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Research Article

Preparation of Eco-Friendly Mosquito Repellent Jelly Using Essential Oils and Evaluation of Its Efficacy

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Abstract

The developed mosquito-repellent jelly represents an innovative and environmentally sustainable solution without relying on toxic chemicals. It was formulated using five essential oils viz., citronella, lemongrass, clove, neem, and lavender to ensure safety for human skin and eyes, which provide effective repellency. The jelly exhibited 100% effectiveness during the first two hours of application. Although its efficacy gradually declined, reducing to 70% over the subsequent three hours and further decreasing to 40% after four hours. The physical and chemical properties of the jelly were thoroughly evaluated through organoleptic analysis, repellency testing, skin patch testing, eye irritation testing, and inhalation testing, all of which confirmed its safety for further use. This mosquito-repellent jelly offers a natural, eco-friendly alternative to conventional chemical repellents, aligning with the growing demand for non-toxic solution in personal care. However, to extend the effective repellency of the mosquito-repellent jelly, an innovative method is required to lock the aroma of the gel, which is responsible for its repellent action.

Keywords: Citronella, Clove, Eco-friendly, Essential oils, Lavender, Lemongrass, Mosquito repellent, Neem, Non-toxic

INTRODUCTION

Vector-borne diseases primarily affect tropical and subtropical regions, with mosquitoes being the exclusive vectors for illnesses such as malaria, dengue, and chikungunya. In 2022, under the World Mosquito Program, Alex Jackson from Monash University stated that annually, over 750 million individuals contract these diseases, leading to approximately three million fatalities[1]. The primary preventive measures currently focus on mosquito control strategies, including larval habitat management, repellents, and protective barriers such as mosquito nets. Although scientific advancements have led to the development of mosquito vaccines, these remain in the early research phases and are not yet recommended for human use. India's diverse geographical landscape, ranging from the Himalayas to Kanyakumari, encompasses a variety of ecological zones, including forests, deserts, and water bodies. Apart from Rajasthan, most parts of India are covered with different forest types, from tropical evergreen to dense forests. This vast ecological diversity fosters the survival and proliferation of various organisms, including mosquitoes.

Mosquitoes belong to the family *Culicidae*, order *Diptera*, class *Insecta*, and phylum *Arthropoda*. There are approximately 3,600 documented mosquito species and subspecies under 188 subgenera across 41 genera worldwide[2]. India's climatic conditions and biodiversity provide a suitable environment for mosquito breeding, thereby contributing to the persistence of vector-borne diseases. The monsoons facilitate year-round agricultural activities, particularly paddy cultivation, which inadvertently creates an ideal breeding ground for mosquito vectors. Several species of the *Culex* genus, viz., *C. quinquefasciatus*, *C tritaeniorhynchus*, *C. pseudovishnui*, and *C. gelidus*, thrive in such environments[3]. Among the diseases transmitted by these species, Japanese encephalitis virus (JEV) has emerged as a significant public health concern due to its high fatality rate and is responsible for nearly 68,000 clinical cases per year[4].

Mosquitoes are hematophagous insects that use their specialized piercing and sucking mouthparts to extract blood from hosts. This feeding mechanism facilitates pathogen transmission, making mosquitoes primary vectors for numerous infectious diseases. Vector-borne diseases flourish in densely populated urban regions where anthropogenic factors, such as inadequate housing, poor sanitation, and inefficient solid waste management, create favorable conditions for mosquito

breeding[5]. A lack of community awareness and inadequate preventive measures further exacerbate the problem. The knowledge, attitudes, and practices (KAP) of residents play a crucial role in determining the efficacy of mosquito control programs. In India, there is no standalone national mosquito control program where vector management is integrated with sanitation and solid waste disposal initiatives managed by local municipalities and panchayats. However, many municipal bodies struggle to implement effective mosquito control measures due to financial and infrastructural constraints. The most common mosquito control methods include Chemical Repellents (20% aerosol spray of N, N-Diethyl-phenylacetamide for mosquitoes, sandflies, black flies, and land leeches)[6], Personal Protection Measures (e.g., Mosquito coils, creams, repellent incense sticks, electric repellent machines, and bed nets), Larval Source Reduction (i.e., elimination of stagnant water sources). Despite their effectiveness, synthetic chemical repellents pose several health and environmental risks. Prolonged exposure to these chemicals can cause allergies, skin irritation, and respiratory issues, particularly among children and domestic animals[7]. Additionally, the excessive use of chemical insecticides contributes to environmental pollution and insecticide resistance in mosquito populations[8], which reduce the long-term efficacy of these control measures.

Growing awareness of environmental conservation has led to an increased emphasis on sustainable mosquito control strategies that mitigate ecological harm. Several plant-based repellents have demonstrated mosquito-repellent properties, offering safer alternatives to synthetic chemicals[8]. Notable natural mosquito repellents include a variety of essential oil-based plants, aromatic herbs, flowers, and other botanicals that have demonstrated significant insect-repelling properties. Essential oil-rich plants such as lavender (*Lavandula spp.*), citronella (*Cymbopogon nardus*), lemongrass (*Cymbopogon citratus*), and clove (*Syzygium aromaticum*) contain bioactive compounds that effectively deter mosquitoes[8]. Additionally, aromatic herbs and flowers, including marigold (*Tagetes spp.*), mint (*Mentha spp.*), rosemary (*Salvia rosmarinus*), basil (*Ocimum basilicum*), beebalm (*Monarda didyma*), and sage (*Salvia officinalis*) have been recognized for their natural repellent properties[8]. Other botanicals such as neem (*Azadirachta indica*), catmint (*Nepeta cataria*), and garlic (*Allium sativum*) have been extensively studied for their insecticidal and repellent effects[9]. The incorporation of these natural repellents into community-wide vector control programs could offer an effective and sustainable approach to managing mosquito-borne diseases which decrease the dependence on synthetic insecticides while promoting environmental and public health. Despite significant advancements in vector control measures, mosquito-borne diseases such as malaria, dengue fever, Zika virus, and West Nile virus continue to pose serious public health threats[10]. The persistent challenge of controlling mosquito populations underscores the need for innovative, sustainable, and environmentally friendly mosquito management strategies. Hence, the present research work was focused towards the development of an eco-friendly mosquito-repellent jelly using essential oils derived from citronella, lemongrass, neem, lavender, and clove, and evaluation of its efficacy.

MATERIALS AND METHODS

The work was conducted at Department of Biotechnology, D.L.S. P.G. College Bilaspur, Chhattisgarh, India**.** The Citronella, Neem, Lemongrass, Clove, and Lavender essential oils were procured from various sources. The detailed description of essential oils used for the preparation of mosquito-repellent jelly is mentioned in Table 1. Generally, jelly is made by combining veg-gelatin with other bioactive ingredients as per the nature of the product and its uses. We have prepared gelatin based-mosquito repellent jelly using natural essential oils.

Table 1: Description of essential oils used for the preparation of mosquito repellent jelly

S. N.	Essential oil	Description
1.	Citronella	The essential oil of citronella plant was obtained from Fresh Focus Consumer Products Pvt Ltd. a trading company based in Kolkata, India. It was ordered through an Amazon online shopping application.
2.	Neem essential oil	The essential oil of the neem plant was obtained from the Dindayal Industries Ltd. Birla Nager Area, Gwalior. It was purchased from an Ayurvedic shop located in Bilaspur named Badhyanath at Gol Bazaar.
3.	Lemongrass essential oil	The essential oils of the lemongrass plant were obtained from the Ayurvedic shop located in Bilaspur named Badhyanath at Gol Bazaar.
4.	Clove essential oil	The essential oils of clove were obtained from the Agrawal Drugs Pvt. Ltd. 300, F.I.E., Patparganj Industries Estate, Delhi. It was purchased from the Apollo pharmacy at Sarkanda, Bilaspur.
5.	Lavender essential oil	The essential oil of lavender was obtained from S K Products, Meerut, Uttar Pradesh. It was purchased from an Ayurvedic shop located in Bilaspur named Badhyanath at Gol Bazaar.

Preparation of mosquito-repellent jelly

Jelly emulsion was prepared using essential oils, viz., citronella oil, neem oil, clove oil, lemongrass oil, and lavender oil. The formulation of the mosquito-repellent jelly was given in Table 2. We have prepared and reported this gelatin-based with multi- essential oil mosquito-repellent jelly formulation for the first time, according to our best knowledge and belief. However, earlier gelatin was claimed for its suitability as an effective natural ingredient for mosquito-repellent jelly[11]. Approximately 50 mL of distilled water was taken in a small container and brought to a boil. Subsequently, 0.5 g of vegetable gelatin was added, and the mixture was allowed to boil for approximately 2 minutes to ensure complete dissolution. The solution was then left to stand for a few seconds to facilitate proper mixing. The hot gelatin solution was transferred to a small container, followed by the gradual addition of the prepared emulsion. The container was sealed with a lid and shaken vigorously to ensure a thorough mixing of the emulsion and the gelatin solution. Once homogenized, the mixture was allowed to cool to room temperature, leading to the formation of a stable jelly.

Table 2: Formulation of the mosquito-repellent jelly

S. N.	Ingredient's	Formulation
1	Distilled water	50.0 ml
2	Veg Gelatin	0.5 g
3	Citronella oil	1.0 ml
4	Lemongrass oil	0.5 ml
5	Clove oil	1.0 ml
6	Neem oil	1.0 ml
7	Lavender oil	3 drops

Evaluation of Physical and Chemical Properties

Organoleptic properties, repellency test, skin patch test, eye irritation test, and inhalation test of mosquito-repellent jelly were evaluated. In this part, the Initial safety of mosquito-repellent jelly was self-assessed (own body) after taking informed consent for the same. We have not used any synthetic chemical ingredient in mosquito-repellent jelly.

Organoleptic properties

The color, odor, pH, and texture of the pharmaceutical formulations were assessed at room temperature (28 ± 5°C) over a 10-day stability evaluation period using Methods mentioned in earlier studies with slight modification[12].

Repellency test

The field test was conducted in accordance with the World Health Organization (WHO) guidelines for repellent efficacy testing in the vicinity of human dwellings. The mosquito occurrence rate and assessment were based on the capture of mosquitoes attempting to attack humans, and the observations were self-assessed. The mosquito repellent jelly was tested under two conditions: (a) in a closed room and (b) in an open area (garden). The response of mosquitoes to the jelly was then observed and recorded.

Skin Patch Test

A small amount of the mosquito repellent was applied to a localized area of skin (inner wrist and forearm). The site was monitored for 24 hours for any signs of irritation, including redness, swelling, or itching. In the absence of any adverse reaction, the repellent was considered safe for topical application.

Eye Irritation Test

A small amount of the repellent near the lower eyelid (avoiding direct contact with the eye) was applied, and any signs of irritation and redness in the eye were observed over 24 h. This test can indicate the potential for eye irritation.

Inhalation Test

A small amount of the repellent was soaked in a cotton ball and held near the nostril. It was further inhaled and observed for any signs of respiratory irritation and discomfort. This test assesses the potential for respiratory irritation.

RESULTS

The physical and chemical properties of the mosquito-repellent jelly were self-evaluated (own body) through organoleptic analysis, repellency testing, skin patch testing, eye irritation testing, and inhalation testing. No additional Human volunteer or animal model was used in the present research work.

Organoleptic properties

The formulated mosquito-repellent jelly initially exhibited a brown color and a consistent texture. The tested organoleptic properties remained unchanged throughout the 10-day stability testing period (Table 3). The pH of the formulated jelly was initially measured at 7.0 but gradually decreased to 4.0 over the evaluation period.

Table 3: Physical and chemical properties of formulated mosquito repellent jelly over 10 days.

S. N.	Organoleptic properties	
	Day 1	Day 10
1	Light brown color jelly with a soft texture	Same as day one
2	pH - 7.0	pH – 4.0

Repellency Test

The formulated mosquito-repellent jelly exhibited high repellency during the initial hour, with its effectiveness gradually decreasing over time. It was found to be 100% effective during the first 2 hours (Fig 1). However, its repellency decreased to 70% over the subsequent 3 hours and further reduced to 40% after 4 hours. The mosquito-repellent jelly was observed to be more effective in closed-room environments compared to open areas.

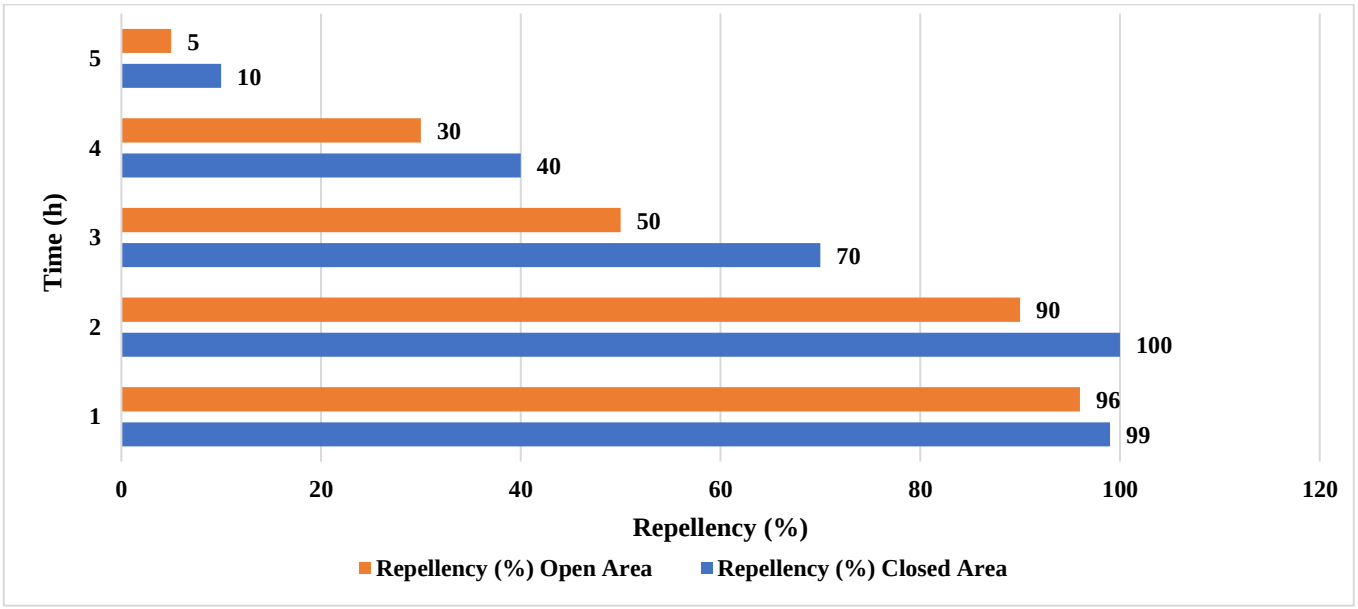

Figure 1: Time-dependent repellency of formulated mosquito-repellent jelly

Skin Patch Test

The formulated mosquito repellent jelly causes no irritation, redness, swelling, or itching in the applied area. Hence, it was not reactive to human skin and safe to use.

Eye Irritation Test

The formulated mosquito repellent jelly causes no irritation, redness, swelling, or itching in the applied area. Hence, it was not reactive to human eyes and safe to use.

Inhalation Test

The formulated mosquito-repellent jelly causes no problems while inhaling. Its scent was not irritating and caused no discomfort in respiration. Hence, it was safer to inhale.

As mosquito jelly was formulated by the use of multiple natural essential oils and no chemicals were added to it. So, safer for the environment.

DISCUSSION

The present research aimed to develop an eco-friendly mosquito-repellent jelly utilizing essential oils, viz., citronella, lemongrass, neem, lavender, and clove oils, and to assess its efficiency. Aforementioned plant-derived bioactive essential oils were used to develop mosquito repellent jelly with veg gelatin base for the first time in the present research work. We tried to make it a simple preparation so that people can easily do so and use it. We have tested its initial safety on to own body (self-assessed) after taking informed consent for the same. We have not used any synthetic chemicals and have obtained satisfactory results with natural ingredients mixed with veg gelatin. Certainly, the present work will proceed further for a complex and more systematic research so that it can meet the requirements of commercial suitability and large-scale production. Initially, 2% neem oil mixed with coconut oil, when applied topically, was observed for providing complete protection against all anopheline species for 12 hours[13]. Neem oil was found to be a safe and effective malaria prevention measure in endemic regions. Nerio et al.[14] observed escalating environmental and public health issues regarding synthetic pesticides, rendering natural products a feasible option. Subsequently, the mosquito-repellent efficacy of lemongrass oil in liquid paraffin solutions, ointments, and cream formulations was evaluated[15]. The repellent effectiveness was assessed using a two-day-starved culture of *Aedes aegypti* L. on the skin of an experimental bird. The principal constituent of the oil, citral, exhibited ≥50% repellency for 2–3 hours in 1% v/v solution and 15% w/w cream and ointment formulations, comparable to a commercial mosquito repellent. Recently, the lemongrass has been reported to exhibit maximum activity and significant efficacy in order to suppress the mosquito population[16]. The efficacy varied according to the formulation, with hydrophilic bases demonstrating the highest performance, followed by emulsion and oleaginous bases. Extensive research has been conducted on essential oils derived from several plants, demonstrating their efficacy as a valuable natural repellent resource. It was documented that mosquito-borne diseases persisted in their global proliferation despite millennia of control efforts[17]. These disorders resulted in considerable morbidity and mortality, disproportionately impacting children and adolescents. The primary obstacles in mitigating their effects in endemic areas were the management of mosquito populations and the implementation of effective public health interventions. Targeted guidance on vaccinations, malaria prevention, and mosquito deterrence was crucial for travelers to these regions.

The present observation revealed 100% effectiveness of repellency during the first 2 hours. However, its repellency decreased to 70% over the subsequent 3 hours and further reduced to 40% after 4 hours. A similar result has been reported by Trivedi et al.[18], they

quoted that the formulations of *Cymbopogon Citrullus*, *Azadirachta indica*, and *Eucalyptus globulus* essential oils demonstrated the highest efficacy, demonstrating 80-95% repellency relative to other repellent essential oils. Likewise, the previous literature also supported the present findings e.g., the mosquito-repellent efficacy of lotion formulations containing citronella oil, citronellal, or citronellol by the human bait method (arm-in-cage assay) targeting *A. aegypti*[19]. It was asserted that clove and clove oil, designated by the EPA as minimum-risk pesticides, were excluded from federal registration pursuant to section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act[20]. Literature mentioned that essential oils are intricate, naturally occurring volatile substances with unique fragrances, generated as secondary metabolites by aromatic flora[21]. Among 17,500 aromatic plant species, around 3,000 essential oils have been identified, with 300 deemed commercially relevant for the pharmaceutical, cosmetic, and fragrance sectors. It was also noted that the lavender essential oil, present in its leaves, released a fragrance that hindered mosquitoe's olfactory perception[22].

Numerous tropical plants exhibited insect-repellent qualities and were utilized for medical applications[23]. Numerous plants, such as lavender, citronella, lemongrass, marigold, mint, neem, clove, catmint, rosemary, basil, beebalm, sage, and allium, functioned as natural insect repellents. Citronella oil gained popularity as a safe insect repellent, among several other plant extracts. Chellappandian et al.[24] discovered that plants inherently generate secondary metabolites and bioactive chemicals as defensive strategies against insect pests. An increasing demand for natural insect repellents is characterized by their affordability, efficacy, non-toxicity, eco-friendliness, and biodegradability[25]. Literature claimed that the efficacy of herbal essential oils as both singular and composite repellents against multiple insect species, e.g., *A. aegypti*, *Anopheles dirus* and *C. quinquefasciatus*[26].

Recently, an anti-mosquito spray derived from citronella oil demonstrated a significant effect compared to the control insecticide applicator in eradicating *A. aegypti* mosquitoes[27]. A mosquito-repellent topical product was formulated using lemongrass oil, which provided ≥ 50% repellency for 2–3 hours[15]. A neem-based eco-friendly mosquito control agent was developed, and identified azadirachtin as an effective compound with toxic effects on mosquitoes[28]. Citronella, lavender oil, lemongrass, and cajeput were examined as mosquito repellents, and observations have found significant effectiveness in mosquito control[29]. During the research investigation, clove and cinnamon were reported to contain high levels of eugenol, and their study revealed notable mosquito repellent properties and mortality rates ranging from 54% to 77.3% against adult *Anopheles* mosquitoes when using clove oil[30]. Over the past 50 years, mosquito-borne diseases have emerged as significant global public health implications in India[31] and Zika, dengue, West Nile, and yellow fever have been widely reported as mosquito-borne flaviviruses globally[32]. Henceforth, the scientific communities have comprehensively revealed several novel formulations of herbal mosquito repellents[33,34]. Therefore, the mosquito-repellent jelly prepared from essential oils derived from citronella, lemongrass, neem, lavender, and clove could be further evaluated to overcome limitations and optimized for better and more durable performance.

CONCLUSION

The developed mosquito repellent jelly was an innovative and environmentally sustainable solution designed to protect against mosquitoes without toxic chemicals. It consisted of five essential oils, viz., citronella, lemongrass, clove, neem, and lavender, to ensure the safety for human skin and eyes. To make the formula, exact amounts of essential oils were mixed to make an emulsion, which was then mixed with a hot vegetable gelatin solution. After thorough mixing, the solution was cooled in a small plastic container to incorporate active ingredients effectively. Rather than killing mosquitoes, the jelly released vapors from essential oils that prevented them from entering the area. Studies indicated its effectiveness for a limited duration, creating a natural barrier against mosquito bites without environmental risks due to its all-natural composition. This mosquito repellent jelly serves a benefit to users without direct skin contact. It is also effective in the prevention of malaria and dengue fevers (mosquito-borne diseases). However, governmental initiatives aimed to control mosquito populations, and personal responsibility played a crucial role. As the high standard of scientific quality and credibility is important for credible research work, but the simple and outcome-based research that serves the baseline public is of prime importance nowadays. Therefore, we have tried to make the right mix of both during the present research work. So that the people can directly benefit from this research. This mosquito repellent jelly provided a natural, eco-friendly alternative to conventional chemical repellents. The study is in a preliminary stage, and can be considered as a pilot project in which all the parameters were self-evaluated, further trials will be conducted for broader application.

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Data Availability Statement: Supplementary data are available on request from the corresponding author.

Ethical approval: Not applicable.

Abbreviation/Symbols

Abbreviation/Symbols	Expansion
JEV	Japanese encephalitis virus
KAP	Knowledge, Attitudes, and Practices
≥	Less than
%	Percentage
°C	Centigrade
v/v	Volume by Volume

REFERENCES

1. Jackson, A. Explainer: How climate change is amplifying mosquito-borne diseases. Published under World Mosquito Program Ltd ABN, Monash University. 2022. https://www.worldmosquitoprogram.org/en/news-stories/stories/explainer-how-climate-change-amplifying-mosquito-borne-diseases

2. Rueda LM, Debboun M. Taxonomy, identification, and biology of mosquitoes. In: Mosquitoes, Communities, and Public Health in Texas. Elsevier; 2020;3-7. https://doi.org/10.1016/B978-0-12-814545-6.00001-8

3. Das BP. Pictorial key to common species of Culex (Culex) mosquitoes associated with Japanese encephalitis virus in India. In: Mosquito Vectors of Japanese Encephalitis Virus from Northern India. Springer India; 2013;25-42. https://doi.org/10.1007/978-81-322-0861-7_3 PMCid:PMC3699239

4. Kulkarni R, Sapkal GN, Kaushal H, Mourya DT. Japanese encephalitis: A brief review on Indian perspectives. Open Virol J. 2018;12(1):121-130. https://doi.org/10.2174/1874357901812010121 PMid:30288200 PMCid:PMC6142657

5. Sutherst RW. Global change and human vulnerability to vector-borne diseases. Clin Microbiol Rev. 2004;17(1):136-173. https://doi.org/10.1128/CMR.17.1.136-173.2004 PMid:14726459 PMCid:PMC321469

6. Kalyanasundaram M, Mathew N. N,N-diethyl phenylacetamide (DEPA): A safe and effective repellent for personal protection against hematophagous arthropods. J Med Entomol. 2006;43(3):518-525. https://doi.org/10.1093/jmedent/43.3.518 PMid:16739410

7. Roy DN, Goswami R, Pal A. The insect repellents: A silent environmental chemical toxicant to the health. Environ Toxicol Pharmacol. 2017;50:91-102. https://doi.org/10.1016/j.etap.2017.01.019 PMid:28171823

8. Şengül Demirak MŞ, Canpolat E. Plant-based bioinsecticides for mosquito control: Impact on insecticide resistance and disease transmission. Insects. 2022;13(2):162. https://doi.org/10.3390/insects13020162 PMid:35206735 PMCid:PMC8878986

9. Asadollahi A, Khoobdel M, Zahraei-Ramazani A, Azarmi S, Mosawi SH. Effectiveness of plant-based repellents against different Anopheles species: a systematic review. Malar J. 2019;18(1):436. https://doi.org/10.1186/s12936-019-3064-8 PMid:31864359 PMCid:PMC6925501

10. Onen H, Luzala MM, Kigozi S, et al. Mosquito-borne diseases and their control strategies: An overview focused on green synthesized plant-based metallic nanoparticles. Insects. 2023;14(3):221. https://doi.org/10.3390/insects14030221 PMid:36975906 PMCid:PMC10059804

11. Rivero R, Archaina D, Sosa N, Leiva G, Baldi Coronel B, Schebor C. Development of healthy gummy jellies containing honey and propolis. Journal of the science of food and agriculture. 2020;100(3):1030-1037. https://doi.org/10.1002/jsfa.10107 PMid:31646633

12. Sundari P, Sushma C, Srija T. Development of Herbal Mosquito-Repellent Formulations and their Comparative Evaluation. Asia n J Pharm Clin Res. 2023;16(6):127-132 https://doi.org/10.22159/ajpcr.2023.v16i6.47274

13. Sharma VP, Ansari MA. Personal protection from mosquitoes (Diptera: Culicidae) by burning neem oil in kerosene. J Med Entomol. 1994;31(3):505-507. https://doi.org/10.1093/jmedent/31.3.505 PMid:7914543

14. Nerio LS, Olivero-Verbel J, Stashenko E. Repellent activity of essential oils: a review. Bioresour Technol. 2010;101(1):372-378. https://doi.org/10.1016/j.biortech.2009.07.048 PMid:19729299

15. Oyedele AO, Gbolade AA, Sosan MB, Adewoyin FB, Soyelu OL, Orafidiya OO. Formulation of an effective mosquito-repellent topical product from lemongrass oil. Phytomedicine. 2002;9(3):259-262. https://doi.org/10.1078/0944-7113-00120 PMid:12046869

16. Dhere P, Kunjir VV, Veerkar PV, Gadakh A. Formulation and evaluation of herbal mosquito repellent coil. Int. J. of Pharm. Sci. 2024;2(12):1293-1304. doi:10.5281/ZENODO.14374402

17. Tolle MA. Mosquito-borne diseases. Curr Probl Pediatr Adolesc Health Care. 2009;39(4):97-140. https://doi.org/10.1016/j.cppeds.2009.01.001 PMid:19327647

18. Trivedi A, Rai P, Kumar J. (2018). Formulation of low smoke herbal mosquito repellent sticks by using different essential oils. J. Pharm. Innov. 2018;7(4):173-175. https://www.thepharmajournal.com/archives/2018/vol7issue4/PartC/7-3-62-780.pdf

19. Songkro S, Hayook N, Jaisawang J, Maneenuan D, Chuchome T, Kaewnopparat N. Investigation of inclusion complexes of citronella oil, citronellal and citronellol with β-cyclodextrin for mosquito repellent. J Incl Phenom Macrocycl Chem. 2012;72(3-4):339-355. https://doi.org/10.1007/s10847-011-9985-7

20. Shapiro R. Prevention of vector transmitted diseases with clove oil insect repellent. J Pediatr Nurs. 2012;27(4):346-349. https://doi.org/10.1016/j.pedn.2011.03.011 PMid:22703681

21. Kalita, B., Bora, S., Sharma, A.K. (2013). Plant Essential Oils As Mosquito Repellent-A Review. Int J Res Dev Pharm Life Sci. 3(1):741-747. https://imsear.searo.who.int/server/api/core/bitstreams/e0406d6c-b17a-491f-afec-45eec94ec9ab/content

22. Yoo C. 12 Mosquito Repellent Plants. Garden Design Magazine. 2022. https://www.gardendesign.com/plants/mosquito-repellent.html

23. Tisgratog R, Sanguanpong U, Grieco JP, Ngoen-Kluan R, Chareonviriyaphap T. Plants traditionally used as mosquito repellents and the implication for their use in vector control. Acta Trop. 2016;157:136-144. https://doi.org/10.1016/j.actatropica.2016.01.024 PMid:26826392

24. Chellappandian M, Vasantha-Srinivasan P, Senthil-Nathan S, et al. Botanical essential oils and uses as mosquitocides and repellents against dengue. Environ Int. 2018;113:214-230. https://doi.org/10.1016/j.envint.2017.12.038 PMid:29453089

25. Shivhare RS, Kamble MA, Mahapatra DK, Ingole AR, Baheti JR. Development of mosquito repellant gel formulations from various natural volatile oils: comparative study with the marketed formulation odomos®. J Drug Deliv Ther. 2018;8(6):106-110. https://doi.org/10.22270/jddt.v8i6.2031

26. Sutthanont N, Sudsawang M, Phanpoowong T, et al. Effectiveness of Herbal Essential Oils as Single and Combined Repellents against Aedes aegypti, Anopheles dirus and Culex quinquefasciatus (Diptera: Culicidae). Insects. 2022;13(7):658. https://doi.org/10.3390/insects13070658 PMid:35886836 PMCid:PMC9322308

27. Halim Rd. Lesmana O. Sitepu FY. The effect of citronella oil as anti-mosquito spray. International Journal of Mosquito Research. 2021;8(5):44-47.

https://www.dipterajournal.com/pdf/2021/vol8issue5/PartA/8-5-9-812.pdf

28. Chatterjee S, Bag S, Biswal D, et al. Neem-based products as potential eco-friendly mosquito control agents over conventional eco-toxic chemical pesticides-A review. Acta Trop. 2023;240(106858):106858. https://doi.org/10.1016/j.actatropica.2023.106858 PMid:36750152

29. Setyaningsih D, Roselly F, Muna N. Formulation of essential oils as mosquito repellent. J Trop Pharm Chem. 2020;5(2):71-79. https://doi.org/10.25026/jtpc.v5i2.231

30. Sanga AG, Mazigo HD, Manjurano A, Morona D, Thomas A, Kweka EJ. Measuring repellence and mortality effects of clove and cinnamon essential oils impregnated nets against Anopheles gambiae senso stricto using tunnel test. Journal of Natural Pesticide Research. 2023;5(100046):100046. https://doi.org/10.1016/j.napere.2023.100046

31. Naik BR, Tyagi BK, Xue RD. Mosquito-borne diseases in India over the past 50 years and their Global Public Health Implications: A Systematic Review. J Am Mosq Control Assoc. 2023;39(4):258-277. https://doi.org/10.2987/23-7131 PMid:38108431

32. Guarner J, Hale GL. Four human diseases with significant public health impact caused by mosquito-borne flaviviruses: West Nile, Zika, dengue and yellow fever. Semin Diagn Pathol. 2019;36(3):170-176. https://doi.org/10.1053/j.semdp.2019.04.009 PMid:31006554

33. Gupta DK, Gupta R, Tiwari A. Novel formulation and evaluation of poly herbal mosquito repellent. Research Square. Published online 2022. https://doi.org/10.21203/rs.3.rs-1900478/v2

34. Ranasinghe MSN. Arambewela L. Samarasinghe S. Development of herbal mosquito repellent formulations. International Journal of Pharmaceutical Sciences and Research. 2016;7(9):3643-3648. https://doi.org/10.13040/IJPSR.0975-8232.7(9):3643-48