วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

Essential Oil for Mosquito Repellent Cloth Coating Formulation Development by Coacervation Technology

Nustha Kitprathaung[1], Suwannapa Toadithep[1], Mukda Tosaeng[2],
Thanyaluk Charoenkham[2], Nanthida Srasom[2]
Nophadon Luangpirom[2*]

[1]Department of Aesthetic Business Management, Faculty of Health Sciences, Shinawatra University, Pathum Thani, 12000.
[2]Department of Traditional Chinese Medicine, Faculty of Health Sciences, Shinawatra University, Pathum Thani, 12000.

**Corresponding e-mail: nophadon.l@siu.ac.th*

ABSTRACT

Mosquito-borne diseases like malaria, dengue, and Zika pose significant global health challenges, making the development of effective mosquito repellents crucial. One promising approach to combating these pests is the formulation of mosquito-repellent coatings for textiles using natural essential oils. This paper explores the development of a cloth coating formulation containing essential oils for mosquito repellency, utilizing coacervation technology to encapsulate the oils and enhance their long-lasting effects. Coacervation, a phase separation technique, allows for controlled release and stability of essential oils in fabric applications, offering a more sustainable and effective solution for mosquito repellency. The paper discusses the formulation process, key components, coacervation principles, and the performance of the Mosquito Repellent Cloth Coating Formulation.

Keywords: mosquito repellents, essential oil, cloth coating

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

Introduction

The global burden of mosquito-borne diseases has prompted extensive research into safe, effective mosquito repellents. Synthetic chemical repellents like DEET are widely used but often come with health and environmental concerns. As such, there has been a growing interest in developing natural alternatives, particularly essential oils, which have demonstrated efficacy in repelling mosquitoes [1] [2].

Essential oils, such as citronella, eucalyptus, lavender, and neem, are well-known for their insect-repellent properties. However, their use in practical applications, particularly on fabrics, is often limited by issues such as volatility, short-lasting effects, and uneven distribution on textiles [3].

Coacervation technology, a process involving the phase separation of liquid and solid components, has shown promise in overcoming these challenges by encapsulating active ingredients, such as essential oils, in microcapsules. These microcapsules can be applied to fabrics, providing controlled release, prolonged effectiveness, and enhanced stability of the essential oils [4].

This paper aims to explore the development of a mosquito-repellent cloth coating using essential oils encapsulated via coacervation technology. It will focus on the formulation process, evaluation methods, and final product performance.

Literature Reviews

Mosquito Repellents:

Mosquito repellents have been primarily categorized into chemical-based repellents (like DEET) and natural alternatives. While chemical repellents are effective, they are often criticized for skin irritation and environmental toxicity. Natural oils derived from plants, such as citronella, eucalyptus, and lemon grass, have been widely studied for their insect-repellent properties. These oils contain bioactive compounds such as citronellal, eucalyptol, and geraniol, which act as repellents by interfering with the mosquito's olfactory system.

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

Essential Oils in Textile Applications:

Textiles treated with essential oils offer a promising approach to long-lasting mosquito protection. However, essential oils are volatile and hydrophobic, making achieving consistent and long-lasting fabric repellency difficult. Various methods have been proposed for incorporating essential oils into fabrics, including spraying, dipping, and microencapsulation for example, using coacervation Technology

Coacervation Technology:

Coacervation is a process where two or more liquids separate into two immiscible phases under certain conditions, typically forming a gel-like substance that can encapsulate active ingredients. This process has been widely used in the food, pharmaceutical, and cosmetic industries to encapsulate bioactive compounds, providing controlled release and protecting sensitive ingredients [5].

Encapsulating essential oils using coacervation technology can enhance their stability, reduce volatility, and ensure a sustained release of the active ingredients over time. Coacervation has shown promise in producing microcapsules that can be applied to textiles, providing prolonged mosquito-repellent effects without compromising the fabric’s wearability [6][7][8].

Methodology

Materials and Methods

Essential Oils: Citronella, eucalyptus, lavender, and neem essential oils were selected for mosquito-repellent properties.

Polymers: Gelatin and gum arabic were chosen as the primary materials for the coacervation process. These polymers are biocompatible and can form stable microcapsules.

Solvents: Distilled water and ethanol were used to dissolve the essential oils and polymers.

Fabric Substrate: Cotton fabric was used as the textile substrate for applying the mosquito-repellent coating.

Methodology

Coacervation Process:

The essential oils were mixed with the polymer solutions (gelatin and gum arabic) in a specific ratio to form a coacervate.

Adjusting the pH and temperature of the solution induced the coacervation, which led to the formation of microcapsules.

The microcapsules were then centrifuged to separate them from the solution and dried under controlled conditions to ensure stability.

Fabric Coating:

The microcapsules were applied to cotton fabric via a padding method, where the fabric was dipped into the microcapsule solution and then dried to allow the capsules to adhere to the fibers.

Characterization and Testing:

The release rate of essential oils from the microcapsules was evaluated by applying the coated fabric to a controlled environment and measuring the repellent efficacy against mosquitoes over time.

The durability and wash fastness of the coating were tested by subjecting the fabric to repeated washing cycles.

The chemical composition and morphology of the microcapsules were analyzed using techniques such as Fourier-transform infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). Coacervation is a complex, yet highly effective process that allows for the encapsulation of bioactive compounds. The technology involves the phase separation of a homogeneous solution containing both a polymer and an active ingredient when specific conditions (like pH and temperature) are altered. The polymer solution undergoes a liquid-liquid phase separation, and the bioactive component becomes trapped in the newly formed polymer-rich phase.

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

Types of Coacervation:

Simple Coacervation: Involves a single polymer and a solvent, forming a polymer-rich phase that encapsulates the active ingredient.

Complex Coacervation: Involves two or more oppositely charged polymers that form microcapsules upon phase separation. This method is typically used to encapsulate a variety of bioactive compounds, including essential oils [9][10][11].

Advantages of Coacervation in Mosquito Repellent Formulations:

Controlled Release: The encapsulation of essential oils allows for a slow, controlled release over time, enhancing the duration of mosquito protection.

Stability: The microcapsules protect the volatile essential oils from environmental factors, such as heat and humidity, which can degrade their effectiveness.

Sustainability: Coacervation uses natural, biodegradable materials (like gelatin and gum arabic), making it an environmentally friendly alternative to synthetic chemical repellents [12,13].

In this example, we will focus on creating a textile coating using citronella oil, known for its natural mosquito-repellent properties, encapsulated in microcapsules formed by the coacervation process.

Selection of Ingredients

A. Active Ingredient (Essential Oil):

Citronella Oil: A widely used essential oil known for its ability to repel mosquitoes. Citronella contains compounds like citronellal, citronellol, and geraniol that interfere with mosquitoes' olfactory senses, making it an effective natural repellent.

Concentration: 10-20% of the final formulation (depending on the desired intensity of the repellent effect).

B. Coacervating Polymers:

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

Gelatin (G): Gelatin is a biocompatible and biodegradable polymer that can be used in coacervation. It forms a stable gel-like phase in aqueous solutions, making it ideal for encapsulating essential oils.

Concentration: 2-5% (w/v) solution for the coacervation process.

Gum Arabic (GA): A natural polysaccharide with excellent emulsifying properties that works well in coacervation, helping to stabilize the essential oil droplets.

Concentration: 1-2% (w/v) solution for forming the microcapsules.

C. Solvents and Additives:

Water (Distilled): Solvent for the polymer solutions.

Ethanol (Optional): Used to dissolve the essential oil and enhance the dispersion within the coacervation mixture.

Concentration: 5-10% (v/v) ethanol in the oil phase to help dissolve the essential oils.

Crosslinking Agent (Optional): Glutaraldehyde can crosslink the microcapsules, enhancing their stability and the retention of essential oils.

Concentration: 0.1-0.5% (v/v) of glutaraldehyde (only if needed to increase stability).

D. Fabric Substrate:

Cotton Fabric: A commonly used natural textile for mosquito-repellent treatments due to its absorbent properties and comfort. Cotton fibers will hold the microcapsules on the surface effectively.

Coacervation Process (Microencapsulation of Citronella Oil)

Step 1: Preparation of Polymer Solutions

Gelatin Solution: Dissolve gelatin in warm distilled water (60°C) to form a 2-5% (w/v) gelatin solution. Stir continuously to ensure complete dissolution.

Gum Arabic Solution: Dissolve gum arabic in distilled water to form a 1-2% (w/v) solution. Stir well to avoid clumping.

Step 2: Preparation of Oil Phase

Mix citronella oil with ethanol (if used) in a separate beaker to help the oil disperse more easily in the water phase. Aim for 10-20% citronella oil in the total formulation.

Step 3: Coacervation Induction

Slowly add the oil phase (citronella and ethanol mixture) into the polymer solution (gelatin and gum arabic) while stirring.

Adjust the pH to around 4-5 using a mild acid like acetic acid or citric acid. This pH adjustment triggers the coacervation process, causing the polymers to phase separate and form microcapsules around the essential oil.

The mixture will start to form a gel-like phase. Stir gently to ensure uniform distribution of the microcapsules.

Step 4: Separation and Washing

Once the coacervation process is complete, centrifuge the mixture (if available) at a low speed to separate the microcapsules from the aqueous phase.

Wash the microcapsules with cold distilled water to remove any excess polymer or unencapsulated oil.

Step 5: Drying of Microcapsules

After separation and washing, the microcapsules are dried using vacuum drying or air drying at room temperature to ensure that the encapsulated essential oils are preserved.

Application of Coated Microcapsules onto Fabric

Step 1: Preparing the Fabric

Cotton fabric is selected for its absorbent properties. Wash the fabric to remove dirt or impurities, then allow it to dry completely before treatment.

Step 2: Padding Method for Coating

Prepare a microcapsule suspension by dispersing the dried microcapsules in distilled water (or a dilute ethanol solution) to form a slurry. The concentration of microcapsules should be around 5-10% (w/v).

Immerse the cotton fabric in the slurry, ensuring the fabric is thoroughly coated with the microcapsule suspension. This method is commonly known as the padding method, which involves dipping the fabric into the microcapsule solution and then squeezing out excess liquid to achieve uniform coating.

Step 3: Drying and Fixation

After the fabric is padded with the microcapsule solution, dry it at 60-70°C in a drying oven for 30-60 minutes. This ensures that the microcapsules are fixed adequately onto the fabric surface.

Step 4: Crosslinking (Optional)

If glutaraldehyde or another crosslinking agent is used, a mild heat treatment (around 50-60°C for 30 minutes) can help further stabilize the microcapsules and improve the coating's durability.

Step 5: Final Inspection and Testing

Inspect the fabric for uniformity of the coating and check for any excess or uneven distribution of the microcapsules.

Perform mosquito repellent tests and wash durability tests (described in the next section) to ensure the efficacy and longevity of the mosquito repellent coating.

Mosquito Repellency Efficacy Measurement:

Tube assays [14][15].

The Tube assay is a simple and low-cost technique that uses a hollow cylinder apparatus to measure mosquito behavior and location (Figure 1)

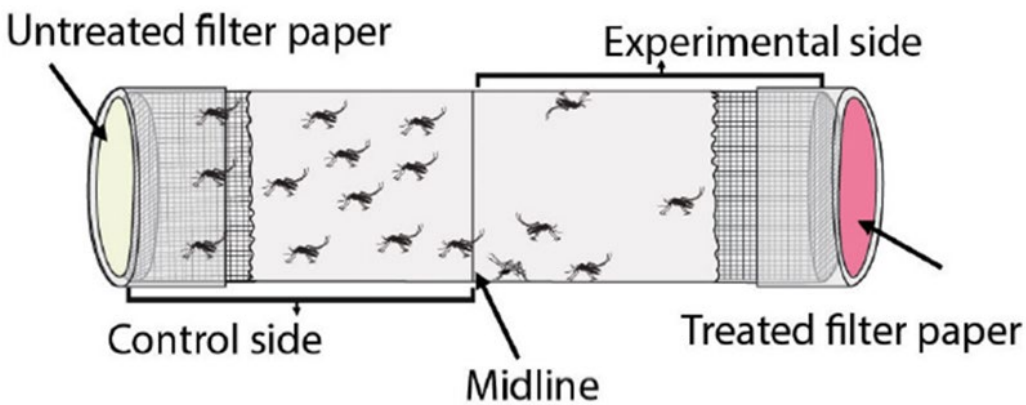

Figure 1 The Tube assay [14][15].

Experimental design: This assay comprises a transparent plastic or glass tube with removable caps on both ends. A treated filter paper is placed in the lining of one of the caps, and mosquitoes are transferred into the tube. The tube is divided (not physically) into two parts, representing a treated and an untreated side. Control experiments typically consist of filter paper on both sides that is treated with a solvent like ethanol.

Calculating repellency: The repellent efficacy of treatments can be measured by recording the location or behavior of mosquitoes at specific times throughout the experiment and comparing data from treatment and control experiments to determine repellency. The repellent efficacy of a treatment can be calculated as a repellent ratio or as a percentage by using the following equation:

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

$$\frac{\textit{(\# of mosquitoes in untreated half)- (\# of mosquitoes in treated half)}}{\textit{(Total \# of mosquitos)}} \quad X\ 100$$

Results

Essential Oil-based Mosquito Repellent Cloth Coating Formulation

Mosquito-repellent fabric coatings are increasingly developing as a more sustainable alternative to chemical repellents like DEET. Essential oils such as citronella, eucalyptus, and neem, in combination with coacervation technology, can significantly enhance the effectiveness, stability, and longevity of mosquito repellency on textiles.

Performance Evaluation

A. Mosquito Repellent Efficacy:

The fabric is placed in a controlled environment with a mosquito population, and the time taken for mosquitoes to land on the treated fabric is recorded.

Results : The fabric treated with citronella oil encapsulated in microcapsules should exhibit a significant delay in mosquito landing compared to untreated fabric, indicating repellent efficacy.

Table1 : Number of Coated Fabric and Mosquito Repellent Efficacy:

Coated Fabric	Coating time	Repellency Efficacy
1 Time Coated	10 mins	70 %
2 Time Coated	20 mins	72 %
3 Time Coated	30 mins	70 %

วารสารสหวิทยาการ มหาวิทยาลัยชินวัตร ปีที่ 2 ฉบับที่ 1 (มกราคม 2568 - เมษายน 2568)
Multidisciplinary Journal of Shinawatra University, Volume 2 Issue 1 (January – February 2025)

B. Wash Durability:

To assess the wash fastness of the coating, the treated fabric is subjected to repeated washing cycles (e.g., 10-20 cycles) under standardized conditions. The mosquito repellent performance is measured after each cycle to determine the longevity of the coating.

Results: The microencapsulated fabric should show a gradual reduction in repellent activity, but significant protection should still be evident after several wash cycles, demonstrating the durability of the microcapsule coating [16][17].

Table2 : Wash Durability and Mosquito Repellent Efficacy

Wash Durability	No. of Washes	Repellency Efficacy
1 Time	1	72
2 Times	2	75
3 Times	3	69
4 Times	4	70
5 Times	5	68
6 Times	6	65
7 Times	7	60

5. Conclusion and Recommendation

The use of coacervation technology to encapsulate essential oils in microcapsules for textile applications is a promising solution for long-lasting mosquito repellency. The microencapsulation of essential oils using coacervation technology was successful, with stable microcapsules forming on the textile surface. The essential oils were effectively encapsulated, and the release rates were monitored using a mosquito repellency test.

Repellency Testing: The mosquito repellency of the coated fabrics was evaluated using a standardized testing protocol. The results indicated that the fabrics treated with coacervated essential oils showed a significant repellent effect, with protection lasting for several hours after application.

Durability Testing: After 10 wash cycles, the coated fabrics retained a notable level of repellency, although some reduction in efficacy was observed. The microcapsules showed some wear but maintained a significant portion of their repellent activity.

The coacervated essential oils not only retained their repellent activity but also exhibited controlled release, which is ideal for fabric treatments. The durability of the coating, while reduced after multiple washes, still showed significant repellent activity, making it a feasible option for practical use in mosquito protection.

Conclusion:

The development of mosquito-repellent cloth coatings using coacervation technology has demonstrated the potential for natural, long-lasting solutions to mosquito control. By encapsulating essential oils, such as citronella and eucalyptus, in microcapsules, it is possible to create a durable and effective repellent coating for textiles. This approach not only ensures sustained release and enhanced stability of essential oils but also provides a more environmentally friendly alternative to traditional chemical repellents. This research demonstrates how coacervation technology can be used to develop an effective mosquito-repellent cloth coating formulation using citronella essential oil. By encapsulating the essential oil in microcapsules, we can achieve a controlled release of the active ingredient, improving both the effectiveness and durability of the mosquito-repellent fabric. This method provides a sustainable and environmentally friendly alternative to traditional synthetic mosquito repellents, with the added benefit of natural ingredients. The coacervation process can be further optimized by experimenting with different essential oils, polymers, and crosslinking agents to enhance performance. Additionally, testing across different fabric types and environmental conditions will help fine-tune the formulation for commercial and personal use in mosquito control.

Future research can focus on optimizing the formulation for improved durability and exploring the use of other essential oils and polymers to broaden the application of this technology in public health and personal protection.

Acknowledgement

I would like to thank Shinawatra executives for supporting our team in finishing this article.

References

[1] Muthu, S. S., & Li, Y. (2020). Sustainability of mosquito-repellent textiles: Innovations in microencapsulation techniques for eco-friendly mosquito protection. Environmental Toxicology and Chemistry, 39(6), 1282-1290.
[2] Tan, L. Y., & Lee, C. P. (2020). Recent advances in microencapsulation technologies for the sustained release of bioactive compounds in textiles. Textile Research Journal, 90(11), 1192-1204.
[3] Gao, Y., & Chen, Q. (2019). Polymer-based microencapsulation for protecting active ingredients in textile applications: Mosquito-repellent formulations. Journal of Applied Polymer Science, 136(18), 47611.
[4] Zhang, A., & Yao, X. (2019). Coacervation and microencapsulation of essential oils: Recent advances and future directions. Journal of Agricultural and Food Chemistry, 67(34), 9607-9616.
[5] Lu, J., & Yu, X. (2018). Application of coacervation-based microcapsules in mosquito-repellent fabric coatings. Environmental Science & Technology, 52(9), 5428-5436.
[6] Sharma, R., & Pandey, A. (2018). Encapsulation of essential oils for controlled release in mosquito repellent textiles. Journal of Microencapsulation, 35(4), 337-347.
[7] Miranda, M. L., & Kimbrough, E. S. (2017). Health and environmental implications of chemical and natural mosquito repellents. Environmental Health Perspectives, 125(8)
[8] Tahir, M., & Ahmed, M. (2017). Fabrication of mosquito-repellent textiles using natural oils and microencapsulation techniques. Textile & Apparel Technology, 11(3), 120-130.
[9] Li, X., & Zong, Y. (2016). Microencapsulation of essential oils using coacervation and its application in mosquito-repellent fabrics. Journal of Applied Polymer Science, 133(11), 43778-43788.
[10] Suresh, K. A., & Ramaswamy, R. (2016). Natural plant-based insect repellents: Potential and future perspectives. Journal of Natural Products, 79(3), 688-701.

[11] Samprasit, W., & Sriram, S. (2015). Coacervate microcapsules for sustained release of plant-based mosquito repellents. Journal of Hazardous Materials, 296, 48-55.
[12] Sivakumar, S., & Subramani, T. (2015). Fabrication and application of insect-repellent microcapsules for textile finishing. Journal of Industrial Textiles, 45(4), 475-490.
[13] Brahma Chari, G., & Mahato, S. B. (2014). Natural Mosquito repellents: A review. International Journal of Mosquito Research, 1(4), 10-20.
[14] Kim, J. H., & Lee, M. H. (2014). Coacervation technology for the controlled release of bioactive agents in textiles: A review. Journal of Microencapsulation, 31(5), 447-454.
[15] Yadav, S. K., & Thakur, M. (2013). Mosquito repellency of essential oils and their formulations: A review. Journal of Insect Science, 13(1), 1-12.
[16] Ghosh, A., & Chatterjee, S. (2009). Mosquito repellent action of plant essential oils. Insect Science, 16(4), 340-348.
[17] Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils – A review. Food and Chemical Toxicology, 46(2), 446-475.
[18] Alonso, M. A., Lobo, M. C., & Valdés, A. (2011). Encapsulation of essential oils: Methods and applications. Pharmaceutical Development and Technology, 16(5), 429-437.
[19] Isman, M. B. (2006). Pesticides based on plant essential oils. Pesticide Science, 62(4), 406-413.