

Review

Transdermal Herbal Patch using *Ocimum Gratissimum*: A Review

Tulsi Bisht*¹, Dipesh Sharma²

¹Professor, Faculty of Pharmacy, Maharaja Agrasen Himalayan Garhwal University, Pauri Garhwal

²M.Pharm Research Scholar, Faculty of Pharmacy, Maharaja Agrasen Himalayan Garhwal University, Pauri Garhwal

Corresponding Author:

Dr. Tulsi Bisht

Email: tulsi.bisht@hgu.ac.in

DOI: 10.62896/ijmsi.2.1.16

Conflict of interest: NIL

Article History

Received: 08/02/2026

Accepted: 10/03/2026

Published: 20/04/2026

Abstract:

This research explores the development and evaluation of a herbal transdermal drug delivery system (TDDS) patch incorporating *Ocimum gratissimum* extract for antifungal therapy. *Ocimum Gratissimum*, rich in bioactive compounds such as eugenol and flavonoids, is extracted and uniformly blended into a biocompatible polymer matrix to create a medicated adhesive patch. This matrix-type TDDS ensures the controlled, sustained release of antifungal phytochemicals through the skin, achieving therapeutic levels at the site of infection while bypassing gastrointestinal metabolism. The advantages of this approach include improved patient compliance, reduced systemic side effects, and steady plasma drug levels, making it particularly valuable for chronic or recurrent skin infections. Ultimately, this study demonstrates the potential of *Ocimum gratissimum*-loaded herbal patches as a safe, natural, and effective alternative in antifungal transdermal therapy, aligned with modern controlled drug delivery principles and patient-centered care.

KEYWORDS: TDDS, *Ocimum gratissimum*, Herbal patch, Controlled release, matrix patch, Biocompatible polymers, Antifungal therapy, Patient compliance, Bypassing First-pass metabolism

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

INTRODUCTION

TDDS refers to a method of delivering drugs through the skin, allowing the active ingredients to enter systemic circulation in a controlled manner. The drugs are incorporated into patches applied on the skin, which release the medication gradually. TDDS is pivotal for modern therapeutics due to its ability to safely deliver drugs in a controlled, patient-friendly manner while avoiding systemic side effects associated with oral or injectable routes. Herbal patches synergize the benefits of TDDS with traditional medicine, improving patient compliance and safety profiles by providing natural, sustained delivery of active plant compounds.

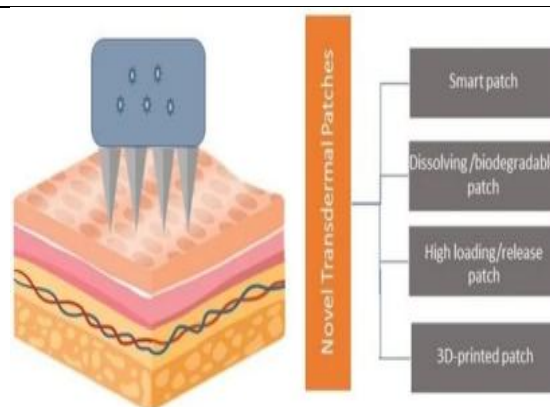


FIG. 1.1 Design Forms Used In TDDS

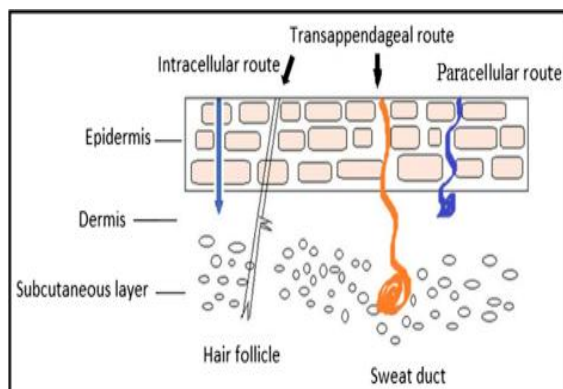


FIG. 1.2 Enhancing Permeation Of Drug Via Skin

Benefits Of TDDS

- **Bypassing First-Pass metabolism:** TDDS avoids degradation of drugs in the gastrointestinal tract and liver, increasing bioavailability.
- **Sustained And Controlled Drug Release:** provides consistent plasma drug levels over extended periods, enhancing therapeutic effectiveness.
- **Improved Patient Compliance:** Non-invasive, painless application removes the need for injections or frequent oral dosing, increasing ease of use, especially for chronic conditions.
- **Reduced Side Effects:** Controlled absorption reduces peak plasma levels, lowering risks of adverse effects common with oral or injectable drugs.
- **Convenience And Flexibility:** Patients can easily terminate treatment by removing the patch, and it allows for targeted, localized delivery in some applications.

Herbal Patches and Compliance

- **Natural and Safe Composition:** Herbal patches use plant-based ingredients like *Ocimum gratissimum*, avoiding synthetic chemicals and reducing risk of side effects or toxicity.
- **Steady Release of Herbal Actives:** Herbal patches provide controlled liberation of phytochemicals, allowing sustained therapeutic effects aligning with traditional medicine.
- **Targeted, Localized Treatment:** Many herbal patches are designed for topical application on affected areas, enhancing efficacy and user satisfaction.

- **Higher Patient Acceptance:** Users preferring natural remedies often demonstrate better compliance due to perception of safety and holistic benefits.
- **Eco-Friendly Polymers:** Use of biodegradable, environmentally friendly polymers further add to the appeal among eco-conscious users.

Need of NDDS in Herbal formulation

This collective evidence supports TDDS, especially herbal patches, as a valuable platform for delivering drugs and natural activities effectively and safely with enhanced patient adherence. Transdermal Drug Delivery Systems (TDDS) deliver drugs through the skin into systemic circulation, offering controlled and sustained release. TDDS is important because it bypasses first-pass metabolism in the liver, increasing bioavailability and reducing gastrointestinal side effects. It provides steady plasma drug levels, reduces dosing frequency, and improves patient compliance due to its non-invasive, painless, and convenient application. TDDS also allows easy termination of therapy by patch removal and can target local or systemic effects effectively.

Herbal patches using TDDS combine these benefits with natural plant-based ingredients, resulting in better safety profiles, reduced side effects, and increased patient acceptance. They provide steady release of herbal actives, maintain localized delivery, and often use biodegradable, eco-friendly polymers. This leads to improved compliance, especially among patients preferring natural or holistic treatments.

TDDS Methods Focused on Herbal Patches

Transdermal drug delivery systems (TDDS) are dosage forms designed to deliver drugs through the skin into systemic circulation in a controlled manner over extended periods. Herbal TDDS patches specifically integrate plant extracts into a polymer matrix that adheres to the skin, allowing sustained, steady release of natural bioactive compounds.

Key Method Steps:

- **Extraction:** Active phytochemicals are extracted from herbal leaves (e.g., *Ocimum gratissimum*) using solvents like ethanol.
- **Polymer Matrix Preparation:** Biocompatible polymers such as chitosan, hydroxypropyl methylcellulose (HPMC), or polyvinyl alcohol (PVA) are dissolved to form a film base.
- **Incorporation:** The herbal extract is dispersed

uniformly in the polymer solution.

- **Casting and Drying:** The mixture is cast on flat surfaces and dried to form flexible patches.
- **Backing and Adhesive Layers:** Optional layers protect the patch and aid skin adhesion.
- **Evaluation:** Physical and chemical properties, and biological efficacy (antifungal activity, release profiles) are tested.

Advantages of TDDS in herbal:

- Bypasses first-pass metabolism and gastrointestinal degradation.
- Provides controlled and sustained drug release.
- Non-invasive, painless, and convenient, enhancing patient compliance.
- Reduced systemic side effects compared to oral drugs.
- Herbal patches offer natural, safer alternatives with potential antioxidant and anti-inflammatory benefits.
- Suitable for localized or systemic treatment with improved patient adherence.
- Herbal TDDS patches are increasingly used for conditions where prolonged and steady delivery of natural agents is beneficial, including antifungal therapies and chronic conditions, with the additional appeal of safety and patient preference for herbal remedies.

Introduction OCIMUM GRATISSIMUM:

Ocimum gratissimum, commonly known as clove basil, has a wide range of medicinal uses supported by its bioactive phytochemicals and essential oils. Traditionally, it has been used to treat diseases such as diabetes, cancer, inflammation, anemia, diarrhea, pains, fungal and bacterial infections.



FIG. 1.3 Clove Basil (*OCIMUM GRATISSIMUM*)

Pharmacologically, it demonstrates antioxidant, anti-inflammatory, anticancer, hepatoprotective, antidiabetic, antihypertensive, antidiarrheal, and antimicrobial properties. Its leaves and extracts are used as tonics, to relieve cough, headaches, respiratory issues, ear infections, skin infections, gastrointestinal ailments, and even wounds. Extracts from the leaves show anti-malarial, antitussive, anticonvulsant, and antiseptic effects. Its essential oil, rich in compounds like eugenol and thymol, exhibit antibacterial and antifungal activity. Despite these extensive uses backed by in vitro and in vivo studies, more human clinical trials are needed to establish safe and effective doses for various treatments.

Medicinal Uses of *Ocimum gratissimum*

- **Antimicrobial:** Effective against bacterial, fungal infections.
- **Antidiarrhoeal & Antidysenteric:** Used to treat diarrhea and dysentery.
- **Anti-inflammatory:** Reduces inflammation in conditions such as colitis.
- **Antidiabetic:** Helps in regulating blood sugar levels.
- **Anticancer:** Exhibits inhibition of tumor growth in experimental models.
- **Hepatoprotective:** Protects liver from damage.
- **Antihypertensive:** Lowers blood pressure.

Common uses of *Ocimum gratissimum*

- Leaf infusions, juice, decoctions, and essential oils.
- Used in traditional medicine for treating gastrointestinal, respiratory, skin, and systemic infections.
- Also used for wound healing and as tonic for general health

MEDICINAL PARTS OF PLANT:

Medicinally useful parts of *O. gratissimum* plant are leaf and seed (Prabhu et al., 2009). Essential oil of the plant is mainly used in perfumery, dental and oral products, food industries, medicines and traditional rituals (Silva et al., 2016). The plant possesses antioxidant, antibacterial, antifungal and ***Ocimum gratissimum*** many other activities (Vieira and Simon, 2000; Nweze and Eze, 2009; Avetisyan et al., 2017). The Respiratory ailments: Used for cough, bronchitis, asthma. Analgesic & Antipyretic: Alleviates pain and fever. Antioxidant: Scavenges free radicals to reduce oxidative stress.

The leaves of the plant are used in the traditional

cuisine as spices. Different countries like, in Indonesia (Sumatra) a tea is made from the leaves, while in Thailand the leaves are applied as a flavoring spice. (Chemical composition and biological potential characterization of leaf extracts of *Ocimum gratissimum* L with different solvent systems)

In India *O. gratissimum* is commonly known as “Ram Tulsi”, which is mainly used for religious ceremonies and rituals (Pande et al., 2009). Leaves and flowering parts of *O. gratissimum* are traditionally used as antispasmodic, aromatic, carminative, digestive, galactagogue, stomachic, and tonic agents (Chah et al., 2006; Junaid et al., 2006; Prabhu et al., 2009; Kristi et al., 2017). They have also been used as a folk remedy to treat various ailments such as; poor digestion, feverish illnesses, nausea, cough, gastroenteritis, abdominal cramps, insomnia, migraine, dysentery, gonorrhoea, depression and kidney malfunctions etc (Labra et al., 2004; Braga et al., 2007). Externally, leaf paste is used for the treatment of acne, snake bites, insect stings, skin infections and as a moth repellent (Martin and Ernst, 2004; Arabacic and Bayram, 2004). (Chemical composition and biological potential characterization of leaf extracts of *Ocimum gratissimum* L with different solvent systems)

CHEMICAL CONSTITUENTS OF OCIMUM GRATISSIMUM

Chemical constituents reported from the *O. gratissimum* are cyanogenetic glycosides, eugenol, anthroquinones, steroidal aglycones etc, carotenoids, etc (Nweze and Eze, 2009; Oladosu et al., 2017). Various solvent systems which have been reported in literature for the extraction of phytoconstituents from plants are methanol, ethyl acetate, chloroform, hexane, etc. They have different abilities to extract the compounds from the plant parts. The type of solvent system used for extraction is important for both quantification and classification of bioactive compounds occurring in plants and obtaining pure compounds for their analysis (Zhang et al., 2018).

MORPHOLOGICAL PARAMETERS OF PLANTS QUALITATIVE CHARACTER:

The plant was observed to be a sub-shrub with a taproot system. The stem of the plant was erect, round to quadrangular and highly branched. Leaves were dark green in colour, oppositely arranged around the stem. The petiole of the leaf

was slender and the leaf blade was elliptical to ovate. Base of the leaf was cuneate and margin was crenate- serrate having acute apex. The leaves were highly aromatic and bitter in taste. Inflorescences were verticillaster type and flowers were hermaphrodite, white in colour. The upper sepal of the flower was ovate and the median lobe of the lower lip was shorter than the lower one.

Table 1: Physical characterization of *O. gratissimum*

Sr. No.	<i>O. gratissimum</i>	Characters
1.	Habit	Sub-shrub
2.	Roots	Taproot
3.	Stem external shape	Erect, round to quadrangular and branched
4.	Leaf	Dark green, opposite, slender petiole, elliptical to ovate leaf blade, base cuneate, crenate-serrate margin, apex acute
5.	Leaf odor and taste	Aromatic and bitter
6.	Inflorescence	Verticillaster
7.	Flowers	Hermaphrodite, white, upper sepal ovate and median lobes of the lower lip are shorter than lower one



FIG. 1.4 OCIMUM GRATISSIMUM Flower

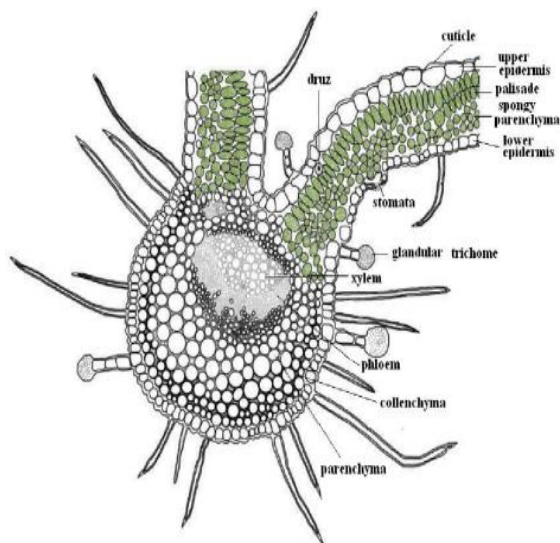


Fig 1.5: The transverse section of leaf of *O. gratissimum*

The first wavy layer observed in the transverse section of the leaf was an epidermal layer present on both upper and lower surfaces of the leaf. Epidermal layer was a single layer of thin walled parenchymatous cells, which was interrupted with 2-9 multicellular celled, non-glandular and glandular trichomes. Below epidermis, 2-3 layers of thick walled mesophyll cells were present. The mesophyll cells were followed by compactly arranged 1-3 layered palisades and 4-7 layered parenchymatous cells. In the mid region of the section vascular bundle was present, which was surrounded by a bundle sheath. The collateral type of vascular bundle consists of a wide bowl shaped vascular strand (xylem and phloem) which is surrounded by a parenchymatous sheath. The xylem is present on the upper band and phloem present on the lower band. The thick walled xylem consist of angular xylem elements and phloem consist of hemispherical cup shaped phloem elements.

- Stem external shape Erect, round to quadrangular and branched
- Leaf Dark green, opposite, slender petiole, elliptical to ovate leaf blade, base cuneate, crenate-serrate margin, apex acute
- Leaf odor and taste Aromatic and bitter
- Inflorescence Verticillaster
- Flowers Hermaphrodite, white, upper sepal ovate and median lobes of the lower lip are shorter than lower one

ANTIFUNGAL ACTIVITY

O. gratissimum essential oil exhibits an effective fungicidal activity against a wide range of human

fungal pathogens as evidenced in various literatures. Plant oil with five chemotypes is very common folk medicine and among this ethyl cinnamate is a very popular Indian chemotype with antifungal activities [16]. Dried or fresh plant samples are utilized to treat superficial mycosis in young children with strong anti-dermatophyte activity against infected scalp and hand [17]. The plant extract has potentiality in suppressing the growth of *Basidiobolus haptosporus*, *B. ranarum*, causing subcutaneous infection in children below ten years, along with *Trichophyton rubrum* and *T. mentagrophytes* that cause skin, feet and fingernail infections in human. *Ocimum gratissimum* exhibits significant antifungal activity, making it valuable for the prevention and treatment of fungal infections. Its extracts and essential oils display efficacy against human, agricultural, and food-related fungal pathogens.

Uses and Preventive Role

- Oral and Skin Infections: Herbal formulations and rinses containing *Ocimum gratissimum* are used to prevent and treat oral fungal infections (such as those caused by *Candida albicans*) and certain skin conditions caused by dermatophytes and yeasts. (2,9,10)
- Food Preservation: The extract is recommended as a natural antifungal preservative, particularly for foods like cashew nuts, inhibiting growth of fungi like *Aspergillus flavus*, *Fusarium solani*, and *Candida* species.
- Agricultural Applications: Essential oils from the plant help manage crop diseases by inhibiting phytopathogenic fungi, acting as a sustainable alternative to chemical fungicides.

Antifungal Effects and Mechanism:

1. The antifungal activity is concentration-dependent, with higher concentrations resulting in greater inhibition of fungal growth.
2. Essential oils and extracts, particularly those rich in eugenol, disrupt fungal cell membranes and induce cytoplasmic/protein leakage in fungi, leading to cell death.
3. Inhibition is strong against *Candida albicans*, *Microsporum canis*, *Trichophyton rubrum*, *Botrytis*

cinerea, *Fusarium* spp., and other dermatophytes.

4. Minimum inhibitory concentrations (MIC) for essential oils range from 125 µg/mL to 500 ppm, depending on the fungus and extract type.

Effectiveness:

- In laboratory assays, *Ocimum gratissimum* extract sometimes surpassed commercial antifungal agents in inhibiting growth of *Candida albicans*.
- Inhibition rates for food spoilage fungi exceeded 50% at high extract concentrations, validating its practical use in food safety.
- Its preventive properties are harnessed in both traditional medicine and modern applications to inhibit establishment and spread of fungal infections.

TDDS with *Ocimum gratissimum* Herbal Patch:

A transdermal drug delivery system (TDDS) using *Ocimum gratissimum* extract integrates the plant's antifungal compounds into a polymer matrix to form a skin patch. The extract—obtained through ethanol or aqueous extraction—is incorporated into biocompatible polymers (such as chitosan or hydroxypropyl methylcellulose), creating a flexible patch that adheres to the skin surface. Dosage Explanation: In experimental and herbal applications, typical dosing involves patches containing 10–50 mg of *Ocimum gratissimum* extract per patch (varies by patch size and release requirement), designed to deliver active compounds steadily over 12–24 hours. The exact therapeutic dosage is tailored based on the extract's potency, severity of the infection, and area covered, but studies often test extracts within these concentration ranges for antifungal effect on skin lesions. The continuous, controlled release achieved by the patch prevents the rapid metabolism or wash-off associated with topical applications, ensuring a consistent therapeutic level at the site of infection.

Benefits:

- Delivers *Ocimum gratissimum*'s natural antifungal bioactives steadily, maximizing skin absorption and local action while minimizing systemic exposure and side effects.

- The patch bypasses gastrointestinal degradation and first-pass hepatic metabolism, enhancing bioavailability and reducing the frequency of administration.
- Painless, non-invasive route improves patient compliance, especially for chronic or recurrent infections.
- The system is easy to cease—removing the patch stops drug delivery instantly.
- Herbal patches specifically appeal to patients seeking natural, safer alternatives synthetic medicines.

Type of TDDS Control System:

Most herbal patches—including those with *Ocimum gratissimum*—are matrix-type controlled release systems. Here, the extract is uniformly distributed throughout the polymer layer, and drug release occurs by diffusion—controlled primarily by the composition and thickness of the polymer matrix. This ensures a slow, sustained release of the herbal actives for local or systemic therapeutic effect.

TRADITIONAL PREPARATION OF OCIMUM GRATISSIMUM HERBAL PATCH:

Leaf extracts typically involve the following steps:

1. Leaves are separated from the stalk, rinsed to remove dirt, and air-dried at room temperature.
2. The dried leaves are ground into a fine powder.
3. The powder is soaked in solvents such as ethanol or water for 24–48 hours at room temperature with occasional shaking or agitation.
4. The mixture is then filtered to separate the liquid extract.
5. The filtrate is concentrated by evaporation to dryness, either at room temperature or using a rotary evaporator, to get a concentrated extract.
6. This extract is stored under refrigeration until use.

FOR ETHANOL EXTRACTION OF OCIMUM GRATISSIMUM LEAVES:

1. Collection and Cleaning: Collect fresh *Ocimum gratissimum* leaves. Rinse thoroughly in clean water to remove dust and debris.

2. **Drying:** Spread the leaves in a well-ventilated, shaded area to air dry completely. Avoid direct sunlight to preserve phytochemicals.
3. **Grinding:** Once dried, grind the leaves into a coarse or fine powder using a grinder or mortar and pestle.
4. **Weighing:** Weigh the powdered leaves. A typical starting quantity is about 50-100 grams for small-scale extraction.
5. **Soaking in Ethanol:** Place the powdered leaves in a clean container and add ethanol (usually 70% or 95% ethanol, depending on availability) at a ratio of about 1:5 to 1:10 (powder to solvent, w/v).
6. **Maceration:** Seal the container and let the mixture macerate for 24 to 48 hours at room temperature. Shake or stir intermittently to enhance extraction.
7. **Filtration:** After maceration, filter the mixture using filter paper or muslin cloth to separate the liquid ethanol extract from the solid residue.
8. **Concentration:** Evaporate the ethanol solvent from the filtrate using a rotary evaporator or by gentle heating at a low temperature (below 40°C) in a water bath until a concentrated extract or residue is obtained.
9. **Storage:** Store the concentrated extract in an airtight container, preferably amber-colored to protect from light, and refrigerate until use. This ethanol extraction method is effective in isolating essential oils, flavonoids, and other bioactive compounds from *Ocimum gratissimum* leaves for medicinal or research purposes.

Benefits in antifungal treatment:

- Sustained and controlled release of *Ocimum gratissimum*'s antifungal agents improves efficacy.
- Non-invasive delivery enhances patient compliance.
- Avoids gastrointestinal side effects associated with oral.
- Use of Soxhlet extraction and chitosan polymer matrix for patch formulation incorporating *Ocimum* extracts. (24)

- Studies on transdermal patches incorporating herbal extracts demonstrating uniform distribution and sustained release. (24,26)
- Characterization of nanostructured lipid carriers and polymeric patches using *Ocimum* extracts with antifungal potential. (25)
- Reviews on antifungal efficacy of *Ocimum gratissimum* and its phytochemicals applicable in TDDS. (1,9)

This methodology indicates the feasibility of formulating *Ocimum gratissimum* into a transdermal patch for antifungal applications, leveraging its natural bioactive compounds with advanced drug delivery technology for enhanced therapeutic outcomes.

Novelty of developing transdermal patch:

In my review on *Ocimum gratissimum*-based herbal transdermal drug delivery system (TDDS) patches, I aim to introduce significant novelty by focusing on standardized and optimized extraction and formulation protocols. Existing studies often employ varied extraction methods and polymer matrices, leading to inconsistencies in the stability, bioavailability, and therapeutic efficacy of the herbal patches. By utilizing advanced extraction techniques such as green or supercritical fluid extraction and incorporating innovative biopolymers or nanocomposites, I will address these reproducibility and scalability challenges, ensuring a more reliable and consistent product. A major research gap exists in the lack of comprehensive clinical trials assessing the safety, efficacy, and patient compliance of *Ocimum gratissimum* TDDS patches in human subjects. My work will pioneer the development and validation of human-focused clinical protocols, including evaluation of skin irritation, bioavailability, and patient-reported outcomes, thus bridging the gap between preclinical promise and real-world application.(27,38) Furthermore, the environmental impact of TDDS patches is often overlooked. There is a need to incorporate eco-friendly and biodegradable materials in the formulation to meet growing sustainability demands. By employing sustainable sourcing of plant materials and green chemistry practices in polymer matrix design, I will contribute to creating environmentally responsible herbal patches.

Through addressing these significant gaps—in extraction and formulation standardization, clinical validation, and environmental sustainability—my research will contribute novel scientific insights and practical advancements to the field of herbal transdermal therapies.

Future scope of herbal patch of *Ocimum gratissimum*

The need for this study is underscored by the extensive therapeutic potential of *Ocimum gratissimum* combined with the advantages of transdermal drug delivery systems (TDDS). *Ocimum gratissimum* possesses a broad spectrum of pharmacological activities, including potent antifungal, antioxidant, anti-inflammatory, and antimicrobial effects, attributed to its rich phytochemical profile such as eugenol and flavonoids. Despite these promising properties, there remains a significant gap in developing standardized, controlled-release delivery systems for this herb that can enhance its bioavailability, stability, and patient compliance. TDDS offers an innovative and non-invasive alternative to conventional oral and topical antifungal therapies by providing controlled and sustained release of active ingredients through the skin while avoiding first-pass metabolism and minimizing side effects. While TDDS technology has been extensively studied for synthetic drugs, its application to herbal extracts like *Ocimum gratissimum* requires further research to optimize extraction methods, formulation stability, and clinical efficacy.

Moreover, the environmental sustainability aspect through biodegradable polymers and green extraction methods aligns this work with the increasing demand for eco-friendly pharmaceutical products. By focusing on these areas, this study aims to fill critical gaps in the translational development of *Ocimum gratissimum* herbal patches, potentially offering safer, effective, and patient-friendly antifungal therapies with improved compliance and therapeutic outcomes.

REFERENCES:

1. Abbaszadeh H., Ebrahimi S.A., Akhavan M.M. Antiangiogenic activity of xanthomicrol and calycopterin, two polymethoxylated hydroxyflavones in both in vitro and ex vivo models. *Phytother Res.*

- 2014;28(11):1661–1670. doi: 10.1002/ptr.5179. [DOI] [PubMed] [Google Scholar]
2. Abdulkhaleq L.A., Assi M.A., Noor M., Abdullah R., Saad M.Z., Taufiq-Yap Y.H. Therapeutic uses of epicatechin in diabetes and cancer. *Vet. World.* 2017;10:869–872. doi: 10.14202/vetworld.2017.869-872. [DOI] [PMC free article] [PubMed] [Google Scholar]
3. Adamu M., Nwosu C.O., Agbede R.I. Anti-trypanosomal effects of aqueous extract of *Ocimum gratissimum* (Lamiaceae) leaf in rats infected with *Trypanosoma brucei brucei*. *Afr. J. Tradit. Complement. Altern. Med.* 2009;6:262–267. [PMC free article] [PubMed] [Google Scholar]
4. Aguiar J.J.S., Sousa C.P.B., Araruna M.K.A., Silva M.K.N., Portelo A.C., Lopes J.C., Carvalho V.R.A., Figueredo F.G., Bitu V.C.N., Coutinho H.D.M., Miranda T.A.S., Matias E.F.F. Antibacterial and modifying-antibiotic activities of the essential oils of *Ocimum gratissimum* L. and *Plectranthus amboinicus* L. *Eur. J. Integr. Med.* 2015;7:151–156. [Google Scholar]
5. Aguiyi J.C., Obi C.I., Gang S.S., Igweh A.C. Hypoglycaemic activity of *Ocimum gratissimum* in rats. *Fitoterapia.* 2000;71:444–446. doi: 10.1016/s0367-326x(00)00143-x. [DOI] [PubMed] [Google Scholar]
6. Ajayi A.M., Ben-Azu B., Onasanwo S.A., Adeoluwa O., Eduviere A., Ademowo O.G. Flavonoid-rich fraction of *Ocimum gratissimum* attenuates lipopolysaccharide-induced sickness behavior, inflammatory and oxidative stress in Mice. *Drug Res.* 2019;69:151–158. doi: 10.1055/a-0654-5042. [DOI] [PubMed] [Google Scholar]
7. Ajayi A.M., Martins D., Balogun S.O., Oliveira R.G., Ascêncio S.D., Soares I.M., Barbosa R., Ademowo O.G. *Ocimum gratissimum* L. leaf flavonoid-rich fraction suppress LPS-

- induced inflammatory response in RAW 264.7 macrophages and peritonitis in mice. *J. Ethnopharmacol.* 2017;204:169–178. doi: 10.1016/j.jep.2017.04.005. [DOI] [PubMed] [Google Scholar]
9. Ajayi A.M., Ologe M.O., Ben-Azu B., Okhale S.E., Adzu B., Ademowo O.G. *Ocimum gratissimum* Linn. Leaf extract inhibits free radical generation and suppressed inflammation in carrageenan-induced inflammation models in rats. *J. Basic Clin. Physiol. Pharmacol.* 2017;28(6):531–541. doi: 10.1515/jbcpp-2016-0096. [DOI] [PubMed] [Google Scholar]
 10. Ajayi A.M., Umukoro S., Ben-Azu B., Adzu B., Ademowo O.G. Toxicity and protective effect of phenolic-enriched ethylacetate fraction of *Ocimum gratissimum* (linn.) leaf against acute inflammation and oxidative stress in rats. *Drug Dev. Res.* 2017;78:135–145. doi: 10.1002/ddr.21384. [DOI] [PubMed] [Google Scholar]
 11. Akara E.U., Okezie E., Ude V.C., Uche-Ikonne C., Eke G., Ugboju A.E. *Ocimum gratissimum* leaf extract ameliorates phenylhydrazine-induced anaemia and toxicity in Wistar rats. *Drug Metab. Pers. Ther.* 2021 doi: 10.1515/dmpt-2020-0185. [DOI] [PubMed] [Google Scholar]
 12. Akinrinde A.S., Oyagbemi A.A., Omobowale T.O., Asenuga E.R., Ajibade T.O. Alterations in blood pressure, antioxidant status and caspase 8 expression in cobalt chloride-induced cardio-renal dysfunction are reversed by *Ocimum gratissimum* and gallic acid in Wistar rats. *J. Trace Elem. Med. Biol.* 2016;36:27–37. doi: 10.1016/j.jtemb.2016.03.015. [DOI] [PubMed] [Google Scholar]
 13. Alabi Q.K., Akomolafe R.O., Omole J.G., Adefisayo M.A., Ogundipe O.L., Aturamu A., Sanya J.O. Polyphenol-rich extract of *Ocimum gratissimum* leaves ameliorates colitis via attenuating colonic mucosa injury and regulating pro-inflammatory cytokines production and oxidative stress. *Biomed. Pharmacother.* 2018;103:812–822. doi: 10.1016/j.biopha.2018.04.071. [DOI] [PubMed] [Google Scholar]
 14. Alagawany M., Abd El-Hack M.E., Farag M.R., Gopi M., Karthik K., Malik Y.S., Dhama K. Rosmarinic acid: modes of action, medicinal values and health benefits. *Anim. Health Res. Rev.* 2017;18:167–176. doi: 10.1017/S1466252317000081. [DOI] [PubMed] [Google Scholar]
 15. Aneke C.I., Nwogwugwu C.C., Ugochukwu I.C.I., Chah K.F. Antifungal activity of ethanolic extracts of *Ocimum gratissimum* and *Vernonia amygdalina* leaves against dermatomycotic agents isolated from domestic animals in South Eastern Nigeria. *Comp. Clin. Pathol.* 2019;28:1791–1795. [Google Scholar]
 16. Antora R.A., Salleh R.M. Antihyperglycemic effect of *Ocimum* plants: a short review. *Asian Pacific J. Trop. Biomed.* 2017;7:755–759. [Google Scholar]
 17. Aziba P.I., Bass D., Elegbe Y. Pharmacological investigation of *Ocimum gratissimum* in rodents. *Phytother Res.* 1999;13:427–429. doi: 10.1002/(sici)1099-1573(199908/09)13:5<427::aid-ptr467>3.0.co;2-t. [DOI] [PubMed] [Google Scholar]
 18. Barboza J.N., da Silva Maia Bezerra Filho C., Silva R.O., Medeiros J., de Sousa D.P. An overview on the anti-inflammatory potential and antioxidant profile of eugenol. *Oxid. Med. Cell. longev.* 2018;3957262 doi: 10.1155/2018/3957262. [DOI] [PMC free article] [PubMed] [Google Scholar]
 19. Baser K.H. Biological and pharmacological activities of carvacrol and carvacrol bearing essential oils. *Curr. Pharmaceut. Des.* 2008;14:3106–3119. doi:

- 10.2174/138161208786404227.
[DOI] [PubMed] [Google Scholar]
20. Beier R.C., Byrd J.A., 2nd, Kubena L.F., Hume M.E., McReynolds J.L., Anderson R.C., Nisbet D.J. Evaluation of linalool, a natural antimicrobial and insecticidal essential oil from basil: effects on poultry. *Poultry Sci.* 2014;93:267–272. doi: 10.3382/ps.2013-03254. [DOI] [PubMed] [Google Scholar]
21. Benitez N.P., León E.M.M., Stashenko E.E. Eugenol and methyl eugenol chemotypes of essential oil of species *Ocimum gratissimum* L. and *Ocimum campechianum* Mill. from Colombia. *J. Chromatogr. Sci.* 2009;47:800–803. doi: 10.1093/chromsci/47.9.800. [DOI] [PubMed] [Google Scholar]
22. Bernell S., Howard S.W. Use your words carefully: what is a chronic disease? *Front.Public Health.* 2016;4:159. doi: 10.3389/fpubh.2016.00159. [DOI] [PMC free article] [PubMed] [Google Scholar]
23. Junyaprasert, V. B., Teeranachaideekul, V., Souto, E. B., Boonme, P., & Müller, R. H. (2009). Q10-loaded NLC versus nanoemulsions: Stability, rheology and in vitro skin permeation. *International Journal of Pharmaceutics*, 377(1-2), 207–214. <https://doi.org/10.1016/j.ijpharm.2009.05.020>
24. Lancelot, A., Sierra, T., & Serrano, J. L. (2014). Nanostructured liquid-crystalline particles for drug delivery. *Expert Opinion on Drug Delivery*, 11(4), 547–564. <https://doi.org/10.1517/17425247.2014.884556>
25. Selvaraju, R., Sakuntala, P., & Jaleeli, K. A. (2021). GC–MS and FTIR analysis of chemical compounds in *Ocimum gratissimum* plant. *Biophysics*, 66, 401–408. <https://doi.org/10.1134/S0006350921030167>
