Free Radicals and Antioxidants., 2025; 15(2):55-65.
https://www.antiox.org

Original Article

Insecticidal and Repellent Activity of Fatty Acids Derived from *Ocimum americanum* (Lamiaceae) Plant Extracts against *Culex quinquefasciatus* Mosquitoes (Diptera: Culicidae)

Kamesh R, Kaniselvam K, Naveen V, Ramakrishnan P, Ranjithkumar B, Sethu Akash S, Subala Subramanian Panchuravindra Rajan*

Department of Biotechnology, Ayya Nadar Janaki Ammal College (Autonomous), Sivakasi, Tamil Nadu, INDIA.

ABSTRACT

Background: Mosquito control efforts are increasingly challenged by the growing resistance to synthetic insecticides. Plant-based insecticides offer a promising alternative for biological control. This study assesses the adulticidal potential of *Ocimum americanum* extracts against and *Culex quinquefasciatus*. **Materials and Methods:** Leaves of *O. americanum* extracted using hexane, ethyl acetate, and methanol in a Soxhlet apparatus. The extracts were characterized by TLC and GC-MS, and evaluated for antioxidant (DPPH, hydroxyl, ABTS), antimicrobial, and larvicidal activities against *C. quinquefasciatus* following standard protocols. Larvicidal toxicity was analyzed using probit analysis to determine LC_{50} and LC_{90} values. Bioactive compounds identified by GC-MS were further subjected to molecular docking studies to predict protein-ligand interactions. **Results:** The hexane extract showed the greatest efficacy against *C. quinquefasciatus*, with LC_{50} and LC_{90} values of 4.714 mg/ml (2.8732-6.6121) and 7.436 mg/ml (5.361-12.370) for *C. quinquefasciatus*, respectively. The plant extracts showed elevated antioxidant activity, as indicated by higher values in the DPPH (55%), ABTS (83%), and hydrogen peroxide (80%) assays. The plant extracts has the high antimicrobial activity with *E. coli* (32.3%), *Klebsiella* (37.2%), and *Streptococcus* sp. (46%). TLC analysis of the hexane extract showed the various spots that are analyzed by GC-MS with 25 compounds. The ligands derived from *O. americanum* were docked with the dengue virus 3DXL protein using the PyRx platform. Prior to docking, cofactors, water molecules, and existing ligands were removed using Molegro Molecular Viewer. *O. americanum* ligands were docked with the dengue virus 4FD6 protein using AutoDock 4.2, and the corresponding complexes were also examined using PyMOL. **Conclusion:** Overall, these findings indicate that *O. americanum* leaf extracts hold promise as an eco-friendly option for mosquito control.

Keywords: *Ocimum americanum*, Antimicrobial, Antioxidant, GC-MS, Larvicidal.

Correspondence:
Dr. Subala Subramanian Panchuravindra Rajan
Assistant Professor, Department of Biotechnology, Ayya Nadar Janaki Ammal College (Autonomous), Sivakasi-626125, Tamil Nadu, INDIA.
Email: subalachitra91@gmail.com

Received: 24-01-2026;
Revised: 12-03-2026;
Accepted: 09-04-2026.

INTRODUCTION

Increased globalization, climate change, and human mobility have led to the ecological expansion of highly invasive species (Dhimal *et al*., 2015). These invasive organisms, among which are arthropods, cause diseases that are deadly and lead to epidemics or pandemics.[1] Most important in that regard are mosquitoes (Diptera: Culicidae) that act as vectors of a variety of harmful pathogens and parasites.[2,3] Of these, the genera *Anopheles, Aedes*, and *Culex* are the most problematic vectors of most important pathogens, causing diseases such as malaria, Dengue, yellow fever, filariasis, Japanese encephalitis, and Zika. There are various approaches being used to control mosquito-borne diseases and these include the use of several behavioral, chemical, biological, and mechanical methods. Various success levels have been achieved but these have been limited by a lack of effective vaccines and delays in the development of antiviral drugs for most arboviruses.[4]

The increasing insecticide resistance in the mosquito vectors, hampering the development of new drugs and vaccines, curtails these efforts. The failing vector control strategies, the proliferation of invasive mosquitoes as well as increased contact between humans and these vectors have led to the constant re-emergence of arboviruses.[5] Mosquito control programs are therefore faced with significant and rapidly changing challenges that necessitate the development of new approaches in the detection and control of diseases as a new requirement in public health. The development of new drugs with increased

OPEN ACCESS

Manuscript TECHNOMEDIA

DOI: 10.5530/fra.2025.2.8

Publishing Partner : Manuscript Technomedia. [www.mstechnomedia.com]

activity, decreased toxicity, and sustained release; green synthesis of new repellent formulations based on natural or synthetic compounds with repellent, adulticidal, or larvicidal activities.[6] and the development of biosensors capable of rapidly detecting and diagnosing mosquito-borne viral diseases. Plants are the promising alternatives to control the different mosquito-borne diseases, improved efficacy and bioavailability of products and drugs that require optimal doses and consequently fewer adverse effects.[7]

Mosquitoes belonging to genera *Anopheles, Culex* and *Aedes* are vectors of various diseases such as malaria, filariasis, Japanese encephalitis, dengue, yellow fever and chikungunya.[8] Presently, organochlorine, organophosphate and synthetic pyrethroid insecticides are being used for public health sprays for control of mosquitoes. Continuous changes in the insecticide exposure result in multiple insecticide resistance in mosquito vectors.[9] Future of vector control mainly relies on the strategies for the management of insecticide resistance in mosquito vectors. The most important aspect of the management of resistance is to either avoid or delay the onset of resistance by effectively manipulating or influencing the factors responsible for the development of resistance. One of the possible ways of avoiding development of insecticide resistance in the field is using a novel botanical compound and bioactive secondary metabolites from plants.[10,11]

Plants having a rich source of secondary metabolites produce good larvicidal efficacy against *Culex quinquefasciatus* and *Aedes aegypti* mosquitoes. Suganya *et al*., 2014 reported that *Cipadessa baccifera* plant extract had a good adulticidal activity against mosquito vectors.[12] *Ocimum canum* (Sims) has cosmopolitan distribution, its leaves and stems are used in the folk medicine for fever, throat pain, stomach pain, diarrhoea, skin diseases and as insect repellent. The whole plant is used as stomachic and in treating sunstroke, headache and influenza. Leaves are used for abdominal pains, sore eyes, ear troubles, coughs and blocked noses. An infusion of the leaves is used as a disinfectant and as an insecticide.[13] Traditionally, basil has been used as a medicinal plant in the treatment of headaches, coughs, diarrhoea, constipation, warts, worms and kidney malfunction.[14] The present study aimed to assess the assayed larvicidal potential of different extracts of *Ocimum amaericanum* against *C. quinquefasciatus* mosquitoes.

MATERIALS AND METHODS

Collection of plants

The plant leaves of *Ocimum americanum* (Figure 1) were sampled from Sanjeevi Hills of Western Ghats in a region that is rich in biodiversity and indigenous populations. Sanjeevi Hills are located in the Rajapalayam, Virudhunagar district which lies between 9.4653o latitude, 77.5275o longitude and the voucher specimen was deposited in the herbarium.

Plant extracts preparations

The leaves were shade dried for 7-10 days. The dried leaves were powdered mechanically using a commercial electrical stainless-steel blender, and the powdered leaves (10 g) were extracted with Hexane (100 mL), ethyl acetate (100 mL), and methanol (100 mL) in a Soxhlet apparatus (boiling point range 50-80°C) for 8 hr. The extract was filtered using Whatman no.1 filter paper and the solutions store at 4°C.

Thin Layer Chromatographic (TLC) analysis

Ethanol extract of each plant sample was subjected to TLC studies. For the TLC analysis, the dimensional ascending method was used (Gujjeti and Mamidala, 2013). 20×20 cm TLC plate coated with silica gel 60G F254 (Merk, India), was cut with a scissor in 14×3 cm. The plate was marked with the pencil softly 1.5 cm far from the both bottom and top. Glass capillaries were used to spot the sample on the TLC plate on the pencil marked bottom line. Then it was placed in the fume hood to dry the plate and loaded the sample again until a dark spot is obtained. Then the solvent Hexane: Ethyl acetate: Acetic acid (4:4:2) about 20 mL was taken in the chamber. The plate was placed in the chamber lining on the top. After the run, plates were dried in the fume hood and then used to detect the spots. All the plates were dried and detected the spots with the help of UV light at 254 nm and 366 nm.[15] The movement of the active compound was expressed by the Retention factor (R_f).

$$Rf = \frac{\text{Distance traveled by solute}}{\text{Distance traveled by solvent}}$$

Antioxidant assays

2,2-Diphenyl-1-Picrylhydrazyl assay (DPPH) assay

DPPH study was performed by ZnO-NPs. In briefly, 1.0 mL of DPPH solution (0.2 mM) was added with 1 mL of three plant extracts and stand for 30 min under dark conditions. After 30 min the absorbance was read at 517 nm.

$$\text{DPPH scavenging effect (\%)} = \text{A0-A1/A0} \times 100$$

A 0 - Control, A1- Plant extracts.

Hydroxyl scavenging assay

As regards with 1 mL of three plant extracts were mixed into 3 mL of hydrogen peroxide solution (1.0 mL of 1.5 mM FeSO4, 0.7 mL of 6 mM hydrogen peroxide and 0.3 mL of 20 mM sodium salicylate). The reaction mixture is incubated for 37°C as well as the absorbance was measured on 562 nm.

$$\text{Hydroxyl Scavenging activity} = [1- (A1-A2)/A0] \times 100$$

A0 - Control, A1 - Plant extracts, and A2 - absorbance without sodium salicylate.

2, 2′- Azino-bis-3-Ethylbenzothiazoline-6-Sulfonic acid (ABTS) assay

The reaction was began via the adding of 1.0 mL of diluted ABTS towards 10 µL of three plant extracts and also 10 µL of ethanol as a control. The absorbance was read at 734 nm after 6 min.

$$IC\ (\%) = [A0 - A1/ A0] \times 100$$

IC - Inhibition concentration; A0 - Control reaction; A1- Plant extracts.

Maintenance mosquito culture

C. quinquefasciatus mosquito larvae were collected from the ICMR- Vector Control Research Centre (VCRC), Madurai, Tamil Nadu, India. The larvae were kept in plastic trays containing tap water and were maintained in the laboratory, and all the experiments were carried out at 27±2°C and 75-85% relative humidity under 14:10 light and dark photoperiod cycles. Larvae were fed with dog biscuit and yeast powder in the ratio of 3:1. They were maintained and reared in the laboratory.

Larvicidal bioassay

WHO standard protocol for evaluating the larvicides was used to evaluate the plant extracts toxicity against mosquito larvae (WHO, 2005), with some minor modifications done by previous studies. Twenty five (25) fourth instar larvae were transferred to a small disposable paper cups with a mixture of 249 mL of water and 1.0 mL of proposed plant extract. The control used as DMSO. Dosage evaluation started with the lowest dosage of 0.01mg/mL to 2 mg/mL. Larvae mortality was monitored after 24 hr of exposure in all replicates of each dosage. The percentage mortality was reported from three replicates. The LC_{50} (Lethal Concentration that kills 50% of the exposed larvae) and LC_{90} values were calculated after 24 hr using probit analysis method.[12]

Antimicrobial Activity

The agar well diffusion method is used to assess the antibacterial efficacy of three different plant extracts. This technique involves inoculating nutrient agar plates with bacterial strains including *Escherichia coli, Staphylococcus pyogenes* and *Klebsiella pneumoniae* and, the positive control as tetracyclin. Different concentrations of the extract were added to wells that have been made in the agar. The zone of inhibition surrounding each well is measured to assess the antibacterial impact after the plates are incubated for 24 hr at 37°C. Greater antibacterial activity is indicated by larger inhibition zones. The potential of ZnONPs as antibacterial agents is demonstrated by this assay.

Gas Chromatography Mass Spectrometry (GC-MS) analysis

The plant extracts of *Ocimum americanum* were analysed using gas chromatography (Polaris Q Ion Trap GC/FID) and mass spectrometry (Perkin Elmer Q-700 equipment). The column temperature programme was 35°C for 2 min, increased to 180°C at 4°C/min, then increased to 280°C at 20°C/min. Helium was used as a carrier gas at a 0.9 mL/min. The best mass spectrum was obtained at 70 eV ionization voltage in the machine. Individual compounds were identified using Wiley/NBS Registry of mass spectral database, the NIST machine (version 3.0) database. The Retention Time (RT) and Kovats Index (KI) values of several authentic reference compounds were compared with isolated compounds for identification.

Statistical analysis

The mean mortality data were analysed using probit analysis for calculating LC_{50}, LC_{90} and other statistics at 95% confidence interval limits of upper and lower confidence limits. The Chi-square values were calculated using the SPSS Statistical software package version 16.0 for windows.

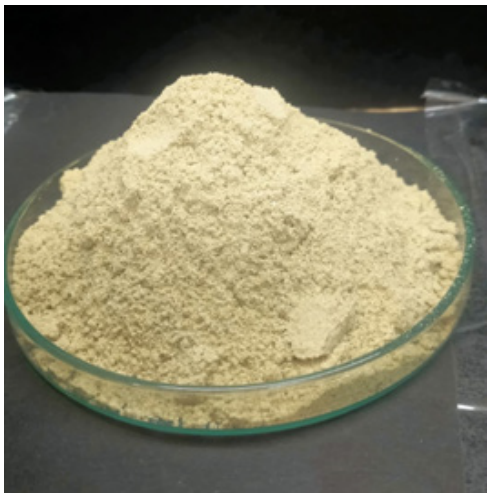


Figure 1: *Ocimum americanum* leaf powder.

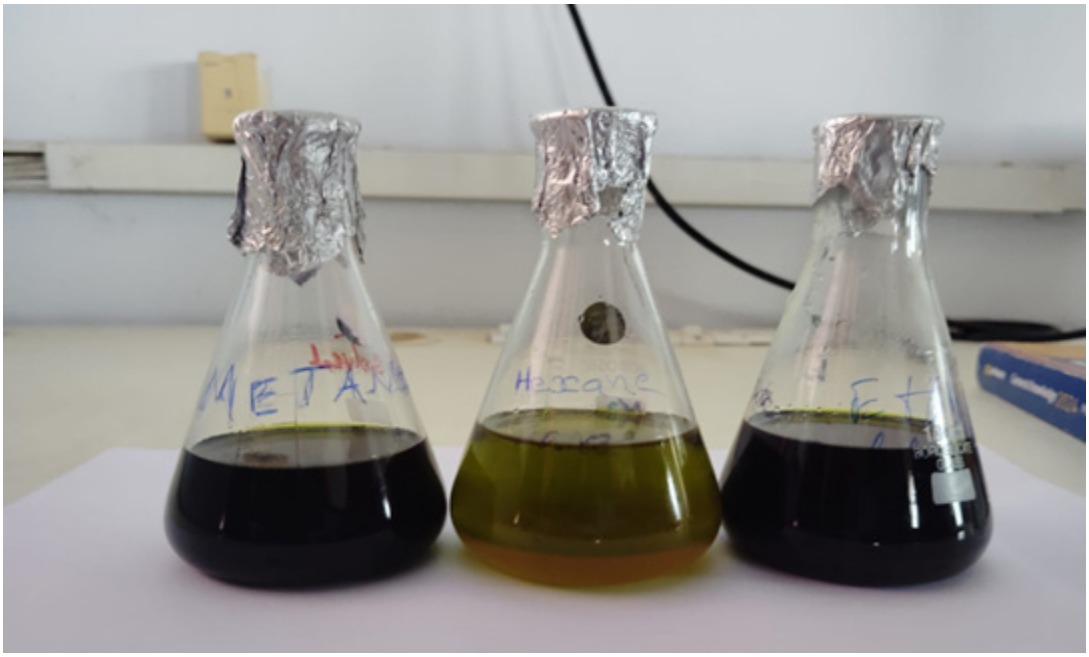


Figure 2: Methanol, Hexane and Ethyl acetate extracts from *Ocimum americanum*.

Molecular docking analysis

The protein data were used to retrieve the crystal structures, which were then assembled using a protein preparation wizard. The chemical structure that had been isolated was verified for accuracy, and hydrogen atoms were added to neutralize the side chains that are not in close proximity to the binding cavity or involved in forming a salt bridge. The site map module, which utilizes novel analytical and search methods to generate binding site information, predicted the active site of the targeted protein (CID: 107568). During the initial search step of site map prediction, grid points were characterized. The protein has multiple target binding sites on its surface that can bind the ligand to the receptor.[16]

Statistical analysis

Mortality was calculated using the Abbott formula (Abbott, 1925). A one-way ANOVA was used to calculate the variances between treatments, and the Tukey's HSD test was done to categorize the homogeneous types of data sets using SPSS software. Using the PRISM, Version 8 software, the data from enzyme assays were subjected to analysis of variance, followed by Dunnett's multiple comparison test (Graph Pad Software Inc, USA). *p*-values of 0.05 were measured as statistically significant.

RESULTS

Plant leaves were dried under shade for a period of 7 to 10 days in the shade at environmental temperatures (27-37°C daytime). A blander was used for powdering the dried leaves of which three hundred grams were extracted separately using the following chemicals for eight hours, chloroform, ethyl acetate, acetone and methanol in a Soxhlet apparatus with boiling point ranging between 50-80°C (Figure 2). The leaf extracts were concentrated at a pressure of 22-26 mm Hg at 45°C. The obtained active ingredients were stored in a room temperature. The antioxidant potential of *Ocimum americanum* leaf extract was determined by DPPH, ABTS and H_2O_2 assays. In this study, DPPH activity was dose depended manner. Antioxidant assay showed superior activity and evidenced by DPPH, ABTS and H_2O_2 radical assays. The percentage of inhibition of DPPH radical scavenging activity is shown in Figure 3a-c.

TLC analysis as done to separate the phytochemicals present in the *Ocimum americanum* plant extract. Here we found three spots in ethyl acetate extract. Further the major one spot was sent into GC-MS analysis (Figure 4). The agar well diffusion method was used to conduct the antimicrobial activity study. The impact of leaf extract was examined with *Escherichia coli, Streptococcus pyogenes, Klebsiella pnemoniae*. Compared to other strains, it is most sensitive to *E. coli*, with a maximal zone of inhibition measuring 31 mm in diameter. The antimicrobial activity of *Ocimum americanum* leaf extracts were evaluated against *E. coli, K. pneumoniae, Streptococcus* with the maximum zone of inhibition were 31 mm, 27 mm, 30 mm, respectively (Figure 5).

The larvicidal activity results were obtained from bioassays of the plant extracts by hexane, methanol, and ethyl acetate solvent leaf extracts of important vector mosquitoes in different extracts tested (Figure 6). The highest larvicidal activity was observed in hexane extracted compounds against *C. quinquefasciatus*, with LC_{50} and LC_{90} values of 4.714 mg/mL (2.8732-6.6121) and 7.436 mg/mL (5.361-12.370), respectively. The 95% confidence limits LC_{50} (95%CI) and LC_{90} (95%CI), chi-square and degree of

freedom (d_f) values were also calculated. In control assays we did not find any significant mortality (Table 1).

The GC-MS is an essential technique that is used to detect and confirm the extract. The phytochemical compounds are identified and confirmed based on the retention time and molecular formula and molecular weight (Table 2). The GC-MS chromatogram of the leaf extract of *O. americanum* shows 25 peaks (Figure 7) which constituents respectively. Further, The GC-MS analysis compound 3D structure was derived from the PubChem database.

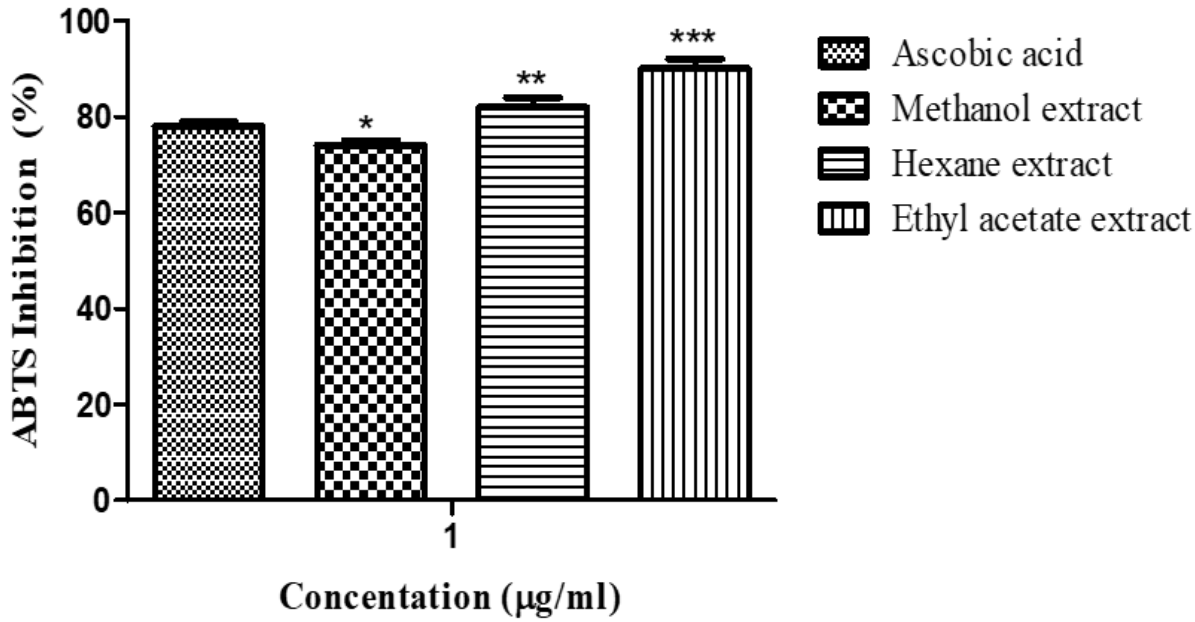
Molecular Docking

In this molecular docking study, the GC-MS analysis of *O. americanum* plant extract phytochemical compound is used as a ligand for docking studies based on the Lipinski rule 5. The ligands belonging to *O. americanum* was docked with 3DXL protein of dengue virus using Pyrx tool, also the cofactors, water molecules, and ligand are removed in Molegro Molecular Viewer. The complex structure was visualized in the Pymol software tool and the ligand belonging to *O. americanum* was docked with 4FD6 protein of dengue virus using AutoDock 4.2 tool, also the complex structure was visualized in Pymol (Figures 8 and 9). The predicted complex binding energy values are reported.

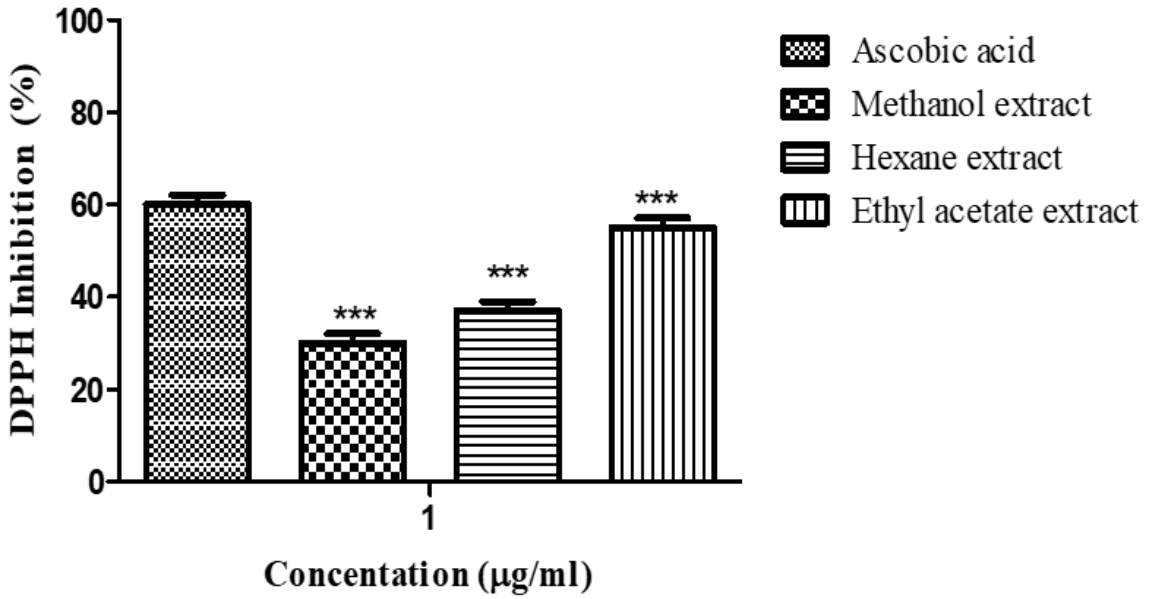
Table 1: Larvicidal activity of *Ocimum americanum* plant extracts against *Culex quinquefasciatus* mosquito vectors.

Sample	n[a]	LC_{50} (mg/mL) (95%CL)	LC_{90} (mg/mL) (95%CL)	X^2	d_f
Hexane Plant extract	600	4.714 (2.8732-6.6121)	7.436 (5.361-12.370)	0.579	3
Ethyl acetate Plant extract	600	10.135 (9.811-11.661)	15.13 (13.513-16.823)	0.426	3
Methanol Plant extract	600	5.602 (5.116-103.82)	8.59 (12.486-15.129)	0.453	3

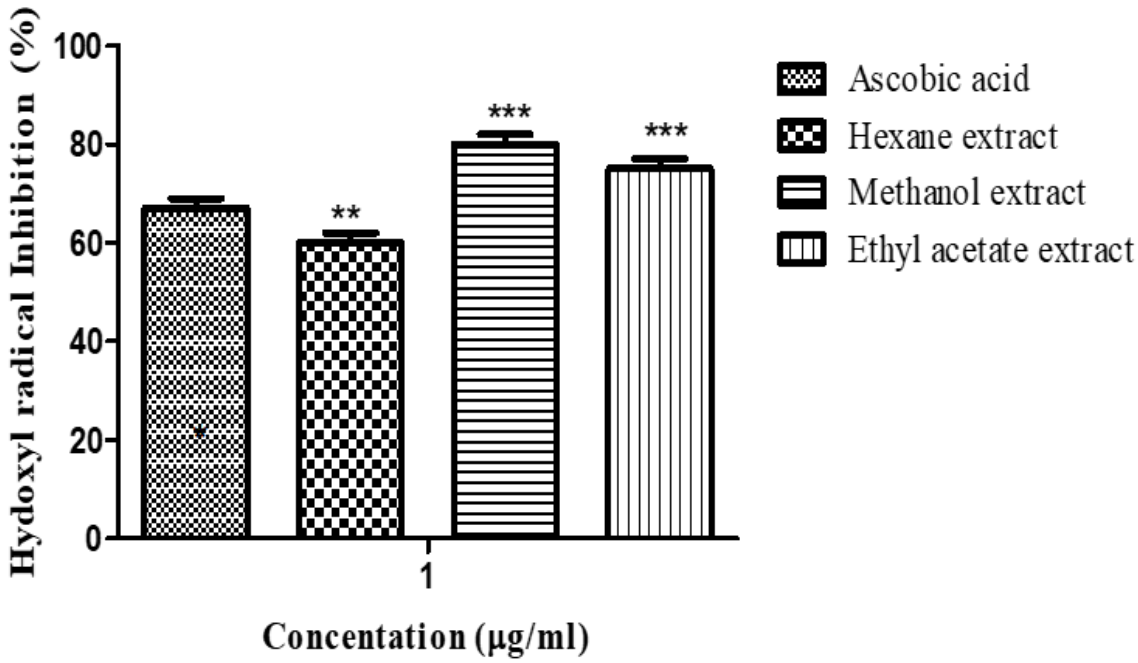
n[a]-total number of mosquitoes larvae used; LC50-Lethal Concentration 50% mortality, LC90-Lethal concentration 90% mortality, LCL-Lower confidence limits, UCL-Upper confidence limits, X^2-chi-square, df- degrees of freedom (Note: Chi square values with a static are significant P<0.05).



(a)



(b)



(c)

Figure 3: Antioxidant activity of the synthesized Plant extracts by *Ocimum americanum* leaf extract. a) DPPH, b) ABTS, c) Hydoxyl radical scavenging assay. The values are expressed as mean ± SD values and analysed by two-way analysis of variance (ANOVA) followed by Bonferroni multiple comparison tests (*; P<0.05 significance; **; P<0.01 significance; ***; p<0.001 significance) using Prism 8.0 software. Asterisk (*) indicates significant different among treatments with respect to ascorbic acid.

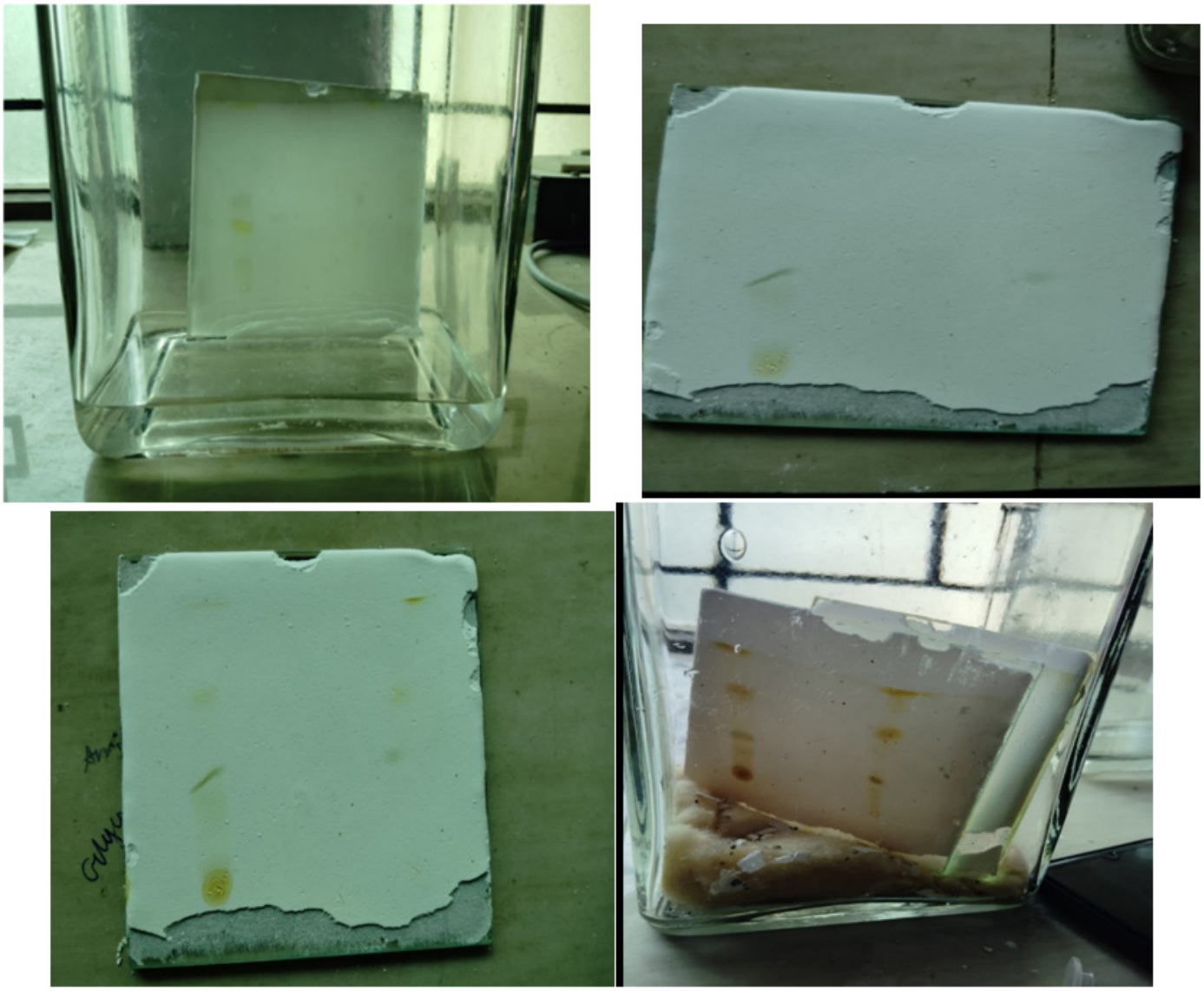


Figure 4: TLC analysis of *Ocimum americanum* plant extract.

DISCUSSION

Kamaraj *et al.*, (2009) reported high larval mortality in methanol extracts of *Cryptocory neauriculata* and *Solanum torvum* against the larvae of *Anopheles subpictus* (LC_{50}: 44.21, 44.69, 53.16, 41.07, 35.32, 28.90 and 44.40 ppm; LC_{90}: 187.31, 188.29, 233.18, 142.66, 151.60, 121.05 and 192.11 ppm, respectively) and *C. tritaeniorhynchus* (LC_{50}: 69.83, 51.29, 81.24, 71.79, 44.42, 84.47 and 65.35 ppm; LC_{90}: 335.26, 245.63, 300.45, 361.83, 185.09, 351.41 and 302.42 ppm, respectively. Bioefficacy of plant extracts differs from species to species of plants parts.[17]

The variation in adulticidal activity of these extracts is probably due to variation in the types and levels of active ingredients that depend not only on the genetic characteristics of the plant species but also on the conditions under which they were grown and harvested. Murugan *et al.*, reported that *Citrus sinensis* plant ethanol extract showing high adult mortality was found with very low LC_{50} and LC_{90} values against *An. stephensi* and *Ae. aegypti*.[18] Similarly, in our experiment smoke toxicity observations were taken at 10-min intervals for 40 min and the mortality data were recorded. *O. canum* leaf powder produces toxicity against 93% *C. quinquefasciatus*, 74% *Ae. aegypti* and 79% *An. stephensi* adult mosquitoes, respectively, and 100% mortality was recorded in the commercial mosquito control. Our results suggest that *O. canum* leaf extract can control mosquito larvae, and mosquito coil developed using *O. canum* leaf powder is a good repellent against mosquitoes. Similarly, we reported that plant leaf powder based smoke repellency had a good adulticidal against mosquitoes.[19]

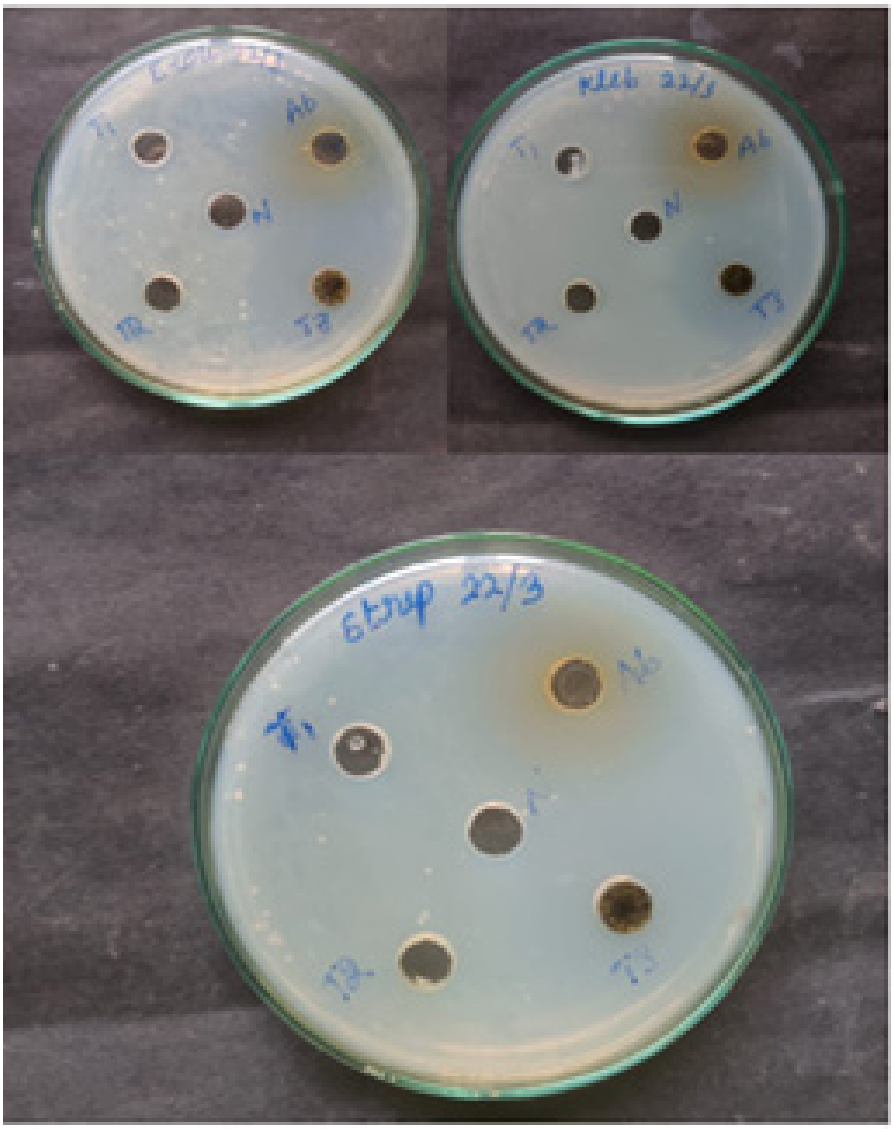


Figure 5: Antimicrobial activity of *Ocimum americanum* plant extract.

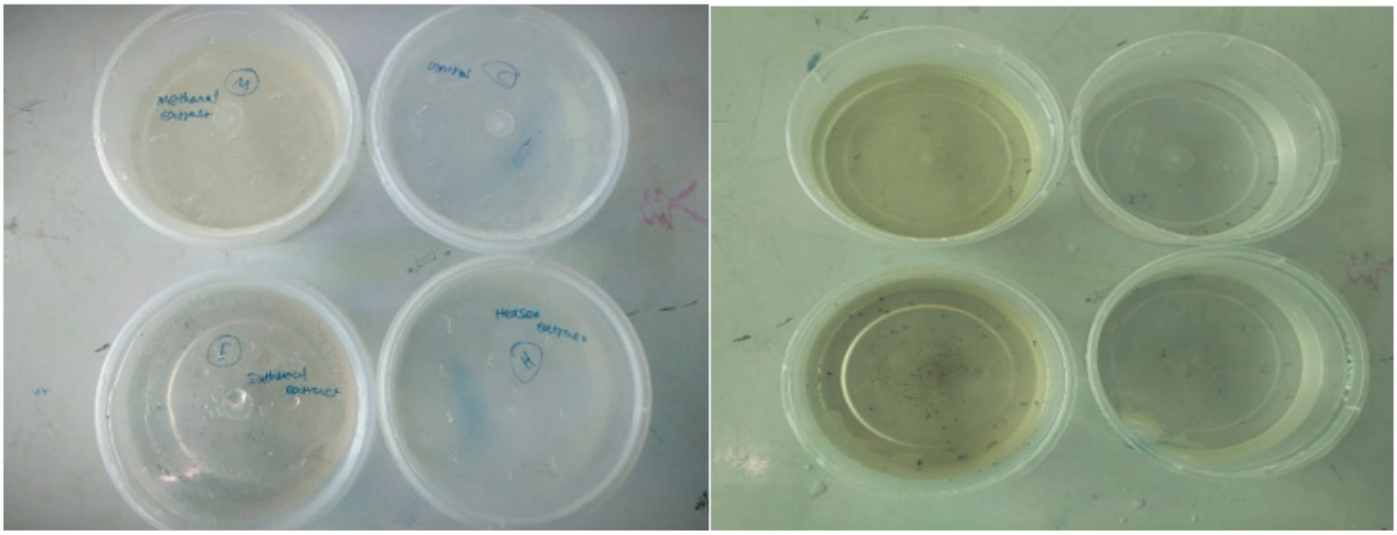


Figure 6: Larvicidal activity.

Table 2: GC-MS Results of *O. americanum* plant extract.

Sl. No.	Rt	Compound name	Molecular formula	Molecular Weight (g/mol)
1.	3.811	Carbonochloridic acid, decyl ester	$C_{10}H_{21}ClO_2$	208.73
2.	4.138	C:\Database\NIST11.L 3-Isopropoxy-1,1,1,5,5,5-hexamethy	$C_{12}H_{27}NO$	201.35
3.	4.833	Trimethylsilyl 3-methyl-4-[(trimethylsilyl)oxy]benzoate	$C_{14}H_{22}O_3Si_2$	310.56
4.	5.513	Eicosane 6,6-Diethylhoctadecane	$C_{20}H_{42}$	282.57
5.	5.705	Eicosane 11H Dibenzo[b,e][1,4]diazepinne, 5,10-dihydro-5-[3-(methylamino)propyl]-	$C_{20}H_{42}$	282.57
6	5.819	Eicosane, 9-octyl-	$C_{20}H_{42}$	282.57
7.	6.109	3-Ethoxy-1,1,1,5,5,5-hexamethyl-3(trimethylsiloxy)trisiloxane	$C_{18}H_{20}N_2$	264.37
8.	6.270	Di-n-decylsulfone	$C_{20}H_{42}O_2S$	346.61
9.	6.358	Ethanone, 1-[4-[4-(2-hydroxyethyl)	$C_{10}H_{12}O_2$	164.20
10.	6.447	Tetradecane	$C_{14}H_{30}$	198.39
11.	6.530	Octadecane, 1-iodo-	$C_{18}H_{37}I$	396.39
12.	6.779	Heneicosane	$C_{21}H_{44}$	296.58
13.	7.033	2-methyltetracosane	C_2yHy_2	352.68
14.	7.702	Di-n-decylsulfone	$C_{20}H_{42}O_2S$	346.61
15.	9.005	4-Amino-5-(4-acetylphenylazo)benzo	$C_{14}H_{13}N_3O$	239.27
16.	9.269	Trimethylsilyl 3-methyl-4-[(trimethylsilyl)oxy]benzoate	$C_{14}H_{24}O_4Si_2$	312.51
17.	9.695	4-(2-Hydroxyethylamino)-1-oxo-2-phenyl-1,2-dihydrophthalazine	$C_{16}H_1yN_3O_2$	281.31
18.	9.850	Phenol, 2-[4-(2-hydroxyethylamino)	$C_8H_{11}NO_2$	153.18
19.	10.997	2-[p-Fluorophenyl]-8-methylcinchoninic acid	$C_{17}H_{13}FNO_2$	281.29
20.	11.199	Trimethylsilyl 3-methyl-4-[(trimethylsilyl)oxy]benzoate	$C_{14}H_{24}O_3Si_2$	296.51
21.	11.786	Cyclotetrasiloxane, octamethyl-	$C_8H_{24}O_4Si_4$	296.62
22.	11.952	6-Chloro-3-ethyl-2-methyl-4-phenylquinoline	$C_{18}H_{16}ClN$	281.78
23.	15.625	2(1H)-Quinolinone, 4-hydroxy-6-methoxy-3-(phenylmethyl)-	$C_{17}H_1yNO_3$	281.31
24.	16.658	6-Methoxy-2-phenyl-hexahydropyrano	$C_{14}H_{18}O_6$	282.30
25.	18.464	5-Amino-2-(4-chlorophenyl)-7-methy l-6-indolizinecarbonitrile	$C_{16}H_{12}ClN_3$	281.75

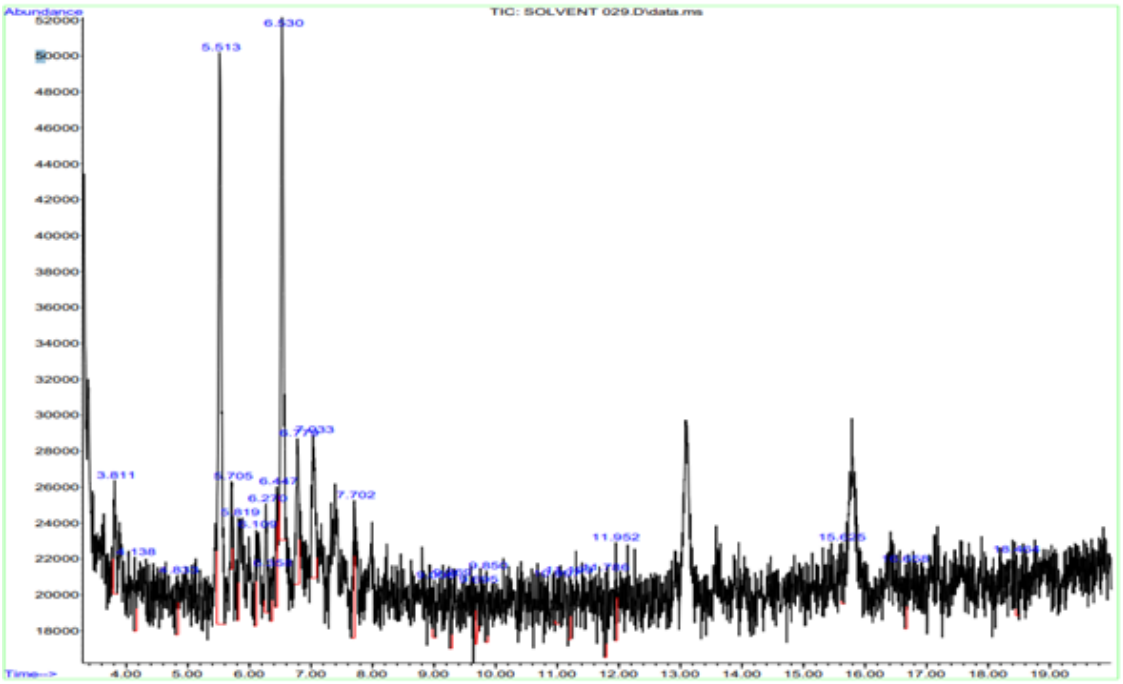


Figure 7: GC-MS Results of *O. americanum* plant extract.

Figure 8: Molecular docking with Ligands of Tetradecane 3DXL protein of dengue virus.

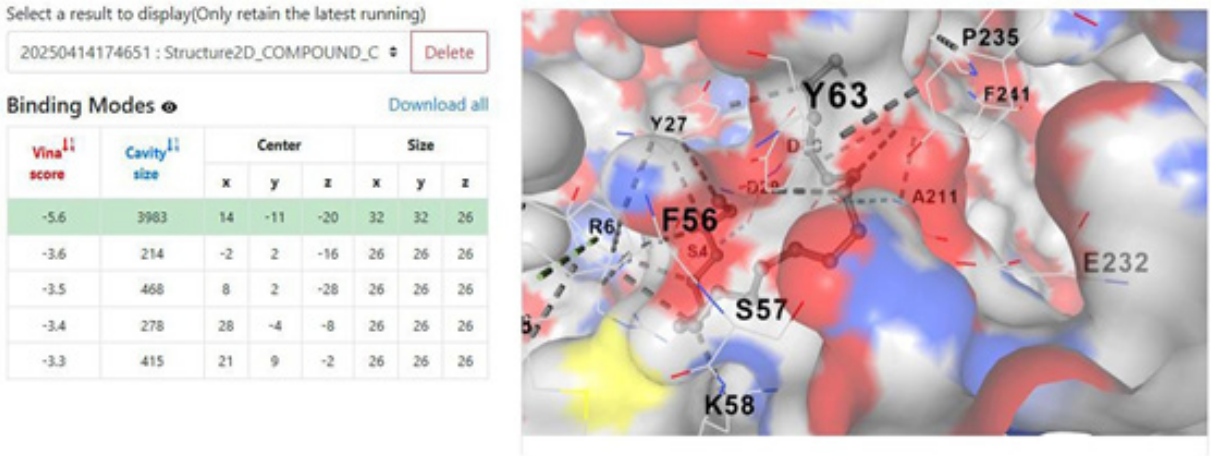


Figure 9: Molecular docking with Ligands of Heneicosane 3DXL protein of dengue virus.

CONCLUSION

In conclusion, GC-MS analysis revealed that the predominant compounds in the leaf extracts included benzene, 1,2,3-trimethoxy-5-(2-propenyl), Z,Z-6,28-heptatriactontadien-2-one, 2-allyl-4-methylphenol, and 2,6,10,14,18,22-tetracosahexaene, 2,6,10,15,19,23-hexamethyl. The larvicidal bioassays demonstrated that *O. americanum* leaf extracts exhibited remarkable toxicity against the larvae of the mosquito vector species. Antimicrobial and antioxidant assays with *O. americanum* leaf extract showed the significant antimicrobial and antioxidant properties. These results indicate that *O. americanum* leaf extracts and their bioactive components hold promise as effective and environmentally safe larvicidal agents for mosquito control. However, additional studies on their mode of action, effects on non-target organisms, and performance under field conditions are required before commercial application. Overall, these findings contribute to the development of selective, biodegradable, plant-based mosquito larval control strategies.

ACKNOWLEDGEMENT

The authors recognize and thank the Department of Biotechnology, Ayya Nadar Janaki Ammal College (Autonomous), Sivakasi, Tamil Nadu, India, for providing infrastructural facilities.

ABBREVIATIONS

ABTS: 2, 2′- Azino-bis-3-Ethylbenzothiazoline-6-Sulfonic acid; **ANOVA:** Analysis of Variance; **CI:** Confidence Interval; **d_f:** Degrees of Freedom; **DMSO:** Dimethyl sulfoxide; **DPPH:** 2,2-Diphenyl-1-Picrylhydrazyl; **GC-MS:** Gas Chromatography Mass Spectrometry; **HSD:** Honestly Significant Difference; **IC:** Inhibition concentration; **ICMR:** Indian Council of Medical Research; **KI:** Kovats Index; **LC_{50}:** Lethal Concentration that kills 50% of the exposed larvae; **LC_{90}:** Lethal Concentration that kills 90% of the exposed larvae; **LCL:** Lower confidence limits; **Rf:** Retention factor; **RT:** Retention Time; **TLC:** Thin Layer Chromatography; **UCL:** Upper confidence limits; **VCRC:** Vector Control Research Centre; **WHO:** World Health Organization; **ZnO-NPs:** Zinc Oxide Nanoparticles.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. Gubler DA, Makowski LM, Troche SJ, Schlegel K. Loneliness and Well-Being During the Covid-19 Pandemic: Associations with Personality and Emotion Regulation. J Happiness Stud. 2021;22(5):2323-42.
2. Benelli G, Jeffries CL, Walker T. Biological control of mosquito vectors: Past, present, and future. Insects. 2016;7:52.
3. Benelli G, Mehlhorn H. Declining malaria, rising of dengue and Zika virus: Insights for mosquito vector control. Parasitol Res. 2016;115:1747-54.
4. Saxena SK, Elahi A, Gadugu S, Prasad AK. Zika virus outbreak: An overview of the experimental therapeutics and treatment. Virus Dis. 2016;27:111-5.
5. Batool K, Alam I, Wu S, Liu W, Zhao G, Chen M, *et al.* Transcriptomic analysis of Aedes aegypti in response to mosquitocidal Bacillus thuringiensis LLP29 toxin. Sci Rep. 2018;8:12650.
6. Magro M, Bramuzzo S, Baratella D, Ugolotti J, Zoppellaro G, Chemello G, *et al.* Self-assembly of chlorin-e6 on γ-Fe_2O_3 nanoparticles: Application for larvicidal activity against Aedes aegypti. J Photochem Photobiol B. 2019;194:21-31.
7. Duran N, Islan GA, Duran M, Castro GR. Nanobiotechnology solutions against Aedes aegypti. SAE Int J Mater Manuf. 2015;9:158-70.
8. Redwane A, Lazrek HB, Bouallam S, Markouk M, Amarouch H, Jana M. Larvicidal activity of extracts from *Querus lusitania* var *Infectoria gals* (oliv). J Ethno Pharmacol, 2002;79:261-3
9. Şengül Demirak MŞ, Canpolat E. Plant-Based Bioinsecticides for Mosquito Control: Impact on Insecticide Resistance and Disease Transmission. Insects. 2022;13(2):162.
10. Amer A, Mehlhorn H. Repellency effect of forty-one essential oils against Aedes, Anopheles, and Culex mosquitoes. Parasitol Res. 2006;99(4):478-90.
11. Raghavendra K, Rahi M, Verma V, Velamuri PS, Kamaraju D, Baruah K, Chhibber-Goel J, Sharma A. Insecticide resistance status of malaria vectors in the malaria endemic states of India: implications and way forward for malaria elimination. Heliyon. 2022;8(12).
12. Suganya P, Vaseeharan B, Vijayakumar S, Balan B, Govindarajan M, Alharbi NS, *et al.* Biopolymer zein-coated gold nanoparticles: Synthesis, antibacterial potential, toxicity and histopathological effects against the Zika virus vector Aedes aegypti. J Photochem Photobiol B. 2017;173:404-11.
13. Kaaya GP, Seshu-Reddy KV, Kokwaro ED, Munyinyi DM. Pathogenicity of *Beauveria bassiana, Metarhizium anisopliae* and *Serratia marcescens* to the banana weevil *Cosmopolites sordidus*. Biocontrol Science and Technology. 1993;3(2):177-87.
14. Parasuraman S, Balamurugan S, Christapher PV, Petchi RR, Yeng WY, Sujithra J, Vijaya C. Evaluation of antidiabetic and antihyperlipidemic effects of hydroalcoholic extract of leaves of *Ocimum tenuiflorum* (Lamiaceae) and prediction of biological activity of its phytoconstituents. Pharmacognosy research. 2015;7(2):156.
15. Biradar SR, Rachetti BD. Extraction of some secondary metabolites & thin layer chromatography from different parts of *Centella asiatica* L. (URB). American Journal of Life Sciences. 2013;1(6):243-7.
16. Navinraj S, Boopathi NM, Balasubramani V, Nakkeeran S, Raghu R, Gnanam R, Saranya N, Santhanakrishnan VP. Molecular docking of nimbolide extracted from leaves of *Azadirachta indica* with protein targets to confirm the antifungal, antibacterial and insecticidal activity. Indian Journal of Microbiology. 2023;63(4):494-512.
17. Kamaraj C, Bagavan A, Rahuman AA, Zahir AA, Elango G, Pandiyan G. Larvicidal potential of medicinal plant extracts against *Anopheles subpictus* Grassi and *Culex tritaeniorhynchus* Giles (Diptera: Culicidae). Parasitol Res 2009;104(5):1163-71
18. Murugan K, Mahesh Kumar P, Kovendan K, Amerasan D, Subrmaniam J, Hwang JS. Larvicidal, pupicidal, repellent and adulticidal activity of *Citrus sinensis* orange peel extract against *Anopheles stephensi, Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae). Parasitology research. 2012;111(4):1757-69.
19. Muthukrishnan J, Pushpalatha E. Effects of plant extracts on fecundity and fertility of mosquitoes. Journal of Applied Entomology. 2001; 125(1-2):31-5.

Cite this article: Kamesh R, Kaniselvam K, Naveen V, Ramakrishnan P, Ranjithkumar B, Akash SS, *et al*. Insecticidal and Repellent Activity of Fatty Acids Derived from *Ocimum americanum* (Lamiaceae) Plant Extracts against *Culex quinquefasciatus* Mosquitoes (Diptera: Culicidae). Free Radicals and Antioxidants. 2025;15(2):55-65.