

MATERIALS NANOSCIENCE

Development of herbal mosquito repellent pellet with nanoencapsulated citronella oil

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ABSTRACT

There are various insects which are harmful for humans such as blackflies, drosophila, mosquitoes, cockroaches, fleas, rodents etc. They are the vector of harmful diseases such as plague, river blindness,



Essential oil

NanoEmulsion

Encapsulated oil

Pellet

dengue, malaria, sleeping sickness etc. among which mosquito is the major issue. In this study, Mosquitoes have been considered as model insect. Mosquito borne diseases are very harmful for both human and animals. It can cause infection like dengue, malaria, chikungunya etc. Thus, mosquito prevention is more important for today's world because there is no vaccine, or any specific treatment developed for mosquito borne diseases. Several insect repellents are available in market, like spray, gel, lotion etc. but they are based on synthetic repellent like DEET, DEPA, DMP etc. Which are toxic and harmful to both human and environment. To avoid this, herbal materials can be utilized as insect repellent. The essential oils are good choices in this regard. But they have less protection time against insects as compared to synthetic repellent. Using encapsulation technology, the efficiency of essential oil can be enhanced against various insects. Here citronella and eucalyptus oils were taken and encapsulated in solid lipid as well as in natural polymers. Encapsulated essential oils were mixed with marigold floral powders and repellent pellets were formed. Repellency of the herbal pellets were tested against mosquitoes by Y-tube method in laboratory condition. Results showed promising protection time for the mosquito. These pellets do not require to burn, no electricity is required to get the essential oil vapours. Only keeping a pellet in a room gives good fragrance as well as insect protection by slow-release diffusion method alone.

Keywords: Citronella, Eucalyptus, Mosquitoes, Repellent, NanoEncapsulation, Solid Lipid Nanoparticles.

INTRODUCTION

In today's era mosquitoes are the biggest issue for every tropical and sub-tropical country. Mosquito borne diseases are very harmful for both humans and animals. Mosquitoes are the vectors of several diseases such as Malaria,¹ Filariasis, Dengue, Chikungunya² etc. There are a lot of species of mosquitoes present in the world. Different species act as a vector of different diseases in humans like Aedes aegypti and Aedes albopictus is a

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DOI: 10.62110/sciencein.mns.2025.v12.1181 ©Authors, ScienceIn Publishing https://pubs.thesciencein.org/jmns vector of Dengue,³ Anopheles is a vector of Malaria^{4,5} etc. Generally male mosquito does not bite humans, female mosquitoes bite and suck the blood of humans because they need blood meal for the development of their eggs. Mosquito-borne infections generally cause illness in tropical and subtropical areas because mosquitoes can easily rear in such areas where open water is stagnated like open sewage, lakes etc. Mosquitoes have contributed enormous number of epidemics amongst the US and foreign military during World War II.⁶ As in today's world there is no vaccine, or any specific treatment developed for mosquito borne diseases.^{7–9} Hence different countries' populations take precautions against mosquito bites by wearing appropriate clothes, applying lotions, gels etc., use different sprays and electrical equipment to control mosquito population. Some

Sprays which are used to control mosquito population are used in indoor houses that are recommended by the WHO. For outdoor protection against mosquito¹⁰ some gels, lotions are available, but these all are time specific as it contains a low volatile compound.¹¹ Which provide protection on skin for a very little time, and it slowly evaporates in the air. The other issues with the lotion, gels and sprays are they are prepared by using chemical repellents such as N, N-diethyl-3- methylbenzamide (DEET), N, N-diethyl phenylacetamide (DEPA), dimethyl phthalate (DMP), N, N-di ethyl benzamide (DEBA), allethrin etc. and are used in the formulations¹² of lotions, sprays for protection against mosquitoes but these are very harmful and non-biodegradable chemicals.¹³ Which can affect humans as well as environment. Their high exposure to the environment may damage the ecosystem,¹⁴ long exposure to the human may cause serious lung diseases or lung damage and when applied at higher doses it may cause discomfort, side effects on skin as well as can be toxic to other parts of body. All repellents which are synthetic may cause serious problems to humans and environment both¹⁵ to save environment from such harmful chemicals, alternative is natural materials can be used. Herbal repellent can be prepared by using essential oils. It contains many chemical components that show defensive mechanism to protect mosquitoes.¹⁶ There are different essential oils like citronella oil, clove oil, lemon oil, eucalyptus oil etc. which are used as an alternative of DEET due to repellent efficacy against mosquitoes.¹⁷ It is safe for the environment and humans because it does not contain any harmful chemicals. But the major problem is Essential oils are highly volatile. They can evaporate in air within few minutes. Thus, in this work, a new method of encapsulation with solid lipid and hydrophilic polymer has been used for the development of repellent formulation using essential oils.

MOSQUITOES BORNE DISEASES:

Mosquitoes are the vector of several diseases. They are considered as a danger species for humans because they spread many deadly diseases. Almost 700 million people become ill due to mosquito borne diseases and about 1 million people have died because of Mosquito Borne diseases.¹⁸ Due to global warming the rate of infection has increased drastically because of the explosive growth of mosquito borne diseases worldwide. Almost 3500 mosquito species are found in tropical and subtropical regions of the world. There are some mosquitos borne diseases which are spread in the world are Zika virus, West Nile virus, chikungunya, Dengue, malaria.¹⁹ Generally female mosquito sucks the blood for their egg development. In their lifespan, 1 female mosquito can take blood meal several times to complete egg development. Mosquitoes are an agent or vector of devastating human disease.²⁰ the most harmful diseases which is spread by mosquito is Dengue and Malaria. From Dengue more than 400 million people are infected. The dengue virus has been a big worldwide problem since 1950. In an average case more than 1/3 population are at risk of the Dengue infection. Another most infected mosquito borne disease is malaria, and it is caused by the plasmodium pathogen which is transmitted by anopheles

mosquito. It is present in more than 100 countries. Malaria is one of the dangers of mosquitoes borne disease.

Mosquito-borne diseases are a threat to humans. Thus, to control mosquito borne disease the effective way is the control the mosquito vector and prevention from mosquito bites. There are various repellents to prevent from the mosquito bites and there are various synthetic spray, electric trap or net etc. to control the mosquito population. Generally, synthetic mosquito repellent is used to prevent mosquito biting but the major problem with synthetic repellent as it contains many harmful chemicals which may cause irritation, long exposure could be bad for human health as well as for our ecosystem.²¹

Chemical method		Non-chemical method		Biological method		
DEET,	HIT,	Mosquito	Net,	Few	Fishes	are
Citronella	Oil,	Mosquito	Trap,	growing in the ponds,		
Neem Oil,	Clove	Electronic		lakes	any open ar	ea so
Oil, Eucalyptus Oil		Mosquito		that	they feed	the
		Rackets,		Mosq	uito larvae	
		Mosquito Band				
		-				

Table 1: Various methods to control mosquitoes

Few other methods are used to control mosquitoes; like fogging but it's a temporary method and very harmful for health of many bugs that are unwanted, and they are badly affected due to fogging, it's a solution which contains 0.5% pyrethrins and 5.0% piperonyl butoxide. It also called as the most effective natural mosquito repellent.²²

There are various synthetic chemicals available in the market in the form of cream, gel, lotion, spray, coil etc. But there is no such 100% natural repellent is used for the protection of mosquito bite. There are many natural oils are repulsive for mosquito but still not used because of their high volatility. Such oils are eco-friendly and do not harmful for humans. There are many essential oils that can be used as a mosquito repellent such as citronella oil, eucalyptus oil, neem oil, clove oil etc.

ESSENTIAL OILS FOR MOSQUITO REPELLENT:

Essential oils are volatile naturally occurring from plants. It has a strong odor and formed by aromatic plants. They are liquid, non-colored, lipid soluble and have lower density than water. There are 17,500 aromatic plants and approx. 3000 essential oils are present, in which 300 oils are used in pharmaceuticals, cosmetics, and perfume industries. Some essential oil is extracted from plants such as neem oil, clove oil, eucalyptus oil, and citronella oil have repellent activity against mosquitoes. These oil contain metabolites like alpha-pinene, cineole, eugenol, limonene, camphor, citronellal, thymol is the common constituent in the essential oils which repel the mosquito.²³ Mosquitoes have hairs on their antennas they are temperature and moisture sensitive. The essential oil interacts with the female mosquito olfactory receptors and block the sense of smell of the mosquito.²⁴

Essential oils are good to prevent mosquitoes and do not have any effect on humans but due to their volatility because when oils are applied on skin, they evaporate within few minutes but if, their effective time will increase then it will be a good repellent for protects from mosquitoes. Thus, a new Technique that is solid lipid nanoparticle is used to increase their effective time. The repellent pellet is formulated with two essential oils that are citronella oil and eucalyptus oil. Both essential oils are effective on mosquitoes.

MATERIALS REQUIRED

Chemicals:

Citronella oil, eucalyptus oil, hexane, stearic acid, sodium alginate, polysorbate, calcium chloride, distilled water, marigold powder, rose powder, starch powder

Apparatus:

Beaker, vacuum oven, centrifuge, magnetic beads, magnetic stirrer, dropper

Procedure:



Flow Chart to Describe the Formulation of Repellent pellet.

Encapsulation Methodology

Hydrophilic polymer coated on solid lipid encapsulated essential oils were prepared using Citronella oil, eucalyptus oil and mixture of citronella and eucalyptus oil (1:1) separately. Stearic acid was used as model solid lipid and sodium alginate was taken as hydrophilic polymer. Emulsion – cross linking technique was used for encapsulating the essential oils.

For Aqueous Phase:

3% sodium alginate solution was prepared in distilled Water. For organic phase:

- stearic acid (solid lipid) was added in hexane
- After dissolving solid lipid in Hexane, Essential oil was added to organic phase.
- Thus prepared organic phase was poured in above prepared aqueous phase.

For emulsion

Organic phase and aqueous phase was mixed in presence of Tween 80 under stirring when stable O/W emulsion (Figure 1) was formed. Stirring was continued for an hour.



Figure 1: Laboratory preparation for an Emulsion



Figure 2: Crosslinking of Emulsion

For cross linking:

- 5% calcium chloride solution was used as the cross linking agent of aqueous polymer solution.
- Cross linking was performed by adding dropwise emulsion in the CaCl2 solution. When White beads were formed after adding dropwise emulsion in the calcium chloride solution (Figure 2).
- Sodium Alginate was converted into calcium alginate after cross linking (Figure 3).



Figure 3: Encapsulated Oil in Calcium alginate

For pellet formulation:

- Solid lipid nanoparticle was centrifuged at 7000rpm for 10 minutes.
- After centrifuge the solid nanoparticle and liquid were separated from the mixture.
- Starch solution was prepared by adding 2.5 g of starch in the 15 ml water.
- Further, solid nanoparticles were weighed and transferred into a clean, dry pestle and mortar. And crushed in it (Figure 4).



Figure 4: Crushing Solid Lipid Nanoparticle in the mortar and pestle

- Marigold and rose powder were added in the solid nanoparticle.
- Powder of marigold and rose mixed well in the solid nanoparticle and starch solution was added for binding (Figure 5).

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Figure 5: Mixture for Pellet Formulation

- After preparing the pellet, dried in the vacuum oven for 2 hours (Figure 6).
- Dry and wet mass of pellets are given in Table 2.



Figure 6: Pellet prepared using essential Oil

Table 2: Average wet and dry weight of Repellent pellet

S. no	Repellen t Pellet	Quanti ty of Cross- linked Emulsi on (in ml)	Average weight obtained after Centrifugatio n(g)	Averag e weight (g) of pellet (per piece)	Total pieces in a quanti ty
1.	Citronell a	40	26.8	2.5-3.0	10
2.	Eucalypt us	40	25	2.2-3.0	10
3.	Citronell a + Eucalypt us	40	31.4	1.6-3.0	10

CHARACTERIZATION

Dynamic light scattering (DLS):

Particle size distribution of prepared encapsulated oil beads was checked using dynamic light scattering (DLS) using Malvern instruments (Zetasizer Nano S-90). The light source used in the instrument was He–Ne laser light having a wavelength of 633 nm and a scattering angle fixed at 90°. The particles size obtained from all three types of encapsulated oil beads are given in Table 3.

Table 3: Particle size of different encapsulated repellent oil beads

s.no	Particle Size of Encapsulated Oil beads	Particle Size(nm)
1.	Citronella	393
2.	Eucalyptus	216
3.	Citronella + Eucalyptus	167
10 8 6 6 4		~
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Figure 7: DLS Analysis of 1: Citronella Oil Encapsulated Beads, 2: Eucalyptus Oil Encapsulated Beads, 3: Citronella Oil + Eucalyptus Oil Encapsulated Beads

Y- Tube olfactometer:

Y- Tube Olfactometer is equipment which is used to test the behavioral response of the mosquito in the two arms of Y-tube. In this equipment there is a y tube in which 3 different zones are present. The Y- tube olfactometer was primarily utilized to assess the impact of different repellent pellets of essential oils against Anopheles (Mosquito). The test was performed in Y-tube olfactometer having dimension of 17cm of each arm and diameter 1.3 cm. Anopheles (Mosquito) was introduced in the Ytube for repellency test. The test was performed in a room with a temperature of 25 to 27° C and 65% to 75% RH. 0.2 gram of all 3 different repellent pellets i.e., citronella oil pellet, eucalyptus oil pellet and citronella+ Eucalyptus oil pellet were kept on Whatman filter paper card (1.5 cm x 1.5 cm) which served as source while similar filter paper card with 0.2-gram pellet without containing any essential oil served as a control. Source paper card was inserted in one arm and control paper card was inserted in another arm of Y- tube Olfactometer. The third lower arm of the Ytube olfactometer served as the entry point for mosquito. Constant flow of air was maintained using air flow meter through the end part of the tube in all the 16 replication tubes. for every pellet 16 repellency tests were done. Automatic test was done on the Ytube olfactometer by using software and in manual 5 replication tubes were arranged for observation and the position of mosquito, for 2 minutes interval of the 10 minutes duration of the assay was recorded and tabulated after tabular Formed Average was used for the Graph of repellency Test.



Figure 8: Y- Tube with having pellet and Insect

DISCUSSION

The repellency data obtained from Y-tube olfactometer for different pellets against mosquitoes is given in Table 4.

Table 4: Result average in Percentage of the different repellentpellets against the Mosquito.

S.no	Pellet	Source (%)	Control (%)	
1.	Citronella	40	60	
2.	Eucalyptus	36.3	63.6	
3.	Citronella + Eucalyptus	5	95	





Figure 9: Graph Shows the Response of the 1: Citronella Pellet against the Mosquito, 2: Eucalyptus Pellet against the Mosquito, 3: Citronella+ Eucalyptus Pellet against the Mosquito

CONCLUSION

From the above results, it can be concluded that Herbal repellent pellets were successfully prepared using essential oils like. citronella oil, eucalyptus oil, and mixture of both. For encapsulation of essential oils, alginate modified solid lipid nanoparticles proved to be an efficient carrier system for prolonged repellency against mosquitoes. Essential Oil based repellent pellet can be used effectively to keep away the mosquitoes. The advantage of the developed pellets is that these are non-toxic, eco-friendly and cost effective. These pellets neither require any electricity nor ignition to show the mosquito repellency.

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REFERENCES

- G. Benelli, H. Mehlhorn. Declining malaria, rising of dengue and Zika virus: insights for mosquito vector control. *Parasitol. Res.* 2016, 115 (5), 1747–1754.
- C.K. Roy, R. Sadiwala. Smart internet of things (IoT) based healthcare framework environment for Chikungunya disease diagnosis. *J. Integr. Sci. Technol.* 2024, 12 (4), 779.
- 3. M.G. Guzman, E. Harris. Dengue. Lancet 385, 453-465.
- P.P. Sharma, M. Kumari, R. Kumar, G. Singh. Synthesis of in-silico designed plasmepsin X inhibitors and evaluation of their anti-plasmodial effects. J. Mol. Chem. 2022, 2 (2), 443.
 - G. Aggarwal, M.K. Goyal. VL-M2C: Leveraging deep learning approach for stage detection of malaria parasites. *J. Integr. Sci. Technol.* **2025**, 13 (3), 1055.
 - C. Beadle, S.L. Hoffman. History of malaria in the united states naval forces at war: World war i through the vietnam conflict. *Clin. Infect. Dis.* **1993**, 16 (2), 320–329.
- P.P. Sharma, A. Sethi, B. Dwivedi, et al. Novel Inhibitors of malarial aspartyl proteases, plasmepsin II and IV: In silico design and validation studies. *Chem. Biol. Lett.* **2022**, 9 (1), 315.
- M. Bansal, S. Kumar, B. Rathi. Synthesis of novel phthalimide-based piperazine conjugated analogs as anti-malarial agents. *Chem. Biol. Lett.* 2023, 10 (4).
- J.C. Dickens, J.D. Bohbot. Mini review: Mode of action of mosquito repellents. *Pestic. Biochem. Physiol.* 2013, 106 (3), 149–155.
- A.B. Mapossa, M.M. Sibanda, A. Sitoe, et al. Microporous polyolefin strands as controlled-release devices for mosquito repellents. *Chem. Eng. J.* 2019, 360, 435–444.
- H. Izadi, W.W. Focke, E. Asaadi, et al. A promising azeotrope-like mosquito repellent blend. *Sci. Rep.* 2017, 7 (1), 10273.
- D.L. Sudakin, W.R. Trevathan. DEET: A Review and Update of Safety and Risk in the General Population. J. Toxicol. - Clin. Toxicol. 2003, 41 (6), 831–839.
- F.B. Antwi, L.M. Shama, R.K.D. Peterson. Risk assessments for the insect repellents DEET and picaridin. *Regul. Toxicol. Pharmacol.* 2008, 51 (1), 31–36.
- P.K. Mittal, U. Sreehari, R.K. Razdan, A.P. Dash, M.A. Ansari. Effcacy of Advanced Odomos repellent cream (N, N-diethyl-benzamide) against mosquito vectors. *Indian J. Med. Res.* 2011, 133 (4), 426–430.
- J. Islam, K. Zaman, V. Tyagi, et al. Protection against mosquito vectors Aedes aegypti, Anopheles stephensi and Culex quinquefasciatus using a novel insect repellent, ethyl anthranilate. *Acta Trop.* 2017, 174, 56–63.
- 16. A. Tawatsin, U. Thavara, U. Chansang, et al. Field evaluation of deet, Repel Care®, and three plant-based essential oil repellents against mosquitoes, black flies (Diptera: Simuliidae), and land leeches (Arhynchobdellida: Haemadipsidae) in Thailand. J. Am. Mosq. Control Assoc. 2006, 22 (2), 306–313.

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- B.M. Kuehn. CDC: New Repellents for West Nile Fight. JAMA 2005, 293 (21), 2583.
- H. Caraballo, K. King. Emergency department management of mosquitoborne illness: malaria, dengue, and West Nile virus. *Emergency medicine practice*. 2014, pp 1–4.
- V. Baghela, K. Meena, N. Kachhwaha. Larvicidal and adulticidal activities of Cymbopogon citratus synthesized silver nanoparticles in different mosquito vectors. J. Integr. Sci. Technol. 2025, 13 (3), 1052.
- K. Michel, F.C. Kafatos. Mosquito immunity against Plasmodium. *Insect Biochem. Mol. Biol.* 2005, 35 (7), 677–689.
- 21. D. Sritabutra, M. Soonwera, S. Waltanachanobon, S. Poungjai.

Evaluation of herbal essential oil as repellents against Aedes aegypti (L.) and Anopheles dirus Peyton & Harrion. *Asian Pac. J. Trop. Biomed.* **2011**, 1 (SUPPL. 1), 124–128.

- Z. Wang, J. Song, J. Chen, et al. QSAR study of mosquito repellents from terpenoid with a six-member-ring. *Bioorg. Med. Chem. Lett.* 2008, 18 (9), 2854–2859.
- L.S. Nerio, J. Olivero-Verbel, E. Stashenko. Repellent activity of essential oils: A review. *Bioresource Technology*. 2010, pp 372–378.
- A.K. Tripathi, S. Upadhyay, M. Bhuiyan, P.R. Bhattacharya. A review on prospects of essential oils as biopesticide in insect-pest management. *J. Pharmacogn. Phyther.* 2009, 1 (5), 52–63.