WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.453
Volume 14, Issue 10, 1455-1473. Research Article ISSN 2277–7105

FORMULATION AND EVALUATION OF LEMONGRASS (*CYMBOPOGON CITRATUS*) DERIVED MOSQUITO REPELLENT ACTION BY TRANSDERMAL DRUG DELIVERY

[1]Balkrishna Tiwari, [2]Garad Shruti Satish, *[3]Kasturi Sanjana Amarnath and [4]Kamuni Shreya Shriniwas

[1]Vice Principal, [2]Research Guide, [3,4]Students,

[1,2,3,4]Amepurva Fourm's Nirant Institute of Pharmacy, Boramani Solapur – 413002.

Article Received on
05 April 2025,

Revised on 25 April 2025,
Accepted on 15 May 2025

DOI: 10.20959/wjpr202510-36931

***Corresponding Author**
Kasturi Sanjana Amarnath
Students, Amepurva Fourm's Nirant Institute of Pharmacy, Boramani Solapur – 413002.

ABSTRACT

Mosquito-borne diseases like malaria, dengue, chikungunya, filariasis, and Zika remain major health concerns, especially in tropical regions. While synthetic repellents are effective, they often cause skin irritation. This study explores herbal transdermal patch using lemongrass (*Cymbopogon citratus*) and ajwain (*Trachyspermum ammi*) extracts, known for their repellent properties. The patch was formulated with HPMC, CMC, PEG 400, lavender oil, and ethanol. It was evaluated for weight, thickness, folding endurance, moisture content, pH, and more. Results showed good physical stability, skin compatibility, and strong mosquito repellent activity in net cage tests. Stability studies confirmed long-term effectiveness. Overall, the herbal patch provides a safe, natural, and skin-friendly alternative to chemical repellents, offering prolonged protection against mosquito-borne diseases.

KEYWORDS: Mosquito-borne diseases, patch, Mosquito repellents, Transdermal drug delivery system, Transdermal patch, Lemongrass.

INTRODUCTION

Mosquito-borne diseases remain a major global health concern, especially in tropical and developing regions. Illnesses such as dengue, chikungunya, malaria, yellow fever, filariasis, and Zika virus cause hundreds of thousands of deaths annually. According to the World Health Organization (WHO), over 700,000 deaths each year are linked to vector-borne

diseases, with mosquitoes being the primary carriers.[1] Rising global temperatures and urbanisation have further increased mosquito breeding grounds and disease transmission.

Personal protection through topical repellents is a key strategy in mosquito control. Synthetic repellents like DEET, picaridin, and permethrin are effective but often cause side effects, including skin irritation and potential neurotoxicity.[2] As a result, there is growing interest in natural, plant-based alternatives. Essential oils from citronella, eucalyptus, ajwain, and particularly lemongrass (*Cymbopogon citratus*) have shown strong repellent activity due to compounds like citral, limonene, and geraniol. Lemongrass is a tropical grass widely used in medicine and aromatherapy. It's essential extract, typically extracted through Soxhlet extraction, has proven effective against *Aedes aegypti* and *Culex quinquefasciatus*, which transmit dengue, Zika, and filariasi.[3] However, its high volatility limits its duration of protection when applied topically. To overcome this, transdermal drug delivery systems (TDDS) are being explored. TDDS offer controlled release, longer duration, and improved compliance by delivering active agents through the skin. Among these, transdermal patches are popular due to their ease of use and steady release of actives.[4] Incorporating lemongrass oil into polymer-based patches, such as those using hydroxypropyl methylcellulose (HPMC) or carboxymethyl cellulose (CMC), enhances stability and prolongs repellent action up to 6–8 hours. This method offers a clean, effective, and user-friendly solution for natural mosquito protection.

1.1 Transdermal Drug Delivery Systems (TDDS)

TDDS are medicated patches applied to the skin that deliver drugs at a controlled rate into systemic circulation, enhancing therapeutic efficacy and minimizing side effects. They maintain drug levels within the therapeutic window, avoiding peaks and troughs. TDDS bypass first-pass metabolism, improve patient compliance, and are ideal for drugs with short half-lives. They offer a non-invasive alternative to oral and injectable routes and have been used since 1979 for systemic delivery. Transdermal patches, available in various sizes, can deliver one or more active ingredients via diffusion, providing steady, painless drug administration that can be easily discontinued.[6]

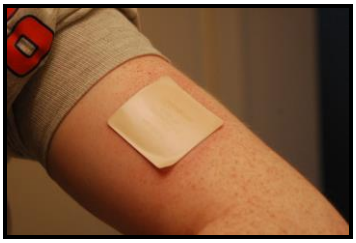


Figure 1: Transdermal patch.

1.1.1 Advantages of TDDS

1. Bypasses first-pass metabolism for sustained drug release.
2. Improves patient compliance with painless, easy use.
3. Avoids gastrointestinal degradation and irritation.
4. Maintains steady blood drug levels.
5. Suitable for drugs with short half-lives or low therapeutic index.

1.1.2 Disadvantages of TDDS

1. Requires drugs with suitable physicochemical properties.
2. Limited to low daily drug doses (<5–25 mg).
3. May cause local skin irritation.
4. Inability to deliver large molecules.
5. Skin barrier variability affects absorption.

1.1.3 Components to a transdermal patch

- **Polymer matrix**: The backbone of TDDS is the polymer matrix, which regulates the drug's release. The polymer should be nontoxic, chemically non-reactive, and not break down while being stored. It should also be reasonably priced. Such as cellulose derivatives, gums, waxes, Polyvinyl alcohol, polyvinyl chloride, etc.
- **Drug:** For medications with the right pharmacology and physical chemistry, the transdermal route is a very alluring choice. Transdermal patches are very beneficial for medications having a short half-life, a small therapeutic window, or substantial first-pass metabolism. Such as nitroglycerine, fentanyl, etc.
- **Permeation enhancers**: these improve the stratum corneum's permeability to reach higher therapeutic medication levels. Surface-active agents, lipophilic solvents, and two-component systems are the three categories.
- **Adhesive:** such as DMSO, increases the stratum corneum's permeability, allowing for the achievement of greater therapeutic medication levels.

- **Backing laminates:** ought to be highly flexible or have a low modulus. Such as polyethylene and vinyl.
- **Release liner**: Preserves the patch while it is being stored. Before using, the liner is taken out.
- Additional excipients, such as solvents and plasticizers.[7,8]

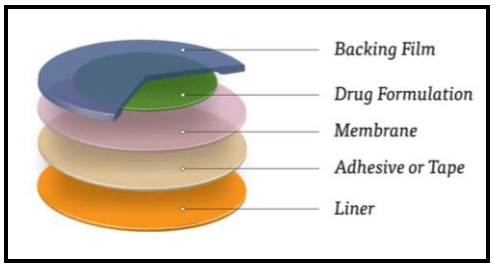


Figure 2: Transdermal Patch layers.

1.1.4. Types of Transdermal Drug Delivery Systems (TDDS)

1. **Adhesive Dispersion System**: The drug is mixed directly into the adhesive layer that sticks to the skin, offering a simple and flexible design.
2. **Reservoir System**: Contains a drug reservoir separated from the skin by a rate-controlling membrane. The drug is released at a constant rate. Example: Nitroglycerin patch.
3. **Matrix System**: The drug is evenly dispersed in a polymer matrix, and it is released as it diffuses through the matrix to the skin.
4. **Micro-reservoir System**: Combines features of reservoir and matrix systems. The drug is enclosed in tiny reservoirs within a polymer matrix for better control.[9]

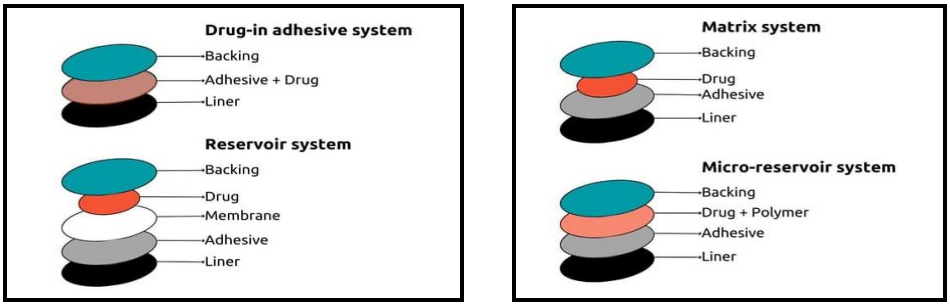


Figure 3: Types of Transdermal Drug Delivery Systems (TDDS).

1.2. Skin Structure

The biggest organ in the body, the skin serves as an essential barrier to protect the body from a variety of dangers and environmental influences. Because of its huge surface area roughly

1.7 square meters in a typical person it can efficiently protect the body against toxins, allergies, ultraviolet (UV) radiation, bacteria, and water loss. For general health and well-being to be maintained, this protective role is essential.[10,11] Furthermore, through exposure to sunlight, the skin contributes to the regulation of body temperature, sensation, and vitamin D production. Maintaining the skin's health and supporting its functions requires proper care.[12] The skin is often divided into three main layers: the epidermis, which is the outermost layer; the dermis, which is the intermediate layer; and the hypodermis, which is the innermost layer.

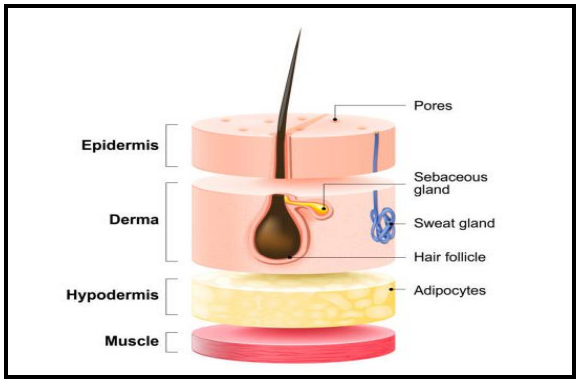


Figure 4: Structure of the skin.

1.2.1. Epidermis

The epidermis is the outermost layer of the skin, forming a watertight barrier without blood vessels. It's mainly composed of keratinocytes, which produce keratin for protection. Other important cells include melanocytes (for skin color), Langerhans cells (immune function), and Merkel cells. The epidermis has four main sublayers: the stratum corneum, granulosum, spinosum, and basal layer. It varies in thickness, reaching about 0.8 mm on the palms and soles. The top layer, the stratum corneum, is rich in keratin (70%) and lipids (20%), crucial for retaining moisture and shielding the body.[13,15]

1.2.2. Dermis

The dermis, located beneath the epidermis and measuring 3–5 mm thick, supports and nourishes the outer skin layer. It contains vital structures such as blood vessels, hair follicles, sweat and sebaceous glands, nerve endings, and structural proteins like collagen and elastin, which provide strength and elasticity. Capillaries near the surface (around 0.2 mm deep) act as filters, limiting the entry of substances and maintaining skin balance. The dermis also plays a key role in temperature regulation, sensation, and wound healing.[16]

1.2.3. Subcutaneous tissue (Hypodermis)

The hypodermis, or subcutaneous tissue, is the deepest layer of the skin and is made up of connective tissue and adipocytes, or fat cells. This layer protects the body's organs and bones from shocks and works as an insulator, assisting in the regulation of body temperature. In order to enter our bloodstream, medications that are given topically, such as creams or patches, must pass through these three layers. Certain medications must penetrate much further, entering the bloodstream. However, for the majority of skin treatments to be successful, they only need to penetrate the stratum corneum, the outermost layer, and remain in the skin layers.[17]

1.2.4. Pathways of Skin Permeation

Skin permeation happens through three main pathways. First is the transcellular route, where substances pass directly through the skin cells, crossing cell membranes and the watery parts inside. Second is the intercellular route, where substances travel between the skin cells, moving through the tiny gaps filled with fat. This path is longer and more winding but avoids entering the cells. Third is the appendageal route, where the substance enters through hair follicles, sweat glands, or oil glands. Though this path covers a small area of the skin, it can help larger molecules or poorly absorbed substances get in. These pathways are important for delivering drugs or repellents through the skin safely and effectively.[18]

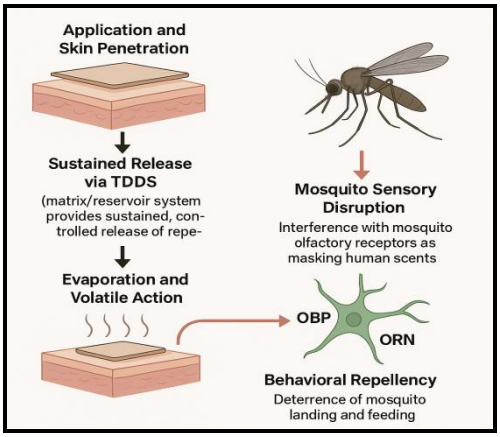


Figure 5: Mechanisms of action of mosquito repellency.

1.2 Control of mosquito

Preventing mosquito bites is an effective way to control mosquito-borne diseases. Insect repellents help keep mosquitoes away from the skin. While chemical repellents are

commonly used, they can cause side effects like irritation or allergies, especially in children. Natural and chemical repellents are both used to discourage mosquito contact.[19]

Table 1: Mosquito repellent methods.[20]

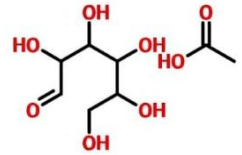
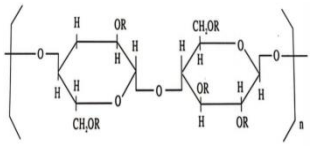
Chemical methods	Non-chemical methods	Biological methods
Synthetic repellents: DEET, Permethrin **Natural repellents**: Neem oil, Citronella, Lemongrass	**Physical method**: Medicated net, Non medicated net, Mosquito traps **Mechanical methods:** Electric mosquito zapper, Mosquito magnet	By growing some fish species that feeds on mosquito larvae in water bodies

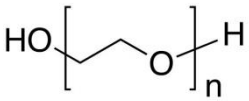
1.3 Description of herbal Ingredients

Table 2: Description of herbal Ingredients.

Sr. no	Biological name	Common name	Family	Chemical composition	Solubility	Storage	Uses	Referencing
1	*Cymbopogan citratus*	lemon grass, citronella	Graminae	lemon grass (0.2–0.5%), limonene, other terpenoids	Soluble in water, oils and alcohol	Keep the container tightly closed in a dry, well-ventilated area and store it in a cool place.	Mosquito repellents, skincare products.	[20]
2	*Trachysperm um ammi*	Ajwain	Apiaceae	Volatile oils, flavonoid, phenolic compound, Thymol	Insoluble in water but soluble in ethanol, methanol, and chloroform	Cool, dry place, away from direct sunlight and moisture and stored in dark, airtight glass bottles to preserve potency.	Herbal sprays, creams, gels, and transdermal patches for repelling mosquitoes.	[22]
3	*Lavandula angustifolia*	lavender	Lamiacea	linalool (20-35%), linalyl acetate (30-55%),	Soluble in alcohol and other organic solvents.	Airtight containers and a cool, dark, dry location.	Strong scent, particularly from linalool, repels mosquitoes.	[24]

Table 3: Description of Ingredients.

Sr. no	Chemical name	Molecular formula	Molecular weight	Uses	Chemical structure	Referencing
1	Sodium Carboxymethyl cellulose	$C_8H_{16}NaO_8$	240.2 g/mol	As improved viscosity and stability		[23]
2	Hydroxypropyl methylcellulose	$C_{56}H_{108}O_{30}$	10,000 to 1,500,000 Da (kilodaltons)	It is polymer in pharmaceutics and cosmetics.		[25]

3	polyethylene glycol 400	$H(OCH_2CH_2)_nOH$	400 g/mol	It's used as a solvent, humectant.		[26]

1.5 Pictures of Ingredients

Fig 6: Lemongrass

Fig 7: Ajwain leaves

Fig 8: Lavender oil

Fig 9: CMC

Fig 10: HPMC

Fig 11: PEG 400

EXPERIMENTAL WORK

Materials

Hydroxypropyl Methylcellulose (HPMC), Carboxymethyl Cellulose (CMC), Polyethylene Glycol 400 (PEG 400) (Purity >99%), was purchased from loba chemiw Pvt. Ltd. Lavender oil was obtained from Ajanta Flavours & Fragrances. Deionized water was used as a solvent throughout the formulation process. Fresh lemongrass and ajwain leaves were collected from the botanical garden of Amepurva Forum's Nirant Institute of Pharmacy, Boramani, Solapur.

Table 4: Ingredients taken and there category.

Sr. No	Ingredients	Category	Quantity taken
1.	Lemongrass Extract	Active ingredient (Mosquito repellent)	15%
2.	Ajwain leaves extract	Mosquito repellent action	12%
3.	Hydroxypropyl Methylcellulose (HPMC)	Film-forming agent, Controlled release polymer	7%
4.	Carboxymethyl Cellulose (CMC)	Bioadhesive polymer, Viscosity enhancer	10%
5.	Polyethylene Glycol 400 (PEG 400)	Emulsifier, Plsticizer	2 ml

6.	lavender oil	Smelling agent, Mosquito repellent action	5 drops
7.	Deionized Water	Solvent	5ml
8.	Ethanol	Solvent	13ml

Figure 12: Ingredients used in formulation.

METHOD

A. Herbal plant extraction process by Soxhlet extraction

The Herbal plant are cut into small pieces, then dried, and then blended until they become powder. The power is placed in a porous thimble, which is then inserted into the extraction chamber of the soxhlet apparatus. A flask containing the extraction solvent i.e ethanol is placed below the extraction chamber. A condenser is connected above the extraction chamber. The flask is heated, causing the solvent to vaporize. The solvent vapor rises into the condenser, where it cools and condenses back into a liquid. The condensed solvent drips onto the solid sample in the thimble, extracting the desired compounds. When the solvent level in the extraction chamber reaches a certain height, it siphons back into the flask, carrying the extracted compounds with it. This cycle of solvent vaporization, and condensation continues repeatedly, allowing for efficient extraction of the desired compounds.

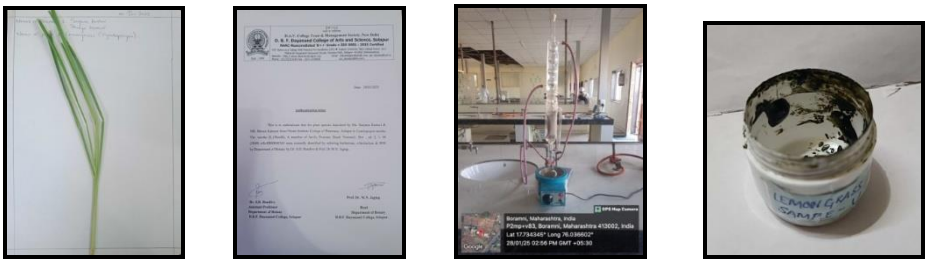


Figure 13: Lemongrass extraction by Soxhlet extraction.

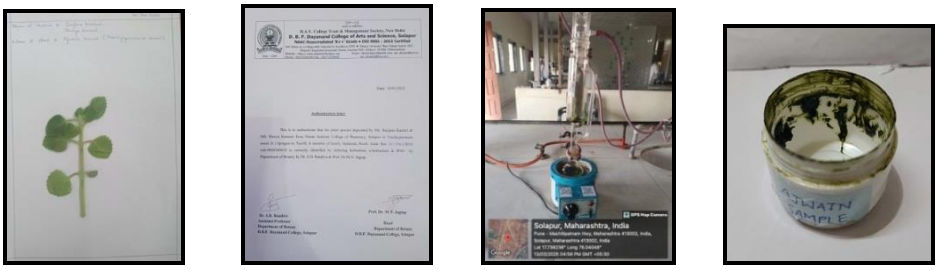


Figure 14: Ajwain leaves extraction by Soxhlet extraction.

B. Patch formulation procedure

Mix Carboxymethyl cellulose (CMC) (10%) in water heated above 100°C while stirring continuously until gel mass forms. Add Polyethylene Glycol 400 (PEG 400) (2 ml) to the gel mass and stir until a homogeneous mixture is achieved. Dissolve hydroxpropyl methyl cellulose (HPMC) (7%) in 96% ethanol, then incorporate it into the gel mass. Introduce lemongrass extract (15%), Ajwain leaves extract (12%), lavender oil (5 drops) into each formulation, stirring thoroughly to ensure uniform distribution. Adjust the volume of the gel mass to 20 mL by adding deionized water. Pour the prepared gel into a mold lined with aluminium foil and allow it to dry at room temperature. Once cooled, cover it with aluminium foil and let it dry completely. After drying, cut the patch into 2×2 cm² pieces, then affix each piece onto a 5×3 cm Hypafix plaster for application.

A) **B)**

Figure 15: A) Control batch and B) Herbal batch patch formulation.

EVALUATION TEST OF FORMULATION

1. **Table 5: Identification test for Citronella and Thymol present by Terpenoid chemical test.[27]**

Sr. no	Test	Procedure	Observation
1.	Libermann-Burchard test	Extract + Acetic anhydride. Boil and Cool Concentrated Sulphuric acid from side of the test tube	Formation of deep red colour indicates presence of terpenoid.
2.	Salkowski test	Extract + Concentrated	Yellow colour at the

		Sulphuric acid	lower layer indicates presence of terpenoid
3.	Sulfur powder test	Test solution Small amount + Sulfur powder	Sulfur powder sinks at the botton

2. Physical Appearance Test

The patches were visually inspected for their shape, smoothness, stickiness, homogeneity and flexibility.[28]

3. pH

The pH was measured using a pH paper or pH meter after the patches were left in contact with chloroform for two hours at room temperature.[28]

4. Weight Uniformity

Each patch formulation is weighed using a digital balance to ensure accuracy. The individual weights are recorded, and then the average weight and standard deviation are calculated. This helps assess the uniformity of the patch weight across different samples, ensuring consistency in formulation.[7]

5. Patch Thickness

The thickness of the patch is determined using a micrometer with a sensitivity of at least 0.01 mm. Measurements are taken at five different spots on the patch, and the average of these five readings is calculated to ensure uniformity in thickness.[29]

6. Folding Durability

The folding endurance of the patch is assessed by repeatedly folding a small section of the film (2 x 2 cm) at the same point until it breaks. The number of folds the film can withstand without tearing reflects its flexibility and mechanical strength.[20]

7. Flatness[28]

A patch should have a smooth surface and should not shrink over time. This is checked through a flatness test. A patch (2×1 cm) is cut from the center and placed on the skin. Its length is measured, and any change in length is used to calculate percent constriction. No shrinkage means 100% flatness.

$\%Constriction = I_1 - I_2 \times 100 / I_1$

Where, I_1 = Final length of each strip, I_2 = Initial length of each strip.

8. Percent moisture content[28]

To determine the percent moisture content, three patches from each formulation are first weighed. Then, they are placed in a desiccator with fused calcium chloride at 37°C until a constant weight is observed. This final weight is recorded. The moisture content is calculated using the formula.

% Moisture Content = (Initial Weight – Final Weight) × 100 / Final Weight**.**

9. Percent moisture uptake[28]

Patches are first weighed and then placed in a desiccator at room temperature for 48 hours. After that, they are exposed to 75.5% relative humidity using a saturated solution of aluminum chloride until they reach a constant weight. The percentage of moisture absorbed is calculated using the formula.

% Moisture Uptake = (Final Weight – Initial Weight) × 100 / Initial Weight.

10. Stability Study

The stability study of the patch was carried out by storing samples at room temperature (25 ± 2°C, 60% RH) and accelerated conditions (40 ± 2°C, 75% RH) for up to 30 days. At regular intervals (0, 15, and 30 days), patches were evaluated the changes. No significant changes were observed, indicating good stability of the formulation.[30]

11. Mosquito Repellency Test

About 20 mosquitos were transferred in the net cage. The mosquito repellent patch was placed in the room for 6- hour. Reduction in mosquito number was observed.[31]

RESULTS AND DISCUSSION

1. Identification test for Citronella and Thymol present by Terpenoid chemical test

Phytochemical screening confirmed the presence of active components like Citronella and Thymol. The Libermann-Burchard test showed a deep red color, and the Salkowski test produced a yellow lower layer, both indicating terpenoids. The Sulfur powder test revealed that the sulfur particles sank to the bottom of the test solution good solubility, further supporting the presence of these compounds. Together, these results validate the extract's potential as a natural mosquito repellent.

Fig 16: Citronella.

Fig 17: Thymol.

2. Physical Appearance Test

The mosquito repellent patches prepared show a uniform shape with a smooth surface and even texture. They exhibited good stickiness without any signs of brittleness or peeling. The patches were flexible**,** non-greasy, and free from cracks, air bubbles, or particulate matter, indicating satisfactory homogeneity and physical integrity suitable for transdermal application.

3. Color and Odor

Color and odor repellent patch containing lemongrass extract, Ajwain leaves extract, lavender oil. The patch shows greenish colour and pleasant citrus-like aroma, typical of lemongrass extract. The scent was mild to moderately strong, natural, and free from any foul or chemical odor, indicating the presence of volatile aromatic compounds like citral and thymol which contribute to its mosquito-repellent activity. For control white or off- white in colour. During storage, stated that the repellent patch did not experience discoloration and odor.

4. pH

The control batch, containing only polymers such as HPMC, CMC, PEG 400, ethanol, and deionized water, showed a pH of 6.4 ± 0.1, which is close to neutral and suitable for skin application. The API batch, which included Lemongrass extract, Ajwain leaf extract, and Lavender oil, showed a slightly lower pH of 5.8 ± 0.1 due to the natural acidity of plant extracts. However, both batches fall within the acceptable skin pH range (4.5–7), indicating that the formulations are gentle and safe for transdermal use without causing irritation.

5. Weight Uniformity and Variation

Weight uniformity was assessed for both control and API batches. The control batch showed an average single patch weight of 0.14 g, while the total weight of 10 patches was 1.15 g (average: 0.115 g), with a variation of +0.025 g. The API batch had a single patch weight of 0.17 g, and 10 patches weighed 1.24 g (average: 0.124 g), showing a variation of +0.046 g.

The slight increase in the API batch is due to added natural extracts. Both batches showed acceptable weight uniformity, indicating consistent formulation.


A) 1 Patch **B) 10 Patches**

Figure 18: A), B) Control batch


C) 1 Patch **D) 10 Patches**

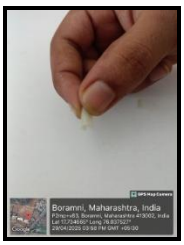
Figure 19: C), D) API batch.

6. Patch Thickness

The thickness of both the control batch and the herbal ingredient batch was measured using a micrometer at five different spots. The control batch had an average thickness of 0.25 mm, while the herbal ingredient batch measured 0.28 mm. Both batches showed minimal variation, ensuring uniformity in patch thickness.

7. Folding capacity

The folding endurance test was performed by repeatedly folding a 2 × 2 cm section of the patch at the same point until it broke. The control batch withstood an average of 50 folds, indicating good flexibility and mechanical strength. The herbal ingredient batch showed slightly higher endurance with an average of 65 folds, suggesting improved flexibility due to the presence of natural extracts. Both batches demonstrated acceptable folding endurance suitable for transdermal application.




A) **B)**


C) **D)**

Figure 20: A) B) Control and C) D) Herbal batch showing folding capacity.

8. Flatness

Both the control and herbal ingredient batches showed no change in patch length, indicating **0%** constriction**.** This confirms that both patches maintained 100% flatness with no shrinkage over time.

A) B)

Figure 21: A) Control and B) Herbal batch showing Flatness.

9. Percent moisture content

The moisture content of the patches was evaluated by weighing them before and after drying in a desiccator containing fused calcium chloride at 37°C. For the control batch, the initial weight was 0.12 g and the final weight was 0.10 g, resulting in a moisture content of 20%. In the herbal ingredient batch, the initial weight was 0.16 g and the final weight was 0.14 g, giving a moisture content of 14.28%**.** The results indicate that both batches retained some moisture, with the herbal batch showing slightly better moisture retention.

A) Initial weight B) C) Final weight

Figure 22: A), B) and C) Show moisture content of control batch.

A) Initial weight B) C) Final weight

Figure 23: A), B) and C) Show moisture content of herbal batch.

10. Percent moisture uptake

The percent moisture uptake was calculated after exposing the patches to 75.5% humidity. The control batch showed 20% uptake (0.10 g to 0.12 g), while the herbal batch showed 14.28% uptake (0.14 g to 0.16 g), indicating lower moisture absorption in the herbal patch.

11. Stability Study

The stability study results showed that both control and herbal mosquito repellent patches maintained their physical integrity, thickness, weight, pH, folding endurance, and repellency over 30 days under room and accelerated storage conditions. No significant changes or degradation were observed, indicating that the patches remained stable and effective throughout the study period.

A) **B)**

Figure 24: A) Control and B) Herbal batch Stability of patch.

12. Mosquito Repellency Test

After placing the mosquito repellent patch in a netted cage containing approximately 20 mosquitoes for 6-8 hours, a noticeable reduction in mosquito activity and number near the patch was observed, indicating effective repellency.

Figure 25: Show mosquito Repellency.

Table 6: RESULT.

Sr. no	Evaluation test	Observation of control batch	Observation of Herbal batch
1.	Identification test for		

	Citronella and Thymol present by Terpenoid chemical test: a) Libermann-Burchard test b) Salkowski test c) Sulfur powder test	_	a) Confirms b) Confirms c) Confirms
2.	Physical Appearance Test	Flexible, non-greasy, and free from cracks, air bubbles.	Flexible, non-greasy, and free from cracks, air bubbles.
3.	Color and Odor	a. Colour- off- white. b. Odor- foul or chemical odor.	a) Colour- Greenish. b) Odor- Pleasant citrus-like aroma.
4.	pH	6.4 ± 0.1	5.8 ± 0.1
5.	Weight Uniformity and Variation	+0.025 g	+0.046 g
6.	Patch Thickness	0.25 mm	0.28 mm
7.	Folding capacity	<50 folds	<65 folds
8.	Flatness	100%	100%
9.	Percent moisture content	20%	14.28%
10.	Percent moisture uptake	20%	14.28%
11.	Stability Study	No significant changes over 30 days at different conditions	No significant changes over 30 days at different conditions
12.	Mosquito Repellency Test	-	>90% repellency for up to 6–8 hours.

CONCLUSION

This study successfully developed and evaluated a herbal transdermal patch using natural mosquito repellents from lemongrass (*Cymbopogon citratus*) and ajwain (*Trachyspermum ammi*). The patch was formulated with biocompatible polymers (HPMC, CMC, PEG 400) and lavender oil for added skin benefits. Physicochemical tests showed good uniformity, flexibility, pH suitability, and moisture control. Stability studies confirmed long-term integrity, while mosquito repellency tests showed significant effectiveness. The patch offers prolonged protection, easy application, and reduced skin irritation compared to chemical repellents like DEET. Its natural, eco-friendly composition makes it especially suitable for sensitive users, validating its potential as a safe and effective alternative.

REFRENCE

1. World Health Organization (2024) Vector-borne diseases. https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases
2. Fradin, M. S., & Day, J. F. (2002). Comparative efficacy of insect repellents against mosquito bites. New England Journal of Medicine, 347(1): (13–18).

3. Dua, V. K., et al. (1996). Repellency of Lantana camara (Verbenaceae) flowers against Aedes mosquitoes. Journal of the American Mosquito Control Association, 12(3): (406–408).
4. Prausnitz, M. R., & Langer, R. (2008). Transdermal drug delivery. Nature Biotechnology, 26(11): 1261–1268.
5. Langer, R., & Peppas, N. A. (2003). Advances in biomaterials, drug delivery, and bionanotechnology. AIChE Journal, 49(12): 2990–3006.
6. Naziya Shaikh, Richa Srivastava. Areview on transdermal drug delivery through patches, IP Indian Journal of Clinical and Experimental Dermatology, 2024; 10(2): 113–121.
7. Sonia djiman, Thakur gurjeet Singh, Ashish Kumar rehni. Transdermal patches: A recent approch to new drug delivery system.
8. Aggarwal G, Dhawan S. Development, Fabrication and Evaluation of Transdermal Drug Delivery System - A Review. Pharmainfo.net, 2009; 7(5).
9. Anjali V. Patel, Biren N. Shah. Transformer drug delivery system review article, An international journal of pharmaceutical science, Pharma Science Monitor, Jan-Mar 2018; 9(1): 378-390.
10. Kumar P, Sankar C, Mishra B. Delivery of macromolecules through skin. Indian Pharm, 2004; 5(3): 7–17.
11. Menon GK. New insights into skin structure: scratching the surface. Adv Drug Deliv Rev, 2002; 54(1): 3–17.
12. Benson HA, Watkinson AC. Topical and Transdermal Drug Delivery: Principles and Practice. Hoboken, NJ, USA: Wiley, 2012.
13. SuhH, ShinJ, Kim Y. MicroneedlePatches for Vaccine Delivery. Clin Exp Vaccine Res, 2014; 3(1): 42–9.
14. Walters KA. Dermatological and Transdermal Formulations. Boca Raton, FL, USA: CRC Press, 2002.
15. Alexander A, Dwivedi S, Giri TK, Saraf S, Saraf S, Tripathi DK, et al. Approaches for Breaking the Barriers of Drug Permeation through Transdermal Drug Delivery. J Control Release, 2012; 164(1): 26–40.
16. Wilson R, Waugh A, Grant A. Anatomy and physiology in health and illness. 9th Edn. Churchill Livingstone, 2001; 363–376.
17. Kumar D, Sharma N, Rana AC, Agarwal G, Bhat ZA. A review: transdermal drug delivery system: tools for novel drug delivery system. Int J Drug Dev Res, 2011; 3(3): 70–84.

18. Barry, B. W. (2001). Novel mechanisms and devices to enable successful transdermal drug delivery. European Journal of Pharmaceutical Sciences, 14(2): 101–114.
19. Sritabutra D., Soonwera M., Sririrat S., Poungjai S. Evaluation of herbal essential oil as repellents against Aedes aegypti(L.) and Anopheles dirus Peyton & Harrion. Asian Pacific Journal of Tropical Biomedicine, 2011; 1(1): 124-128.
20. Somi borah, Bhupen kalita. Formulation and evaluation of control release mosquito repelslent patch, 2023.
21. Maia MF, Moore SJ. Plant-based insect repellents: A review of their efficacy, development and testing. Malaria J., 2011; 10(1): S11.
22. KK Chahal, K Dhaiwal, A Kumar, D Kataria and N Singla. Chemical composition of Trachyspermum ammi L. and its biological properties: A review, Journal of Pharmacognosy and Phytochemistry., 2017; 6(3): 131-140.
23. Rowe, R. C., Sheskey, P. J., & Quinn, M. E. (Eds.). (2009). Handbook of Pharmaceutical Excipients (6th ed.). Pharmaceutical Press.
24. Cavanagh, H. M. A., & Wilkinson, J. M. (2002). Biological activities of lavender essential oil. Phytotherapy Research, 16(4): (301–308).
25. Thakur, V. K., & Thakur, M. K. (2015). Processing and characterization of natural cellulose fibers/thermoset polymer composites. Carbohydrate Polymers, 109; 102–117.
26. Polyethylene Glycol 400. (2021). PubChem Compound Summary for CID 8224. National Center for Biotechnology Information.
27. Pranita Sonar, Dibyendu Stil, Saamenda Deb Ray. A Review on Terpenoids Introduction. ResearchGate, January 2003.
28. Pronobesh Chattopadhyay, Sunil Dhiman, Kangujam Adiya Devi. Ultra low concentration deltamethrin loaded patch development and evaluation of its repellency against dengue vector Aedes (S) albopictus, Chattopadhyay et al. Parasites & Vectors, 2013; 6: 284.
29. Pronobesh Chattopadhyay, Sunil Dhiman, Somi Borah (2015). Essential oil based polymeric patch development and evaluating its repellent activity against mosquitoes, volume 6.
30. Avinash Kumar Saroj, Rizwana Khan and Bhawna Sharma. Transdermal drug delivery system (Patch), World Journal of Pharmaceutical Research, 8(10): 325-343.
31. Virendra Kumar Singh1, Ramesh Kumar Singh1, Bharat Mishra2, Divyani Singh. Formulation and evaluation of eco-friendly handmade herbal mosquito repellent cone, International Journal of Pharmaceutics and Drug Analysis, 2021; 9(4): 230-235.