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INSECTICIDAL ACTIVITY OF METHANOLIC AND ETHYL ACETATE EXTRACTS OF *CAPSICUM ANNUUM* FRUITS AGAINST AMERICAN COCKROACH *PERIPLANETA AMERICANA*

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ABSTRACT

Cayenne pepper (*Capsicum annuum*) has long been valued for its bioactive compounds, and its potential as a natural insecticide offers a safer alternative to synthetic ones. In this study, the insecticidal properties of cayenne pepper extracts were evaluated against cockroaches (*Periplaneta americana L*). 35 cockroaches were divided into 7 groups (n = 5), consisting of 1 control and 6 treatment groups. The treatment groups were exposed to the methanolic and ethyl acetate extracts of Capsicum annuum at three concentrations each (20%, 40%, and 80%). Mortality was monitored over 24 hours. Results showed that the methanolic extract caused significantly higher mortality than the ethyl acetate extract, achieving 100% mortality at 80% concentration, whereas the ethylacetate extract induced only immobility and sluggishness at similar doses. GC-MS analysis of the methanolic extract revealed 18 compounds, dominated by oleic acid (44.27%), palmitic acid (20.27%), and capsaicin (6.47%). The insecticidal effects of methanolic extract are attributed to the presence of these fatty acids and capsaicin, while minor compounds, such as terpenoids and fatty acid derivatives, are likely to enhance the efficacy through synergistic effects. This study demonstrates that cayenne pepper extracts, especially those obtained with methanol, could serve as eco-friendly, readily available alternatives to synthetic cockroach control agents. Further studies are needed to explore fractionation of the methanol extract, and more evaluations to validate its potentials in pest management.

Keywords: *Capsicum annuum*, Ethylacetate extract, Methanol extract, Cockroach, GC-MS, Fatty acids

INTRODUCTION

Cockroaches (Order Blattodea) are the most persistent household pests that pose significant public health and economic problems in both residential and commercial environments. Species such as the American cockroach, *Periplaneta americana* (L.), contaminate food and surfaces, mechanically transmit human and animal pathogens, and contribute to allergic disease through faecal and integumentary allergens (Oparaeke, 2012). Effective control of cockroaches is therefore a public health priority. However, conventional reliance on synthetic insecticides has significant drawbacks. Repeated use of chemical insecticides promotes selection for resistant pest populations, can result in environmental contamination and non-target toxicity, and raises concerns over human exposure, particularly in domestic settings and food handling facilities (Oparaeke, 2012; Ogendo et al., 2015). These problems motivate the search for safer, sustainable, and locally available alternatives.

Biobased insecticides have emerged as attractive candidates because they often combine multi-dimension modes of actions, lower human toxicity, and biodegradability (Scott et al., 2008; Awoyinka, Salami, & Omole, 2021). Among plant species studied for pesticidal potential is *Capsicum annuum* (cayenne pepper). Cayenne pepper is consumed worldwide as a common spice for its special odour and taste. Its distinct flavor and medicinal properties has gained attention in recent years. Cayenne or Capsicum consists of the dried fruit of *Capsicum annum*, or a large number of hybrids of these species and their varieties within the Solanaceae (Nightshade) family are capsaicin rich. Its fruits contain a complex mixture of secondary metabolites, principally capsaicinoids (capsaicin, dihydrocapsaicin), phenolics, terpenoids, and a variety of lipid constituents, many of which have documented bioactivity against insects (Scott et al., 2008; Adesina, 2017). Capsaicinoids are well established as neuroactive and repellent compounds, while fatty acids and volatile terpenes are increasingly recognized for contact toxicity and fumigant or synergistic effects that enhance mortality in exposed insects (Aguilar-Marcelino et al., 2022; Akinneye et al., 2013. Recent scientific investigations have unveiled the diverse insecticidal effects of Cayenne pepper extracts, sparking a surge of interest among researchers to delve deeper into its pesticidal properties. Research indicates that the insecticidal properties of active constituents of cayenne is attributed to the ability to inhibit reactive oxygen species (Azodo et al. 2021) (Kovacic & Somanathan, 2018). Extracts from cayenne pepper, particularly those obtained using n-hexane as a solvent, have shown high efficacy in controlling *Callosobruchus maculatus* on cowpea seeds (Okafor et al., 2024) and *Sitophilus zeamais* on maize grains (Oni, 2014a ; Oni, M. O. 2014b). These extracts achieved up to 100% adult mortality and reduced seed damage at various concentrations. The insecticidal activity of cayenne pepper was generally superior to that of other pepper (Oni, 2014a, while the effectiveness of these extracts decreased over storage time (Oni, 2014b). Notably, whole hot pepper fruits have also been found to possess insecticidal properties against stored product pests (Yusuf & Yusuf, 2005). These findings suggest that *Capsicum* extracts, especially from cayenne pepper, could be integrated into pest management strategies as effective and natural insecticides. Moreover, Cayenne pepper fruit extracts' insecticidal and acaricidal properties against cabbage looper and spider mite have been reported suggesting their potentials as natural pesticides (Antonius et al., 2007). Similar activity was reported against *Sitophilus zeamais* Oni, (2014b). Aqueous and ethyl alcohol extracts of the whole fruit, pulp and seed also showed a significant insecticidal and anti-feeding effects on the Curculionidae, maize weevil (Guimarães et al., 2014). It is worthy to note that the effectiveness of cayenne pepper extracts is influenced by environmental factors such as temperature and humidity (Pramanik, *et al* 2020).

Cayenne pepper has long been recognized for its potent active compounds, particularly capsaicinoids, responsible for the characteristic pungency and fiery sensation. Numerous studies have investigated the insecticidal effects of capsaicinoids extracted from cayenne pepper. These compounds have shown potential insecticidal properties, making cayenne pepper a promising candidate for pest control (Echave *et al*, 2020). Researchers have reported that these compounds including glucoscinates exhibit toxicity against a wide range of insect pests, including aphids, Aphis cytisorum, thrips, mites, and certain lepidopteran larvae. Studies have shown that cayenne extracts, rich in capsaicinoids and polyphenols, effectively combat significant grapevine pathogens such as *Botrytis cinerea* and *Plasmopara viticola*, with significant reduction in their populations (Braidot et al., 2023). Similarly, Khoerunisa et al., 2024 in their finding validated that capsaicin in cayenne peppers has anti-insecticidal properties that can be used as a natural vegetable pesticide through the disruption in digestive system, growth and nervous system, causing their death. The mode of action of capsaicinoids involves disrupting the insect's nervous system, leading to paralysis and ultimately death (Aguilar-Meléndez., *et al*, 2020). Studies also indicate that the oleoresin extracted from cayenne pepper, with capsaicin are particularly effective against several fungal and insect pathogens, as demonstrated with its inhibitory effects on *Botrytis cinerea* and *Guignardia bidwellii*, suggesting its multifaceted role in pest management (Braidot et al. 2023). Capsaicinoids and glucosinolates extracted from *Capsicum chinense* have insecticidal properties against the aphid pest *Aphis cytisorum* (Claros et al., 2019). However, study conducted by Li et al., 2019 found that natural capsaicinoids had weaker insecticidal activity compared to commercial pesticide ingredients, but showed impressive activity against some insects like *Aphis gossypii* and improved control when sprayed twice in field experiments.

Despite the accumulated evidence for *Capsicum* efficacy against insects, the insecticidal potential of *C. annuum* against domestic cockroaches, particularly *Periplaneta americana*, is still unexplored. Cockroaches differ physiologically and behaviorally from many stored-product pests: they are larger, possess robust cuticular defenses, and exhibit sheltering and grooming behaviors that can reduce exposure to contact agents. The relative scarcity of targeted studies on *P. Americana* therefore represents an important loophole. To address this gap, the present study evaluates the insecticidal efficacy of two solvent extracts (methanolic and ethyl acetate) of *Capsicum annuum* fruits against *Periplaneta americana* under controlled laboratory conditions and subject the most effective extract to GC–MS profiling to identify probable bioactive constituents.

MATERIALS AND METHODS

Sample collection and Preparation

Fresh cayenne pepper fruits were obtained from Kawo market, Kaduna Nigeria, washed with water, sliced into small bits and air dried under shade at room temperature for two weeks. The dried fruits were milled into fine powder using a laboratory grinder and sieved through a 0.5 mm mesh to ensure uniform particle size. 50 g of the powdered sample were weighed into a 500 mL beaker and soaked in 300 mL of analytical-grade methanol. The mixture was macerated for 72 hours with occasional shaking to maximize extraction. The extract was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated using a rotary evaporator under reduced pressure at 50 °C. Same procedure was carried out for ethylacetate extract. 100% stock solutions of the two extracts were prepared by dissolving 10 g of crude methanol extract in 20 mL of distilled water in a 100 mL volumetric flask and made up to the mark while ethyl-acetate was firstly dissolved in 4 mL of acetone in another 100 mL volumetric flask and made up to the mark with distilled water. Three test concentrations (20%, 40%, 80%) were prepared from stock solutions of each extract. 1 drop of emulsifier (Tween 80) was added to each solution.

Blattodea Colony

Adult *Periplaneta americana L* (Cockroaches) were captured from domestic dwellings in Kaduna using manual traps and reared in perforated plastic containers. The insects were acclimatized for 5 days under laboratory conditions (25–28 °C, 70–80% RH, 12:12 h light: dark cycle) and provided with bread and water ad libitum. 35 healthy, active individuals were selected for the bioassay.

Insecticidal Assay

This was conducted using modified method of Ajayi & Adeleke, 2019. Briefly, the cockroaches *Periplaneta americana L* were divided into 7 groups. Each group contains 5 cockroaches. Group 1 (control) was exposed to solvent only (distilled water), The remaining 6 groups were treated with 20%, 40%, and 80% ethyl acetate (groups 2-4) and methanol (group 5-7) extracts respectively. Treatments were applied using a 50 cL hand sprayer, with 10 mL of extract solution sprayed uniformly per replicate. No food was provided during the 24-hour exposure period. Responses were categorized as Alive (A = normal movement; B = alive .with altered behavior), Sluggish (S), Immobile (I), or Dead (D).

Data Analysis

Results are presented in tables. Percentage mortality was calculated using the formula;

$$\text{Percentage Mortality} = \left(\frac{Number\ of\ Dead\ Cockroaches}{Total\ Initialcount}\right) X\ 100$$

Qualitative Analysis

The methanolic extract, which showed the highest bioactivity, was analyzed using Gas Chromatography–Mass Spectrometry (GC–MS, Agilent 7890A GC coupled to 5975C MS detector) under the following conditions: Column: HP-5MS (30 m × 0.25 mm × 0.25 µm), Carrier gas: Helium at 1.0 mL/min, Injector temperature: 250 °C. Detector temperature (MS ion source): 230 °C. Oven temperature program: Initial 70 °C (held for 2 min), increased at 10 °C/min to 200 °C, then ramped at 5 °C/min to 280 °C and held for 10 min. Injection volume: 1 µL in splitless mode. Mass range: m/z 50–550. Compounds were identified by comparing mass spectra with the NIST library.

RESULTS AND DISCUSSION

Insecticidal Activity

The insecticidal activities of methanolic and ethylacetate extracts of *Capsicum annuum* fruits against *Periplaneta americana* are presented in Table 1. Mortality increased with extract concentration in both solvents. The methanolic extract caused higher mortality across all concentrations, achieving 100% mortality at 80%, compared to only partial mortality for the ethyl acetate extract at the same concentration. The control group (distilled water) showed no mortality during the observation period.

Table 1: Effect of Cayenne Peppers Extracts on *Periplaneta Americana L* after 24 hrs

Group	D	I	S	A/B	% Mortality
1 (Control 0%)	0	0	1	4	0
2 (EtoAc 20%)	0	1	3	1	0
3 (EtoAc 40%)	0	1	4	0	0
4 (EtoAc 80%)	2	3	0	0	40
5 (Methanol 20%)	0	0	5	0	0
6 (Methanol 40%)	2	3	0	0	40
7 (Methanol 80%)	5	0	0	0	100

Key; D= Death, I = immobile, S= sluggish, A- alive, B= alive with behavioral changes

Qualitative Analysis

The methanolic extract, which exhibited the highest insecticidal activity, was analyzed using GC–MS. A total of 18 compounds were identified (Table 2). The most abundant constituents were oleic acid (44.27%), palmitic acid (20.27%), and capsaicin (6.47%). Other minor compounds included linoleic acid, stearic acid, and various terpenoids.

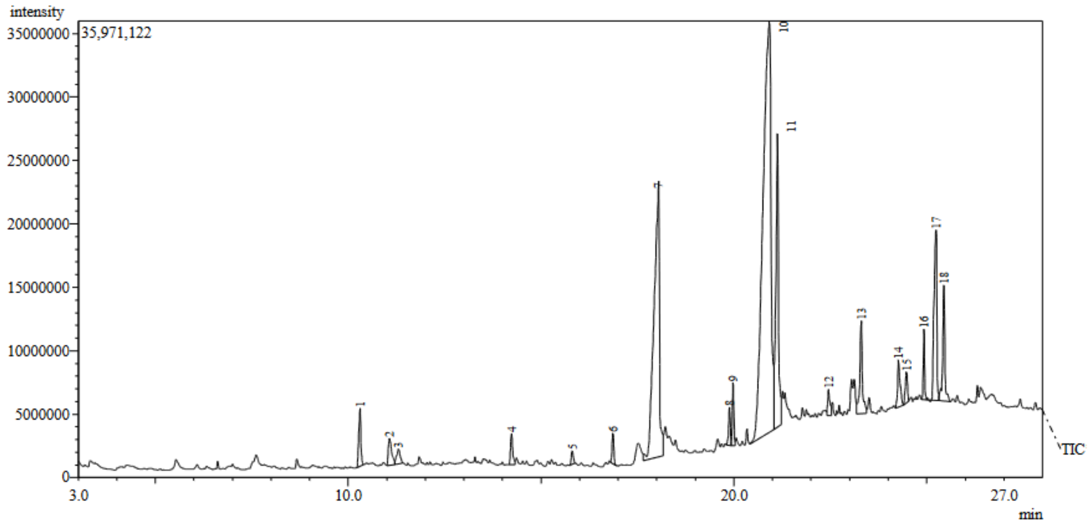


Figure 1: GC-MS Chromatogram of Methanolic Extract of Cayenne Pepper (*capsicum annuum*)

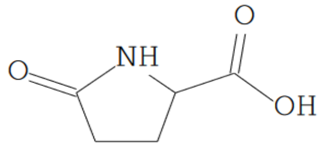
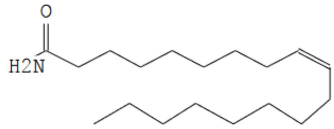
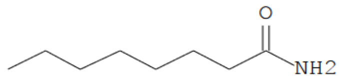
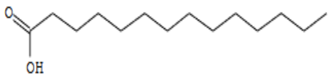
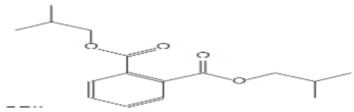
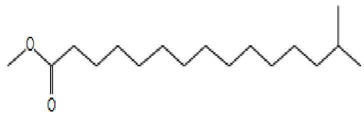
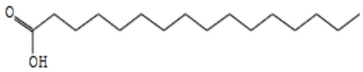
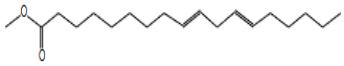
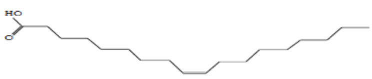
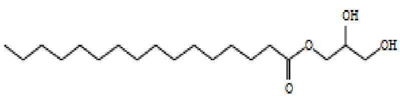
Peak Report TIC

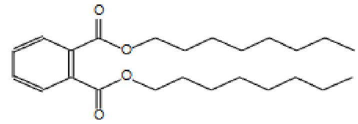
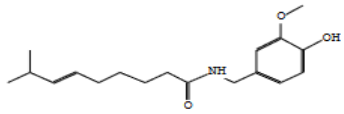
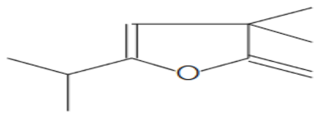
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	10.308	10.217	10.400	17457583	1.65	4546403	3.19	3.84		
2	11.073	11.000	11.208	12505717	1.18	2119744	1.49	5.90		
3	11.303	11.208	11.425	7335227	0.69	1147951	0.81	6.39	V	
4	14.235	14.167	14.325	9632611	0.91	2448169	1.72	3.93		
5	15.810	15.750	15.883	3794507	0.36	1068165	0.75	3.55		
6	16.862	16.800	16.950	7812233	0.74	2391414	1.68	3.27		
7	18.050	17.650	18.167	214725541	20.27	21752543	15.26	9.87	V	
8	19.885	19.808	19.933	9298886	0.88	3012403	2.11	3.09		
9	19.978	19.933	20.033	13609313	1.28	4957581	3.48	2.75	V	
10	20.917	20.417	21.033	469071326	44.27	32368560	22.70	14.49		
11	21.132	21.033	21.225	109134862	10.30	23137766	16.23	4.72	V	
12	22.450	22.408	22.525	8464152	0.80	2065715	1.45	4.10	V	
13	23.299	23.183	23.442	33059210	3.12	7291706	5.11	4.53	V	
14	24.267	24.192	24.400	16302853	1.54	3714780	2.61	4.39		
15	24.471	24.400	24.533	9341385	0.88	2453550	1.72	3.81		
16	24.926	24.858	25.000	13371348	1.26	5561077	3.90	2.40		
17	25.240	25.000	25.317	68564806	6.47	13438868	9.42	5.10	V	
18	25.446	25.317	25.617	36066355	3.40	9114968	6.39	3.96	V	
				1059547915	100.00	142591363	100.00			

Spectrum

Figure 2: Peak Report for Methanolic Extract of Cayenne Pepper (*Capsicum Annuum*)

Table 2: Bioactve Compounds Identified in the Methanolic Extract of Cayenne Pepper

S/N	RT	Compound Name	Molecular Formula	Molecular Weight	Structure	Area%
1	10.308	5-Oxo-L-proline	C5H7NO3	129		1.65
2	11.073	9-Octadecanamide, (Z)-	C18H35NO	289		1.18
3	11.303	Octanamide	C8H17NO	143		0.69
4	8.44	n-Tetradecanoic acid	C14H28O2	228		0.91
5	15.810	1,2-Benzenedicarboxylic acid, bis(2-methyl propyl) ester	C16H22O4	278		0.36
6	16.862	1,4-methyl-, methyl ester	C17H34O2	270		0.74
7	18.050	Hexadecanoic acid	C16H32O2	256		20.27
8	19.885	9,12-Octadecadien-1-ol, (Z,Z)-	C19H34O2	266		0.88
9		11-Octadecanoic acid, methyl ester	C19H36O2	296		1.28
10	14.38	Oleic acid	C18H3402	282		44.27
11	15.29	Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester	C22H44O4	372		10.30
12	16.62	Hexadecanoic acid, 2,3-dihydroxypropyl ester, $(^{+}/_{-})$-	C19H38O4	330		0.80
13	17.08	Ecosanoic acid	C20H40O2	312		3.12
14	17.52	9-Octadecenal	C18H34O	266		1.54
15	17.96	Octadecane,2-methyl	C19H40	268		0.88

S/N	RT	Compound Name	Molecular Formula	Molecular Weight	Structure	Area%
16	18.43	Di-n-Octyl phthalate	C24H38O4	390		1.26
17	18.64	Capsaicin	C18H27NO3	305		6.47
18	20.29	5-Isopropyl-3,3-dimthylene-2,3-dihydrofuran	C10H16O	152		3.40

Discussion

Insecticidal Analysis

This study demonstrated that the methanolic extract of *Capsicum annuum* fruits had significantly greater insecticidal efficacy against *Periplaneta americana* than the ethylacetate extract, with mortality increasing in a dose-dependent manner and complete mortality observed at 80% concentration.

For the ethylacetate extract, no mortality was observed at 20% and 40%, although cockroaches displayed sluggishness and immobility, suggesting sub-lethal physiological stress. At 80%, mortality increased to 40%, indicating that ethylacetate can extract some bioactive compounds responsible for insecticidal activity, but not in sufficient amounts to cause total lethality. This agrees with earlier findings that solvent polarity determines the yield and profile of extracted phytochemicals (Ogendo et al., 2015; Adesina, 2017). Ethylacetate, being semi-polar, may not have extracted high levels of capsaicinoids or related alkaloids, which are known to contribute to insecticidal activity. The control group recorded 0% mortality, with nearly all cockroaches alive and active. The methanol extract showed remarkable stronger toxicity, showing a clear dose-dependent progression. At 20%, cockroaches became sluggish but showed no mortality. At 40%, mortality rose to 40% with the remainder immobile, while at 80% concentration, 100% mortality was achieved within 24 hours. This demonstrates that methanol is more efficient in extracting a wider range of insecticidal compounds from cayenne pepper. Previous studies have reported methanol extracts from different plants to contain high concentrations of capsaicin, dihydrocapsaicin, and other phytochemials with insecticidal and repellent activity (Scott et al., 2008; Oparaeke, 2012). Additionally, these findings also corroborate with previous research, where methanol extracts of pepper and extracts from other plants significantly performed better than extracts from less polar solvents in insect control (Ajayi & Adeleke, 2019; Awoyinka et al., 2021). The superior performance of methanol may be attributed to its ability to extract both polar and moderately non-polar compounds, ensuring higher concentrations of capsaicinoids, flavonoids, and saponins which are known compounds that disrupt insect nervous systems and feeding behavior (Akinneye et al., 2013). Overall, the insecticidal effect appears to result from a synergistic mechanism between fatty acids and capsaicinoids. Oleic and palmitic acids, the dominant compounds identified in methanol extract, are known to disrupt the insect cuticular wax layer, leading to desiccation and increased permeability. Once the protective cuticle is compromised, capsaicin, a neurotoxic alkaloid penetrate more effectively, acting on insect nerve receptors and causing paralysis and death. This dual-action mechanism highlights the importance of metabolite synergy in botanical insecticides.

The control group which recorded 0% mortality, with nearly all cockroaches alive and active confirms that the solvent alone had no lethal effect, and that the observed mortality was solely due to the active constituents present in cayenne pepper extracts. Because ethylacetate extract is not readily soluble in water, it was dissolved in acetone prior to dilution and bioassay application. However, a separate solvent control group treated with acetone alone was not included in the experimental design. This omission means that it cannot be ruled out that part of the observed mortality in the ethyl acetate treatments may have been influenced by the presence of acetone rather than the extract itself. Although acetone is generally considered to have minimal insecticidal activity at low volumes, previous reports indicate that solvent effects can vary depending on insect physiology and exposure method. Therefore, the absence of a solvent control constitutes a significant limitation that should be addressed in future studies. Including an acetone-only control group would allow a more accurate attribution of insecticidal activity to the *Capsicum annuum* extract itself, thereby strengthening the validity of the findings.

Quantitative Analysis

The chromatogram of the GC-MS analysis of the methanol extract presented in Figure 3 reveals the presence of 18 bioactive compounds shown in Table 2 is largely dominated by fatty acids, fatty acid derivatives, and the alkaloid capsaicin. This profile provides a basis for the cockroach mortality observed in the bioassay and aligns with prior evidence that methanolic extracts of *Capsicum* species possess potent insecticidal properties.

The extract was found to be rich in oleic acid (44.27%) and palmitic acid (20.27%), with smaller amounts of eicosanoic and tetradecanoic acids. Fatty acids are known to disrupt insect cuticular lipids, impair membrane function, and cause desiccation and death. Aguilar-Marcelino et al. (2022) reported the larvicidal effects of palmitic and linoleic acids on *Spodoptera frugiperda*. In stored product pests, Akinneye et al. (2013) similarly observed contact toxicity of saturated fatty acids. The high abundance of oleic and palmitic acids in this study therefore suggests that fatty acids were the primary drivers of the strong contact insecticidal activity recorded in cockroaches. Notably, the concentrations observed here (44% oleic acid; 20% palmitic acid) are higher than those reported in other *Capsicum* extracts (Liu et al., 2012), which may explain the high mortality rates observed.

Although Capsaicin was present at a moderate level (6.47%), capsaicin plays a crucial role in insecticidal activity. Capsaicin is a known neurotoxic agent that disrupt neuronal transmission by modulating ion channels, causing insect paralysis and death. Kamezaki et al. 2025 confirmed its ability to paralyze cockroach nerve cords, while Scott et al. (2008) highlighted its dual role as a repellent and contact toxicant. In the present study, capsaicin likely contributed to the rapid knockdown effects and complete mortality (100% at 80% extract concentration), acting synergistically with fatty acids. The finding supports earlier reports that methanol efficiently extracts capsaicinoids, unlike less polar solvents Adesina, (2017), which explains why the methanol extract performed significantly better than the ethyl acetate extract in insecticidal activity.

Other detected compounds that may have contributed synergistically to insecticidal activity include fatty acid derivatives (amides, esters, and aldehydes) and terpenoids, though individually present at lower levels, may enhance overall toxicity. Fatty acid amides (octadecanamide) act as neuromodulators Fowler, (2002), while aldehydes and esters have been associated with anti-feedant and growth-regulating effects (Liu et al., 2012). The terpenoid derivative detected (3.40%) is consistent with reports that monoterpenes such as linalool and eugenol act as fumigants and exhibit knockdown effects against cockroaches and beetles (Ogendo et al., 2015; Shaaya et al., 1997). These compounds may therefore account for the sluggishness and immobility observed in reated cockroaches prior to death.

CONCLUSION

The anti-insecticidal properties of ethylacetate and methanolic extracts of *Capsicum annuum* pepper was investigated. The study establishes that the methanolic extract of *Capsicum annuum* fruit extract is a potent insecticidal agent against the American cockroach (*Periplaneta americana*), with its efficacy attributable to the synergistic action of cuticle-disrupting fatty acids and neurotoxic capsaicin. The combination of these compounds creates a dual mechanism that compromises the insect's protective barrier and nervous system, resulting in rapid mortality. These findings highlight the potential of *C. annuum* as a viable, natural alternative to synthetic insecticides, particularly for domestic and public-health pest control where safety and environmental sustainability are paramount. The identification of fatty acids as major contributors alongside capsaicin further expands the understanding of the phytochemical basis of insecticidal activity in pepper extracts. To strengthen and advance this research, future work should fractionate the methanolic extract to isolate and identify the most bioactive fractions, develop and test formulated products (e.g., sprays) suitable for household or commercial use. Evaluation of mammalian toxicity and environmental safety to ensure suitability for integrated pest management programs

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