Varying Concentrations of *Z. officinale*

Concentrations	Knockdown (Minutes) Mean \pm SE					
	10	20	30	40	50	60
5 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
10 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
25 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
50 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
100 μ l/ml	0.00 \pm 0.00 ^c	2.50 \pm 1.44 ^c	7.50 \pm 1.44 ^c	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
200 μ l/ml	2.50 \pm 1.44 ^b	7.50 \pm 1.44 ^b	15.00 \pm 0.00 ^b	10.00 \pm 5.77 ^a	0.00 \pm 0.00	0.00 \pm 0.00
400 μ l/ml	10.00 \pm 1.15 ^a	16.00 \pm 0.00 ^a	20.00 \pm 0.00 ^a	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
Control	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^b	0.00 \pm 0.00	0.00 \pm 0.00
Total	1.56\pm0.63	3.25\pm1.00	5.31\pm1.36	1.25\pm0.87	0.00\pm0.00	0.00\pm0.00
p Value	<0.001*	<0.001*	<0.001*	0.021*	NA	NA

Means along the same column with different superscript(s) = significant

Means along the same column with the same superscript(s) = are not significant

Table 4: Mean Knockdown Values of *P. americana* Exposed to Varying Concentrations of *S. aromaticum*

Concentrations	Knockdown (Minutes) Mean \pm SE					
	10	20	30	40	50	60
5 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b
10 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b
25 μ l/ml	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	1.00 \pm 1.00 ^b	2.00 \pm 2.00 ^b	2.00 \pm 1.15 ^a
50 μ l/ml	2.00 \pm 2.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	8.00 \pm 1.63 ^a	11.00 \pm 1.00 ^a	0.00 \pm 0.00 ^b
100 μ l/ml	0.00 \pm 0.00 ^c	1.25 \pm 1.25 ^c	8.00 \pm 1.20 ^b	9.00 \pm 3.00 ^a	12.00 \pm 4.00 ^a	0.00 \pm 0.00 ^b
200 μ l/ml	12.00 \pm 0.00 ^b	16.00 \pm 0.00 ^b	20.00 \pm 1.45 ^a	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b
400 μ l/ml	16.00 \pm 0.00 ^a	20.00 \pm 0.00 ^a	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b
Control	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b	0.00 \pm 0.00 ^b
Total	3.75\pm1.11	4.66\pm1.40	3.50\pm1.21	2.25\pm0.76	3.13\pm1.01	0.25\pm0.17
p Value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.021*

Means along the same column with different superscript(s) = significant

Means along the same column with the same superscript(s) = are not significant

Data presented in Tables 5 and 6 show that both oils were toxic to the insects at different concentrations. The lowest percentage mortality (25% and 40%) for ginger and cloves oils respectively were recorded in the lowest concentrations of the oil (5 μ l/ml) after 48 hours exposure. Complete mortality was recorded at the highest concentration of

400 μ l/ml after 24 hours of exposure for both oils. However, there was no mortality recorded in the control experiment for the both oils (Table 3 and 4). Also, no mortality was observed in cockroaches exposed to 5 and 10 μ l/ml of ginger oil and 10 μ l/ml of cloves oil after an exposure period of 24 hours (Table 5 and 6). Furthermore, analysis of variance

revealed that there was significant difference *americana* to the concentrations of the two at ($p \leq 0.05$) observed in mortality of *P.* oils (Tables 7 and 8).

Table 5: Percentage Mortality of *P. americana* Exposed to Different Concentrations of *Z. officinale*

Concentration	No. of <i>P. americana</i> Introduced	% Mortality	
		24 hours	48 hours
5 µl/ml	80	0%	25%
10 µl/ml	80	0%	34%
25 µl/ml	80	11.25%	33%
50 µl/ml	80	25%	50%
100 µl/ml	80	25%	87.5%
200 µl/ml	80	62%	100%
400 µl/ml	80	100%	100%
Control	80	0%	0%

Table 6: Percentage Mortality of *P. americana* Exposed to Different Concentrations of *S. aromaticum*

Concentration	No of <i>P. americana</i> Introduced	% Mortality	
		24 hours	48 hours
5 µl/ml	80	0%	40%
10 µl/ml	80	10%	60%
25 µl/ml	80	17%	80%
50 µl/ml	80	80%	100%
100 µl/ml	80	90%	100%
200 µl/ml	80	90%	100%
400 µl/ml	80	100%	100%
Control	80	0%	0%

Table 7: Mean Mortality Values of *P. americana* Exposed to Varying Concentrations of *P. Z. officinale*

Concentration	24h Mortality Mean ± SE	48h Mortality Mean ± SE
5µl/ml	0.00±0.00 ^c	6.00±1.15 ^c
10µl/ml	0.00±0.00 ^c	8.00±0.00 ^{bc}
25µl/ml	2.50±1.44 ^c	7.50±1.44 ^{bc}
50µl/ml	5.00±2.89 ^c	10.00±0.00 ^b
100µl/ml	5.00±2.89 ^c	17.50±1.44 ^a
200µl/ml	12.50±1.44 ^b	20.00±0.00 ^a
400µl/ml	20.00±0.00 ^a	20.00±0.00 ^a
Control	0.00±0.00 ^c	0.00±0.00 ^d
Total	5.63±1.30	11.13±1.25
p Value	<0.001 *	<0.001 *

Means along the same column with different superscript(s) = significant

Means along the same column with the same superscript(s) = are not significant

Table 8: Mean Mortality Values of *P. americana* Exposed to Different Concentrations of *S. aromaticum*

Concentration	24 h Mortality Mean ± SE	48h Mortality Mean ± SE
5µl/ml	0.00±0.00 ^d	8.00±0.00 ^d
10µl/ml	2.00±1.15 ^c	12.00±0.00 ^c
25µl/ml	4.00±0.00 ^c	16.00±2.31 ^b
50µl/ml	16.00±0.00 ^b	20.00±0.00 ^a
100µl/ml	18.00±1.15 ^{ab}	20.00±0.00 ^a
200µl/ml	18.00±1.15 ^{ab}	20.00±0.00 ^a
400µl/ml	20.00±0.00 ^a	20.00±0.00 ^a
Control	0.00±0.00 ^d	0.00±0.00 ^e
Total	9.75±1.52	14.50±1.27
p Value	<0.001 *	<0.001 *

Means along the same column with different superscript(s) = significant

Means along the same column with the same superscript(s) = are not significant

Median Lethal Concentration (LC₅₀) of the Oils

The 24- and 48-hour LC₅₀ values (ginger oil) were 117.82µl/ml and 56.564µl/ml respectively while (cloves oil) were 37.067µl/ml and 7.344µl/ml for 24 and 48 hours respectively (Table 9). Thus, adults of *P. americana* were more susceptible to the essential oil of cloves plant as judged by the 24 and 48 hours LC₅₀ values.

Table 9: The 24 and 48h LC₅₀ Values of Ginger and Clove Oils

Oil	LC ₅₀ Values	
	24 hours (µl/ml)	48 hours (µl/ml)
Ginger (<i>Zingiber officinale</i>)	117.827	56.564
Clove (<i>Syzygium aromaticum</i>)	37.067	7.344

DISCUSSIONS

Studies have shown that many pathogenic organisms such as poliomyelitis virus, protozoa, bacteria, fungi, and helminthes have been associated with cockroaches (Fathpour *et al.* 2003; Tاتفeng *et al.*, 2005; Saichua *et al.*, 2008). The effective control of cockroaches can reduce the nuisance they constitute as well as reduce the incidences of the diseases associated with them. The control of cockroaches mostly relies on using insecticides. However, like many arthropod vectors, cockroaches have shown resistance to different insecticides (Gondhalekar and Scharf, 2012; Zhu *et al.* 2016; Wang *et al.*, 2019). The need for safer control strategies that will remain effective even in the face of growing insecticide resistance has necessitated much investigations into botanicals which have shown great success in the fight against insect vectors. In this study, the essential oils

obtained from the rhizomes of ginger and the buds of cloves were used against *P. americana* to test their knockdown and insecticidal effects. Plant based pesticides have proved to be effective against different insect species and they are also environment friendly and biodegradable (Ubolom *et al.*, 2019; Umohata *et al.*, 2020)

Plants are a plentiful source of bioactive substances that can be employed as a viable replacement to create eco-friendly pest management solutions. In this study, the knockdown and toxic effects of the essential oils of rhizomes of ginger and the buds of cloves plants against adult of *P. americana* were tested. The test oils exerted some deleterious effect on the insects. On exposure to the different concentrations of the essential oils, the insects lost their agility and were observed to be weak, some were knocked down. Other toxic effects observed were ataxia and finally mortality. The toxicity of the oils of ginger and cloves reported in this

study could be attributable to the chemical constituents of the two oils (Feng *et al.*, 2018; Gonzalez-Haro *et al.*, 2021). *Zingiber officinale* and *Syzygium aromaticum* possess major aromatic constituents such as eugenol. Eugenol is a phenylpropanoid compound whose insecticidal properties have been reported (Khalil *et al.*, 2017; Fernandes *et al.*, 2020). Also, the phenylpropanoid compound has been reported to exhibit antimicrobial and anti-inflammatory properties (Korkina *et al.*, 2011; Sharma *et al.*, 2016). The eugenol compound may have acted independently or jointly with other constituents to contribute to the knockdown and mortality recorded in this study. Some of the chemical components of these oils may have interfered with the nervous system of the test insects. This was supported by the observation that no mortality was noted in the control experiments as the cockroaches were still actively moving.

Interestingly, the adults of *P. americana* were more susceptible to the essential oils of cloves than those of ginger. This could be attributed to the differences in the chemical compositions of the oils (Feng *et al.*, 2018; Fernandes *et al.*, 2020; Gonzalez-Haro *et al.*, 2021). The higher susceptibility of *P. americana* to clove oil was judged by the 24 and 48h LC₅₀ values. The values also demonstrated a higher tolerance of the test insect to ginger oil. Furthermore, Syed *et al.* (2014) reported that the efficacy of plants extracts against insects may vary depending on plant species, plant parts and age of plants among other reasons. This may have accounted for the variation in susceptibility of *P. americana* to the two oils.

This investigation revealed a concentration dependent activity of the essential oils from the rhizomes of ginger and the buds of cloves against *P. americana*. Studies on the toxicity of extracts of *Z. officinale* against the black bean aphid (*Aphis fabae*) has been documented (Abdulhay and Yonius, 2019).

Their result revealed that the potency of the methanol extract of the rhizomes of ginger varied according to the different concentrations used. Similarly, the dose dependent activity of the essential oil from the buds of *S. aromaticum* against *Hyalomma scupense* has been reported (Alimi *et al.*, 2023). The toxicity and repellency of clove oil against *H. scupense* was reported to be increase with increase in the concentration. Furthermore, different plant-based pesticides have been reported to exhibit a concentration dependent activity against cockroaches (Thavara *et al.*, 2007, Sittichok *et al.*, 2013 and Ubulom *et al.*, 2021). These reports corroborates the concentration dependent activity of the essential oils from *S. aromaticum* and *Z. officinale* against adult *P. americana* reported in this study.

CONCLUSION

The fight against insect vectors is gradually shifting from relying solely on the use of synthetic insecticides to the use of plant derived insecticides which are friendly to both humans and the environment. The present study evaluated the knockdown and toxicity effects of oils obtained from the rhizomes of ginger and buds of cloves against the American cockroach (*Periplaneta americana*). Both oils were potent against *P. americana*. The test vector was more susceptible to the oil of *Syzygium aromaticum* than the oil of *Zingiber officinale* in both the knockdown and toxicity test. The result obtained from this research revealed that essential oils obtained from the rhizomes of *Zingiber officinale* and the buds of *Syzygium aromaticum* hold potential as toxicants against the American cockroach, *P. americana* and they should be further explored.

RECOMMENDATION

Based on the findings of this study, the essential oils obtained from the rhizomes of *Z. officinale* and the buds of *S. aromaticum* had knockdown and insecticidal effects on *P. americana*. Thus, the incorporation of these oils in the production of commercial pesticides against this insect is recommended.

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