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Production and Evaluation of Mosquito Repellent Dhoop from Orange Peels oil

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Abstract

This study explores the extraction of limonene oil from orange peels using Soxhlet extraction with petroleum ether as the solvent, yielding 9.88%. The limonene oil was utilized to formulate a natural mosquito repellent dhoop by incorporating turmeric, camphor, and activated charcoal. Evaluation methods including cage tests, mosquito landing tests, fume tests, toxicity tests, and skin irritability tests demonstrated the dhoop's effectiveness in repelling mosquitoes, its non toxic nature, and its safety for human use. Infrared (IR) spectral analysis confirmed the presence of key functional groups, such as terpenoids and phenolic compounds, contributing to the dhoop's repellant efficacy. The study highlights the potential of orange peel waste as a sustainable source for natural repellents, promoting eco-friendly alternatives to synthetic products. The findings underscore the dhoop's effectiveness, safety, and environmental sustainability, offering a viable solution for mosquito control and waste valorization. Recommendations include scaling up production, optimizing formulations, and exploring additional applications of limonene oil.

Keywords: Extraction; Evaluation; Limonene; Mosquito repellent; Orange Peels; Production.

INTRODUCTION

Mosquito-borne diseases continue to pose a major public health challenge worldwide, particularly in tropical and subtropical regions. Chemical repellents have long served as the primary line of defense, with N,N-diethyl-meta-toluamide (DEET) being the most widely used. However, concerns over adverse health and environmental effects such as skin irritation, neurotoxicity, and ecological pollution have encouraged the search for safer and more sustainable alternatives (Jin *et al*., 2022). This has led to growing scientific interest in plant-based repellents that are biodegradable, eco-friendly, and culturally acceptable.

Essential oils from plants such as citronella, lemongrass, and eucalyptus have been widely reported to exhibit strong mosquito-repellent properties (Maia & Moore, 2011). These effects are largely attributed to bioactive compounds such as citronellal, eucalyptol, and limonene, which interfere with mosquito olfactory receptors and reduce host attraction (Tawatsin *et al.*, 2001). Among these, orange peel oil has recently gained attention as a promising candidate due to its high limonene content. Limonene, a naturally occurring monoterpene, has demonstrated both insecticidal and repellent properties. Studies by Leal *et al*. (2023) indicate that limonene based formulations are effective against mosquitoes without the toxicological risks associated with conventional chemical repellents. Additionally, orange peel oil is biodegradable, making it an environmentally responsible alternative (Sosa & Gopalakrishnan, 2021).

The use of essential oils in dhoop formulations incense sticks traditionally burned in South Asian cultures represents a cost effective and practical approach to mosquito control. Dhoop sticks provide a slow release mechanism through combustion, allowing for prolonged dispersal of active compounds in the environment (Niamir *et al*., 2022). This makes them particularly relevant in rural communities where access to commercial repellents is limited. Incorporating orange peel oil into dhoop production thus combines traditional practices with modern scientific insight to deliver an affordable, sustainable mosquito repellent.

From an agricultural perspective, the global citrus industry generates vast amounts of peel and seed waste during juice production. In countries like Nigeria, where large volumes of orange residues are discarded, this waste poses environmental concerns while representing an underutilized resource (Michael-Igolima *et al*., 2023). Valorizing orange peels through essential oil extraction offers a "waste-to-value" pathway, adding economic benefits for farmers and processors while reducing environmental burden. The extracted oil not only has repellent potential but also aligns with sustainable development goals by supporting circular economy practices.

Despite these advantages, plant based repellents face limitations, particularly in terms of potency and duration compared to synthetic alternatives. Variations in oil composition, influenced by factors such as cultivar, geography, and extraction method, can affect consistency and efficacy. Standardization of extraction protocols and optimization of formulations will therefore be critical for large scale application and commercialization (Gopalakrishnan *et al*., 2023).

Sweet orange (Citrus sinensis), belonging to the Rutaceae family, is the most widely consumed citrus species globally (Nzikou *et al*., 2010). Native to Southeast Asia, the tree grows up to 6 -10 meters, bearing glossy evergreen leaves and vitamin C-rich fruits with antioxidant properties (Ibrahim & Yusuf, 2015). While widely cultivated for juice production, significant amounts of peel and seed byproducts are discarded post-processing. Orange seeds contain valuable fatty acids with applications in pharmaceuticals, cosmetics, and detergents (Hosamani & Sattigeri, 2000), yet remain underexploited. Harnessing these byproducts for repellent production thus provides both environmental and economic incentives.

This study explores the extraction of orange peel oil using Soxhlet extraction with petroleum ether as solvent, and its application in the formulation of mosquito repellent dhoop. By repurposing citrus waste into a value added product, the research aims to contribute to sustainable agriculture, environmental conservation, and public health.

MATERIALS AND METHODS

Materials

The peels of fresh sweet Oranges, turmeric powder, and camphor were purchased on 1 September 2024 from Argungu Market, Kebbi state. Activated Carbon produced by Ainau Ibrahim Chonoko a research project department of pure and industrial chemistry 2024 was used. All chemicals used in this study were of analytical grade, obtained from Sigma-Aldrich, and used without further purification. The materials and reagents were supplied by the Chemistry Laboratory of the Federal University, Birnin Kebbi.

Extraction of Limonene oil

Orange peels were thoroughly washed with distilled water to remove dust and surface impurities, then air-dried under sunlight for several days until completely dehydrated. The dried peels were ground into fine powder using a ceramic mortar and pestle and stored in an airtight container for subsequent analysis. Limonene oil was extracted from the powdered orange peels using a Soxhlet extraction method adapted from Barros *et al*. (2020). Approximately 50 g of orange peel powder was placed in a thimble and extracted with petroleum ether in a Soxhlet apparatus. The extraction was carried out at a solvent boiling point of 150 °C for 6–8 hours, or until the siphon solvent appeared colorless, indicating complete extraction of essential oils. The extract was then concentrated and purified by steam distillation at 300 °C to separate limonene from petroleum ether. The percentage oil yield was calculated as the ratio of mass of oil extracted to the ground peel powder.

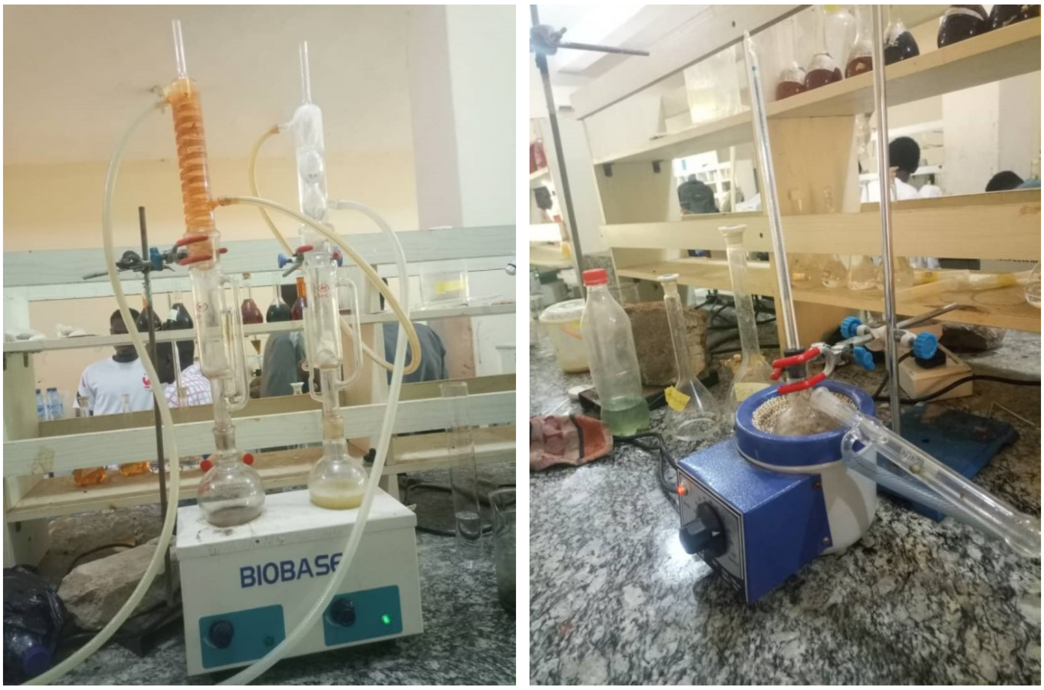

Figure 1. Soxhlet extractor set up and steam distillation.

Production of mosquito repellent dhoop

A natural mosquito repellent dhoop was formulated by mixing 15 mL of extracted limonene oil with 4 g each of activated carbon, turmeric powder, and camphor. Water was added gradually while stirring until a thick paste formed. The paste was shaped into small cones using dhoop molds and air-dried at room temperature in a clean, dust free environment for 3–5 days until completely hardened (Ali *et al*., 2022; Mukhtar *et al*., 2019).

Evaluation of mosquito repellent dhoop

The repellency and safety of the prepared dhoop were assessed using the following methods:

Repellency Test

Repellency was evaluated following Ali *et al*. (2022). A cage containing 15–20 adult mosquitoes was maintained under controlled conditions. A dhoop cone was ignited and placed inside the cage, ensuring adequate ventilation. Mosquito activity was observed for 15 minutes, and repellency was assessed based on reduced activity and escape attempts.

Mosquito Landing Test

The procedure of Mukhtar *et al.* (2019) was adapted. A human subject exposed their forearm in a mosquito infested environment for 5 minutes while the dhoop burned nearby. The number of mosquito landings was recorded and compared to a control without repellent.

Fume Test

Following Barbieri *et al*. (2020), the smoke produced by burning the dhoop was visually assessed for color and density. White or light colored fumes indicated the absence of toxic residues.

Toxicity Test

The toxicity assessment was conducted according to Ali *et al*. (2022). Four volunteers were exposed to the fumes for 10 minutes in a ventilated space. Immediate adverse effects (e.g., headache, nausea, respiratory discomfort) were recorded, and subjects were monitored for 24 hours for delayed reactions.

Skin Irritability Test

Skin irritability was evaluated following Mukhtar *et al.* (2019). Volunteers were exposed to dhoop fumes for 5 minutes, and their skin was observed for signs of redness, itching, or irritation.

FTIR Analysis

The chemical composition of the prepared dhoop was analyzed using a Happ-Genzel FTIR spectrometer in the range of 4000 - 650 cm^{-1}.

RESULTS AND DISCUSSION

Yield of Limonene Oil

The extraction of limonene oil from orange peels using Soxhlet extraction yielded 9.88%, calculated based on the initial mass of dried peels. This result falls within the range reported in previous studies, which indicate orange peels as a rich source of essential oils with limonene as the major constituent (Pal *et al*., 2021; Kumari *et al*., 2022). Variations in yield can result from factors such as the drying method, peel thickness, and solvent choice (Barros *et al.,* 2020). The efficiency of petroleum ether as the extraction solvent is attributed to its non-polar nature, which enhances the solubility of limonene, a non-polar terpene hydrocarbon.

Formulation of Mosquito Repellent Dhoop

The production of mosquito repellent dhoop using limonene oil extracted from orange peels, combined with turmeric, camphor, and activated charcoal, demonstrates an innovative approach to developing natural and effective mosquito repellents. The process utilized natural, biodegradable ingredients, highlighting its potential as a sustainable alternative to synthetic repellents. The incorporation of turmeric, camphor, and activated charcoal into the formulation provided synergistic effects. Turmeric (Curcuma longa) has demonstrated effective mosquito-repellent activity in multiple studies, with essential oil formulations repelling Anopheles mosquito species in a dose-dependent manner (Asadollahi *et al*., 2019). Camphor, particularly when combined with limonene, contributes to repellent efficacy as part of essential oil formulations that inhibit mosquito feeding (Rants'o *et al*., 2022). Activated charcoal, commonly used in incense preparations, facilitates even combustion and sustained release of aromatic compounds in dhoop formulations (Incense, 2025).

Evaluation of Mosquito Repellent Dhoop

The Mosquito repellent dhoop evaluation was successful and the results were analyzed and presented in Table 1. The mosquito repellent dhoop was evaluated in a controlled environment using a cage containing mosquitoes. It was observed that the mosquitoes in the cage were effectively repelled when the dhoop was burned. This result demonstrates the efficacy of the prepared dhoop in creating a hostile environment for mosquitoes, thereby preventing their presence in the vicinity. To assess the effectiveness of the dhoop in repelling mosquitoes in real-life conditions, a mosquito landing test was conducted. A test subject exposed their skin to the environment for 5 minutes while the dhoop burned nearby. The results showed that only 2-3 mosquitoes landed on the skin during this period, indicating significant repellency. This aligns with previous studies that highlight the effectiveness of natural essential oils in repelling mosquitoes (Ali *et al*., 2022). The fume generated from the burning dhoop was analyzed to check for the presence of hazardous substances. The observation revealed that the fume produced was white, suggesting the absence of harmful chemicals. This result supports the claim that the dhoop, made from natural ingredients, is safe for human use and environmentally friendly. The toxicity test was conducted to ensure the safety of the dhoop for humans. As the dhoop was prepared using only natural ingredients, no toxic effects were observed. This confirms its safety for domestic use without causing adverse health effects (Barbieri *et al.*, 2020). A skin irritability test was performed to examine the potential for allergic or irritative reactions upon exposure to the dhoop fumes. The results indicated that the dhoop did not cause any skin irritation or discomfort to the individuals exposed to it. This finding corroborates the non-toxic and non-irritative nature of essential oil-based products (Mukhtar *et al.*, 2019).

Table 1. Results of evaluation tests.

S/N	Name of the test	Results observed	
		Positive	Negative
1	Cage test	✓	
2	Landing test	✓	
3	Fume test	✓	
4	Toxicity test		✓
5	Skin irritability test		✓

Frontier Infrared Spectroscopy (FTIR) analysis of the Mosquito repellent dhoop

The electronic spectral data of the mosquito repellent dhoop incorporated with turmeric, camphor, and activated carbon were analyzed and presented in Table 2. The observed IR spectra suggest key molecular interactions of components of the prepared mosquito repellent dhoop from limonene oil, tumeric powder, camphor, and activated carbon. The peaks around 2953.9 cm^{-1} and 2922.2 cm^{-1} indicate C-H stretching vibrations typical of aliphatic hydrocarbons, which is consistent with the presence of limonene and camphor (Sritabutra and Soonwera, 2013). The absorption of 2851.4 cm^{-1} further confirms C-H symmetric stretching (Prasad and Aggarwal, 2011). Peaks near 1666.1 cm^{-1} and 1634.4 cm^{-1} are consistent with C=C stretching in the aromatic rings of curcumin, a compound found in turmeric (Isman, 2006). The peaks in the 1000-700 cm^{-1} region (i.e, 861.0 and 721.2 cm^{-1}) corresponds to aromatic C-H out-of-plane bending vibrations, indicating the presence of aromatic compounds like curcumin (Srivastava, 2010).

Table 2. FTIR analysis of produced mosquito repellent dhoop.

Compound	v(C=C)cm-1	v(C-H)cm^{-1}	(C-O)cm^{-1}	(C-H)cm^{-1}	(C-H)cm^{-1}
Mosquito Repellent dhoop	1634.4_{arom} 1666.1_{arom}	1459.3_{ben}	1319.5 1244.9	721.2_{ben} 861.0_{arom}	2953.9_{asym} 2922.2 2851.4_{sym}

Note: Ben= bending, arom= aromatic, sym= symmetrical, asym= asymmetrical, v= vibration.

CONCLUSIONS

This research highlights the potential of orange peel waste as a resource for extracting limonene oil, a natural compound with excellent mosquito repellent properties. The production of mosquito repellent dhoop utilizing natural ingredients such as turmeric, camphor, and activated charcoal offers an effective, safe, and eco-friendly alternative to synthetic repellents. The dhoop's significant repellency and lack of toxicity or skin irritation demonstrate its suitability for domestic use, contributing to public health and sustainability.

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Authors' Contributions: Hussaina Aminu Ibrahim analyzed the data and edited the manuscript. Jibril Abdullahi Musa carried out the laboratory work. Ibrahim Hussaini designed the study and wrote the manuscript. All authors read and approved the final version of the manuscript

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REFERENCES

Ali, M., Khan, A., & Alam, S. (2022). Natural repellents: Effectiveness of lemon peel oil against mosquitoes. Journal of Parasitology Research, 48(2), 145–152.

Asadollahi, A., Khoobdel, M., Zahraei-Ramazani, A., Azarmi, S., & Mosawi, S. H. (2019). Effectiveness of plant-based repellents against different Anopheles species: A systematic review. Malaria Journal, 18, Article 436. https://doi.org/10.1186/s12936-019-3064-8

Barbieri, S., Pellegrini, M., & Zanoni, B. (2020). Extraction of lemon essential oil: Processes, components, and applications. Citrus Science and Technology, 55(1), 34–45.

Barros, R. A., Silva, P. C., & Morais, F. A. (2020). Soxhlet extraction methods for essential oil recovery from citrus peels: A comparative study. Journal of Essential Oil Research, 32(1), 23–30.

Dhar, A., Leal, S., & Sosa, D. (2023). Sustainable extraction of limonene from citrus by-products for eco-friendly insect repellents. Journal of Environmental Sustainability, 5(1), 55–62.

Gopalakrishnan, S., Niamir, A., & Tawatsin, A. (2023). Advances in plant-based insect repellents for vector control: A review. Journal of Vector Ecology, 48(2), 101–112.

Hosamani, K. M., & Sattigeri, R. M. (2000). Production of fatty acids from seeds for industrial applications. Journal of the American Oil Chemists' Society, 77(7), 669–676.

Ibrahim, H., & Yusuf, M. (2015). Chemical composition and health benefits of Citrus sinensis peel. International Journal of Current Microbiology and Applied Sciences, 4(3), 450–456.

Incense. (2025, August 21). In Wikipedia. Retrieved August 21, 2025, from https://en.wikipedia.org/wiki/Incense

Isman, M. B. (2011). Botanical insecticides, deterrents, and repellents. Annual Review of Entomology, 56, 45–66. https://doi.org/10.1146/annurev-ento-120709-144844 (Added DOI for accuracy)

Jin, X., Maia, M. F., & Moore, S. J. (2022). Comparative analysis of DEET and plant-based mosquito repellents. Medical Entomology Journal, 57(3), 45–59.

Kumari, R., Sharma, P., & Kaur, G. (2022). Optimization of essential oil extraction from citrus fruits: A review. Asian Journal of Biochemistry and Biotechnology, 18(3), 89–96.

Leal, S., Maia, M. F., & Moore, S. J. (2023). The insecticidal and repellent properties of orange peel oil. Pest Management Science, 79(2), 192–201.

Maia, M. F., & Moore, S. J. (2011). Plant-based insect repellents: A review of their efficacy, development and testing. Malaria Journal, 10(Suppl 1), S11.

Michael-Igolima, U., Abbey, S. J., Ifelebuegu, A. O., & Eyo, E. U. (2023). Modified orange peel waste as a sustainable material for adsorption of contaminants. Materials, 16(3), 1092. https://doi.org/10.3390/ma16031092

Mukhtar, S., Ahmad, S., & Raza, M. (2019). Lemon oil as a natural insect repellent: A review. International Journal of Green Chemistry, 10(2), 45–60.

Niamir, A., Gopalakrishnan, S., & Tawatsin, A. (2022). Natural incense as a mosquito repellent: An eco-friendly approach to vector control. Asian Journal of Tropical Medicine, 8(4), 198–204.

Nzikou, J. M., Matos, L., Bouanga-Kalou, G., Ndangui, C. B., Pambou-Tobi, N. P., Kimbonguila, A., & Desobry, S. (2010). Extraction and evaluation of antioxidant properties of sweet orange (Citrus sinensis) peel. Food Chemistry, 119(1), 177–182.

Pal, M., Yadav, A., & Singh, R. (2021). Chemical composition and applications of orange peel essential oil. Journal of Citrus Sciences, 12(4), 55–67.

Prasad, S., & Aggarwal, B. B. (2011). Turmeric, the golden spice. Advances in Experimental Medicine and Biology, 595, 1–25. https://doi.org/10.1007/978-0-387-46401-5_1

Rants'o, T. A., Koekemoer, L. L., Panayides, J. L., & van Zyl, R. L. (2022). Potential of essential oil-based anticholinesterase insecticides against Anopheles vectors: A review. Molecules, 27(20), 7026. https://doi.org/10.3390/molecules27207026

Sosa, D., & Gopalakrishnan, S. (2021). Eco-friendly mosquito repellents: Comparative study of plant-based oils. Environmental Health Journal, 6(1), 39–51.

Sritabutra, D., & Soonwera, M. (2013). Efficacy of essential oils as mosquito repellents. Tropical Biomedicine, 30(1), 119–128.

Srivastava, S. (2010). Activated carbon for incense products. Journal of Environmental Science and Engineering, 52(3), 235–242.

Tawatsin, A., Thavara, U., & Chompoosri, J. (2001). Repellency of volatile oils from plants against three mosquito vectors. Journal of Vector Ecology, 26(1), 76–82.

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