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Review TDD

Formulation and Evaluation of Transdermal Patch to Enhance Treatment of Alopecia

Jagtap Umakant Sanjay[1,*], More Krutika Arvind[1], Jain Aachal Vinod[1], Sulbha Gopal Patil[2]

Abstract

The improvement of novel topical sedate conveyance frameworks has picked up noteworthy consideration due to their potential in upgrading the helpful viability and persistent compliance whereas minimizing systemic side impacts. This thinks about centers on the definition and assessment of transdermal patches planned to discharge allicin, the essential naturally dynamic compound determined from garlic (Allium sativum) extricate. Allicin is eminent for its wide range of pharmacological properties, counting antimicrobial, anti-inflammatory, antioxidant, and wound mending exercises, making it a promising candidate for dermal applications. In any case, allicin is known for its chemical flimsiness and instability, which posture critical challenges for its joining into steady details. The physicochemical characteristics of the patches were assessed, counting thickness, pliable quality, collapsing continuance, dampness substance, sedate substance consistency, and pH compatibility. In vitro medicate discharge ponders were conducted utilizing Franz dissemination cells with manufactured and porcine skin layers to recreate human skin conditions. The optimized definitions illustrated supported discharge of allicin over 24 hours with negligible corruption, keeping up organic action all through the testing period. Microbiological tests affirmed the antimicrobial adequacy of the allicin-loaded patches against both Gram-positive and Gram-negative microscopic organisms, counting Staphylococcus aureus and Escherichia coli. Furthermore, preparatory in vivo considers on creature models demonstrated eminent enhancements in wound recuperating highlights the potential of garlic-derived allicin topical patches as a characteristic, successful, and non-invasive elective for treating skin contaminations, wounds, and fiery conditions. The effective stabilization and controlled discharge of allicin in a transdermal fix arrange gives a promising establishment for assist improvement into clinically practical home-grown therapeutics. Future considerations will center on long-term solidness, large-scale generation, and clinical trials to survey security, adequacy, and persistent acknowledgment.

Keywords: Allicin, garlic extract, transdermal patches, topical drug delivery, herbal therapeutics, and irritation diminishment compared to control bunches

***Author for Correspondence**
Jagtap Umakant Sanjay
E-mail: umakantjagtap2002@gmail.com

[1]Student, B. Pharm, Department of Pharmaceutics, P. S. G. V. P, Mandal's College of Pharmacy, Shahada, Maharashtra, India
[2]Associate Professor, Department of Pharmaceutical Chemistry, P. S. G. V. P, Mandal's College of Pharmacy, Shahada, Maharashtra, India

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INTRODUCTION

Topical sedate conveyance has developed as a promising and successful elective to customary systemic organization, advertising a few focal points, such as localized helpful activity, evasion of gastrointestinal debasement, bypassing first-pass digestion system, and progressed understanding compliance. Among different topical conveyance frameworks, transdermal patches stand out due to their capacity to convey a supported and controlled discharge of dynamic pharmaceutical fixings through the skin over amplified periods. These frameworks are non-invasive, self-administrable, and competent of making strides bioavailability of compounds with

destitute verbal retention or systemic steadiness. In a long time, there has been developing intrigued in coordination phytochemicals and home grown extricates into cutting edge medicate conveyance frameworks, pointing to combine conventional restorative information with progressed pharmaceutical innovations. One such strong common bioactive compound is allicin, the major organically dynamic organosulfur compound determined from new garlic (*Allium sativum*). Allicin is not display in intaglio garlic cloves but is enzymatically delivered when garlic is smashed or chopped, through the activity of the chemical alliinase on the forerunner alliin. Allicin has been broadly considered for its different pharmacological properties, counting antimicrobial, anti-inflammatory, antioxidant, antifungal, and wound recuperating exercises [1].

Despite its helpful potential, the clinical application of allicin has been constrained due to its chemical insecurity, destitute dissolvability, and fast debasement upon introduction to warm, light, and oxygen. These impediments make it troublesome to define steady and viable dose shapes for therapeutic utilization. Furthermore, allicin's impactful odor and tall reactivity contribute to challenges in its detailing. Hence, inventive conveyance frameworks are basic to protect its action and empower controlled, focused on discharge at the location of activity. In this setting, transdermal patches display a novel methodology to tackle the helpful benefits of allicin. By consolidating stabilized shapes of garlic extricate or typified allicin into polymeric lattices, it is conceivable to secure the dynamic compound from debasement whereas encouraging its continuous discharge through the skin. The stratum corneum, although a imposing obstruction, can be overcome utilizing saturation enhancers and detailing optimization, permitting successful dermal assimilation of the dynamic compound. This inquiries about points to create and assess topical transdermal patches containing stabilized garlic extricate improved with allicin, tending to both the steadiness and conveyance challenges related to this characteristic compound. The detailing approach incorporates selecting suitable polymers, plasticizers, and infiltration enhancers, as well as investigating methods, such as epitome, nano emulsion, and complexation to improve allicin solidness and bioavailability. The ultimate patches are anticipated to show worthy mechanical properties, controlled discharge profiles, antimicrobial adequacy, and skin compatibility [2].

ALOPECIA

Alopecia is the medical term for hair loss. It refers to the partial or complete absence of hair from areas of the body where it normally grows, especially the scalp. Alopecia can result from genetics, autoimmune conditions, medical treatments, infections, or other underlying health issues. It can be temporary or permanent, and its severity ranges from small bald patches to total loss of hair on the scalp or body.

CAUSES

Genetic Factors

- 7 Androgenetic alopecia (male or female pattern baldness)
- Family history of hair loss

Autoimmune Disorders

- Alopecia areata the immune system attacks hair follicles
- Lupus erythematosus

TYPES OF ALOPECIA

1. *Androgenetic Alopecia:* Moreover known as male-pattern or female-pattern hair loss.
2. *Alopecia Areata:* Immune system clutter where the safe framework assaults hair follicles Sudden sketchy hair misfortune on the scalp.
3. *Telogen Effluvium:* Brief hair shedding due to push, ailment, or hormonal changes Hair rashly enters the telogen (resting) stage [3].

To assess the safety and efficacy of specific therapy approaches in minimizing hair loss and encouraging hair growth in people with different forms of alopecia, with an emphasis on enhancing patient quality of life, scalp health, and hair density.

ROLE OF ALICIN IN ALOPECIA

1. *Anti-inflammatory Properties:* Alopecia, particularly shaped, like alopecia areata, includes resistant framework brokenness and irritation around hair follicles. Garlic contains compounds, such as sulfur compounds (like allicin) which will diminish irritation and tweak safe reactions, making a difference to reestablish a more advantageous environment for hair development.
2. *Advances Circulation:* Garlic has been appeared to make strides blood circulation. Improved blood stream to the scalp can help give hair follicles with the supplements and oxygen they require, possibly supporting hair development and quality. A few ponders recommend that garlic can act as a normal vasodilator, extending blood vessels and making strides circulation.
3. *Antioxidant Impacts:* Oxidative stretch is another figure in hair misfortune, particularly in conditions like androgenetic alopecia. Garlic contains cancer prevention agents, like selenium and vitamin C, which may help neutralize free radicals and decrease oxidative harm to hair follicles. This might advance hair wellbeing and possibly invigorate regrowth.
4. *Antimicrobial Properties:* Alopecia can now and then be activated or exacerbated by scalp diseases, dandruff, or contagious conditions. Garlic has solid antimicrobial and antifungal properties, which might help kill pathogens that meddled with hair follicle work.
5. *Hormonal Adjust and DHT Restraint:* Within the case of androgenetic alopecia (male or female design hairlessness), hair misfortune is frequently related to the impacts of dihydrotestosterone (DHT), a hormone derived from testosterone. A few thinks about recommending that garlic might help lower DHT levels, although usually still beneath examination. On the off chance that garlic can impact hormone control in this way, it might possibly moderate down hair misfortune related with DHT [4].

BENEFITS OF TRANSDERMAL DRUG DELIVERY SYSTEM

1. *Enhanced Bioavailability:* TDDS helps increase the bioavailability of active ingredients. Instead of being broken down in the digestive system (as oral treatments are), drugs or compounds can be delivered directly through the skin into the bloodstream, bypassing the first-pass metabolism in the liver. This results in more efficient and consistent delivery of the active compound to the target areas, such as the hair follicles.
2. *Targeted Delivery to the Scalp:* TDDS provides localized treatment to the affected areas of the scalp, ensuring that the active compound is concentrated where it's most needed. This localized delivery minimizes the risk of systemic side effects, which can be a concern with oral medications, and improves the effectiveness of the treatment.
3. *Sustained Release:* One of the key advantages of TDDS is the ability to provide controlled and sustained release of active ingredients. This means that the medication can be released over a long period, ensuring a steady and consistent concentration of the active compound in treatment. For alopecia, this could promote prolonged stimulation of hair follicles and reduce the frequency of application.
4. *Minimized Side Effects:* Because the active ingredient in a TDDS is delivered directly to the targeted area (the scalp, in this case), the risk of systemic side effects is reduced. Traditional oral treatments for alopecia can lead to side effects affecting other parts of the body, but TDDS ensures that the active compounds stay focused on the scalp [5].

The effective, long-lasting, and targeted distribution of therapeutic substances to the scalp is what gives TDDS patches their unique potential for treating alopecia. For different types of alopecia, these patches can increase patient compliance, reduce side effects, and perhaps increase the overall efficacy of treatment. For those looking for a more practical and targeted method of hair regrowth, TDDS patches are an appealing option because they can integrate many treatments in a single patch, lessen scalp pain, and provide a non-invasive, painless alternative [6].

PHARMACOLOGICAL ACTIVITIES OF ALLICIN

- *Anti-Inflammatory Impacts:* Allicin upgrades resistant cell action, represses the SDF1α chemokine, and diminishes the trans endothelial relocation of neutrophils, contributing to its anti-inflammatory properties.
- *Anticancer Action:* It actuates apoptosis in cancer cells by upgrading p38 expression and cleaved caspase 3 levels. Allicin and its subsidiaries, such as ajoene, have too been appeared to hinder the development of different cancer cell lines.
- *Antioxidant Properties:* Allicin tweaks responsive oxygen species (ROS), increments glutathione levels, and upgrades cellular antioxidant proteins, subsequently securing cells from oxidative harm.
- *Cardioprotective Impacts:* It avoids platelet accumulation, restrains platelet actuation, and upgrades fibrinolytic action, contributing to cardiovascular wellbeing.
- *Antidiabetic Impacts:* Allicin diminishes affront emission from pancreatic cells, upgrades liver digestion system, and increments short-acting affront generation, in this manner supporting blood sugar control.
- *Hepatoprotective Action:* It offers security against liver harm by balancing different biochemical pathways, in this manner supporting liver wellbeing.
- *Neuroprotective Impacts:* Allicin progresses mitochondrial work by upgrading the expression of warm stun protein 70 (HSP70) and atomic figure erythroid 2-related calculate 2 (Nrf2), lessening oxidative stretch, and moderating neuroinflammatory forms, which are useful in avoiding neurodegenerative infections [7].

TRANSDERMAL DRUG DELIVERY SYSTEM

Transdermal Sedate Conveyance Frameworks (TDDS) are inventive pharmaceutical definitions outlined to manage restorative operators through the skin, giving controlled and orderly sedate assimilation into the circulatory system. These frameworks offer an elective to verbal and injectable courses, upgrading quiet compliance and restorative efficacy [8].

Advantages of TDDS

- *Bypass First-Pass Digestion system:* TDDS permits drugs to enter systemic circulation straightforwardly, dodging the hepatic first-pass impact, which can lead to sedate debasement and decreased bioavailability when taken orally.
- *Supported Discharge:* These frameworks convey a reliable sedate measurement over an amplified period, keeping consistent plasma concentrations and progressing restorative results.
- *Upgraded Understanding Compliance:* The comfort of applying a fix that conveys medicine over time diminishes dosing recurrence, making it simpler for patients to follow to their treatment regimens.
- *Decreased Side Impacts:* By keeping up consistent sedate levels, TDDS minimizes peak-trough variances, possibly diminishing the event of side impacts related to fluctuating sedate concentrations.
- *Non-Invasive and Effortless:* Application of TDDS is clear and effortless, advertising a non-invasive elective to infusions, which can be especially advantageous for patients who encounter needle fear or have trouble with infusion organization [9].

Drawbacks of TDDS

- *Skin Bothering:* Delayed contact with the cement or the sedate itself can cause nearby skin responses, counting aggravation or unfavorably susceptible reactions.
- *Constrained Medicate Candidates:* As it were drugs with appropriate physicochemical properties – such as moo atomic weight, suitable lipophilicity, and moo softening point – are reasonable for transdermal conveyance. Also, TDDS is for the most part successful for powerful drugs that require moo day by day doses [10].

METHODS OF PREPARING TRANSDERMAL PATCH

Solvent Casting Method

- ***Steps***
  - Prepare a homogeneous drug-polymer solution.
  - Cast the solution into a mold.
  - Allow solvent evaporation to leave behind a solid film.
  - Cut the film into desired patch shapes and sizes.
- ***Advantages***
  - Simple and cost-effective.
  - Good for achieving uniform drug distribution.
- ***Disadvantages***
  - Solvent residue could affect drug release and patch safety.
  - Requires careful control of solvent evaporation to avoid defects [11].

Film Casting with Solvent Evaporation

- ***Steps***
  - Prepare a drug-polymer solution.
  - Cast the solution onto a mold or flat surface.
  - Allow solvent to evaporate under controlled conditions.
  - Peel off the film once dried and cut it into patches.
- ***Advantages***
  - Good control over film thickness.
  - Ideal for heat-sensitive drugs.
- ***Disadvantages***
  - Solvent residue can remain if not properly evaporated.
  - The process may take time due to slow evaporation rates [12].

AIM, OBJECTIVE, AND NEED OF STUDY

Aim

Formulation and evaluation of transdermal patches to enhance the treatment of alopecia.

Objective

1. Extraction of garlic.
2. Formulation of transdermal patches.
3. Evaluation of transdermal patches.

Need

Alopecia is a disorder marked by partial or total hair loss from the scalp and other parts of the body where hair normally grows. Numerous factors, such as heredity, autoimmune diseases, hormonal imbalances, malnutrition, stress, and some drugs, might contribute to it. Androgenetic and alopecia areata are the most common forms among the several types. A person's quality of life and sense of self-worth can be greatly impacted by hair loss, which makes effective treatment methods necessary.

MATERIAL AND METHODS

Role of Ingredient (*Hydroxy Propyl Methyl Cellulose* (HPMC)

Controlled Release of Active Ingredients

- *Function of HPMC:* HPMC is widely used in matrix-based transdermal patches, where the active drug is embedded within the polymer matrix. Due to its gel-forming characteristics, HPMC helps regulate the release of active compounds, such as minoxidil, commonly utilized in treatments for alopecia (Figure 1) (Table 1).
- *Advantage for Alopecia:* In the treatment of alopecia, it's crucial that minoxidil or other therapeutic agents are released slowly over time. HPMC ensures a steady release, maximizing the

effectiveness of the treatment while minimizing the need for frequent applications. This controlled release maintains consistent drug levels in the skin, enhancing therapeutic outcomes.

Table 1. Chemical composition and quantities used in the formulation.

Name of Chemical	Quantity Taken
1. Hydroxyl propyl methyl cellulose (HPMC)	1.5 gm.
2. Dimethyl sulfoxide (DMSO)	0.25 ml.
3. Propylene glycol	3 ml.
4. Glycerine	5 ml.
5. Ethanol	10 ml.
6. Garlic extract	1–2 drop.
7. Polyvinyl chloride	10 ml.

Figure 1. Chemicals.

Enhancement of Skin Penetration

- *Function of HPMC:* HPMC improves the skin penetration of active ingredients by forming a gel barrier that hydrates the skin, allowing the drug to be absorbed more effectively. This gel layer also acts as a reservoir, facilitating the drug's penetration into deeper skin layers [13].
- *Advantages for Alopecia:* In alopecia treatments, it is vital for the active ingredient (e.g., minoxidil) to penetrate the skin layers and reach the hair follicles. The gel matrix formed by HPMC helps transport these ingredients more effectively into the scalp's deeper layers, boosting the treatment's effectiveness.

Formulation Stability and Adhesion

- *Function of HPMC:* HPMC helps stabilize TDDS patches, ensuring the active drug remains stable within the formulation. It also enhances the adhesive properties of the patch, ensuring it stays securely attached to the scalp over an extended period.
- *Advantages for Alopecia:* Stability is crucial in alopecia treatments, as the patch needs to remain intact throughout its use. HPMC contributes to a strong adhesive bond, preventing the patch from shifting or falling off, thus ensuring consistent delivery of the active drug to the target area on the scalp.

Viscosity Control

- *Function of HPMC:* HPMC plays a key role in regulating the viscosity of formulations, allowing for the creation of products with the desired texture – neither too runny nor too thick.

- *Advantage for Alopecia:* The consistency of a TDDS formulation is important for smooth and even application on the scalp. HPMC ensures that the patch or gel formulation has an ideal consistency, making it easier and more pleasant for users to apply, especially for individuals with alopecia.

Mucoadhesive Properties

- *Function of HPMC:* HPMC has inherent mucoadhesive properties, meaning it can adhere to mucosal or skin surfaces for prolonged periods, facilitating continuous drug delivery.
- *Advantages for Alopecia:* Alopecia treatments benefit from a formulation that remains in contact with the scalp for longer durations to allow the active ingredients to be effective. HPMC's mucoadhesive qualities ensure the transdermal patch or gel remains in place, reducing the need for frequent reapplications and providing sustained release of the active compound.

Biocompatibility and Safety

- *Function of HPMC:* HPMC is highly biocompatible, non-irritating, and safe for topical applications, making it an excellent choice for skin-based formulations.
- *Advantage for Alopecia:* Since alopecia treatments are often applied to sensitive areas, like scalp, HPMC's biocompatibility ensures the formulation is safe, reducing the risk of irritation or adverse reactions, making it well-suited for long-term use [14].

DIMETHYL SULFOXIDE (DMSO)

One common solvent and penetration enhancer in transdermal drug delivery systems (TDDS) is dimethyl sulfoxide (DMSO). By increasing the penetration of active components (such as minoxidil, finasteride, or other therapeutic agents) into the scalp, DMSO plays a critical role in the treatment of alopecia and increases the efficacy of the medication. In TDDS patches for alopecia, DMSO works as follows.

Increasing the Solubility of Drugs

- *Function of DMSO:* For a variety of medications, particularly those that are poorly soluble in water, DMSO is an extremely efficient solvent. It is the perfect solvent for transdermal applications since it can dissolve both hydrophilic and lipophilic substances.
- *Benefit for Alopecia:* DMSO can aid in the dissolution of medications used to treat alopecia that have low water solubility, such as finasteride or some types of minoxidil, enhancing their stability and enabling their integration into TDDS formulations. The effectiveness of the treatment may be improved because of improved medication availability at the site of action.

Improving Comfort and Reducing Irritation

- *Function of DMSO:* When administered at the right quantities, DMSO is typically regarded as non-toxic and non-irritating, despite its potent penetration-enhancing properties. Additionally, it can lessen the possibility of discomfort from other excipients in the formulation.
- *Benefit for Alopecia:* DMSO can assist increase user comfort by lowering the risk of irritation or discomfort, which is particularly crucial for prolonged use, as alopecia therapies sometimes entail topical application to sensitive areas like the scalp.

Increased Stability and Adhesion

- *Function of DMSO:* By interacting with the skin's surface and encouraging improved contact between the patch and the skin, DMSO, when added to the formulation, can assist increase the transdermal patch's adherence to the skin.
- *Alopecia benefit:* A stable, well-adhering patch guarantees that the active ingredient is continuously applied and stays in contact with the scalp for the necessary amount of time. By keeping the patch from coming loose and improving its stability over time, DMSO helps in this process.

PROPYLENE GLYCOL

1. *Solubilizing Specialist:* Propylene glycol serves as a dissolvable in minoxidil arrangements, improving the solvency of minoxidil, which is ineffectively dissolvable in water. This permits viable topical application and conveyance to the scalp.
2. *Improving Skin Entrance:* As a entrance enhancer, propylene glycol encourages the assimilation of minoxidil into the scalp. Ponders have appeared that definitions with higher propylene glycol substance can increase the infiltration of minoxidil through the skin.
3. *Additive and Humectant:* In expansion to its part in solubilizing and infiltration, propylene glycol acts as an additive and humectant. It makes a difference keep up the steadiness of the definition and holds dampness, avoiding the scalp from getting to be dry.
4. *Benefits:* Moved forward Adequacy By improving the dissolvability and entrance of minoxidil, propylene glycol contributes to the viability of hair regrowth treatments.

GLYCERINE

A common excipient in the formulation of transdermal drug delivery systems (TDDS), such as patches for the treatment of alopecia, is glycerine, sometimes referred to as glycerol. It is a solvent and humectant that offers several advantages for improving the effectiveness and user experience of TDDS formulations. The function of glycerine and its advantages for treating alopecia are broken down as follows:

1. *Retention of Moisture and Humectant: Glycerine's value:* Glycerine absorbs moisture from the surroundings and holds it in the mixture since it is a humectant. This feature keeps the skin from drying out and helps to keep it hydrated. Benefits for Alopecia: Preserving moisture is crucial in alopecia treatments, especially for the scalp, to avoid dryness and irritation. Glycerine aids in keeping the scalp hydrated when
2. the TDDS patch is being applied. Maintaining the health of the skin, avoiding flaking, and improving the active ingredient's (like minoxidil's) absorption into the scalp all need this hydration.
3. *How to Avoid Skin Irritation: Glycerine's function:* Glycerine is well-known for its calming and non-irritating qualities. It lessens skin irritation that other chemicals in the transdermal patch formulation could cause. Benefit for Alopecia: Because the scalp is a sensitive area, topical therapies that irritate it may cause discomfort and lower patient compliance. Because glycerine reduces irritation, users can wear the TDDS patch for longer periods of time without experiencing any discomfort.
4. *Glycerine's Function in Stabilizing the Formulation:* By keeping the active chemicals in the TDDS formulation from deteriorating or crystallizing, glycerine can help stable the formulation and keep it safe and effective over time.

Benefit for Alopecia: Because the patch needs to stay intact during use, stability is essential for alopecia treatments. Glycerine stabilizes the formulation, which is crucial for long-term therapy since it keeps the active component uniformly distributed and effective [15].

ETHANOL

In transdermal drug delivery systems (TDDS), such as those intended to treat alopecia, ethanol is a frequently used solvent and excipient. Ethanol is essential for improving the TDDS patch's performance and efficacy, and its characteristics support the stability of the formulation as well as the effectiveness of the active components, such as minoxidil, which is frequently used to treat alopecia.

Improving Film Formation and Adhesion

- *Function of Ethanol:* By enhancing the interaction between the active components and the polymer matrix, ethanol helps the TDDS patch's adhesive qualities. It also aids in the formation of a consistent film.
- *Benefit for Alopecia:* For continuous drug release in alopecia treatments, the patch's ability to stick to the scalp is essential. Ethanol improves the stability and length of the treatment by

ensuring that the patch stays in place while being used. Because fewer reapplications are required, patient compliance is increased.

Antimicrobial Characteristics: Function of Ethanol

Due to its inherent antibacterial qualities, ethanol helps lower the possibility of microbial contamination in the formulation.

- *Benefit for Alopecia:* Ethanol's antibacterial qualities lessen the likelihood of microbial growth in TDDS patches for alopecia because the patches are placed to the scalp, an area that is prone to bacteria and fungi. This is especially crucial for guaranteeing the product's safety and hygienic conditions during an extended period of use [16].

GARLIC

One of the many health benefits of garlic (*Allium sativum*) is that it may be used to treat alopecia. Allicin, one of the active ingredients in garlic, is thought to have antibacterial, anti-inflammatory, and antioxidant qualities. Incorporating garlic into transdermal drug delivery systems (TDDS), such as patches, can significantly increase the effectiveness of alopecia treatments**.**

Improving Hair Development

- *Garlic's role in treating alopecia:* Garlic contains a lot of sulfur compounds, especially allicin, which have been demonstrated to increase hair growth by enhancing blood flow to the scalp. These substances might also promote the formation of new hair by having a proliferative effect on hair follicles.
- *Benefit of TDDS Patches:* A transdermal matrix can absorb garlic's active components, guaranteeing gradual, controlled release. The TDDS patch can sustain a steady supply of these growth-promoting elements to the scalp by releasing garlic's bioactive compounds gradually. This can boost follicle stimulation and assist hair regrowth over time.

Enhancing Microcirculation and Scalp Health

- *Garlic's role:* Garlic includes chemicals that may assist the increase of the scalp's microcirculation. More oxygen and nutrients are delivered to hair follicles by improved blood circulation, which enhances hair growth.
- *Benefit of TDDS Patches:* The transdermal patch's gradual release of garlic may support improved blood flow to the scalp, encouraging the growth of healthier follicles. This can promote hair development, especially for people who are losing hair because of poor circulation in their killings. Garlic plays a crucial role to realizing allicin and impact on promoting the regrowth cycle of hair which helps to prevent loss of hair [17].

POLYVINYL CHLORIDE

Polyvinyl chloride (PVC) may be an engineered plastic polymer commonly utilized in different applications, counting therapeutic devices and customer items. In any case, its part within the treatment of alopecia (hair misfortune) is not set up, and it has been related to certain well-being concerns.

- *PVC Presentation and Wellbeing Concerns:* Ponders have inspected the impacts of PVC introduction on regenerative wellbeing. For occasion, inquire about including male Wistar rats uncovered to PVC shown potential antagonistic impacts on regenerative organs and sperm quality. Co-administration of resveratrol appeared a few defensive impacts against PVC-induced harmfulness.
- *PVC in Therapeutic Applications:* Whereas PVC is broadly utilized in restorative gadgets, such as intravenous packs and tubing, its application is essentially for control and delivery of solutions or liquids, not as a treatment for conditions like alopecia. There is no considerable proof supporting the utilization of PVC itself as a helpful specialist for hair misfortune.

PREPARATION OF GARLIC EXTRACT

Materials Require

- New garlic bulbs.
- Blender or mortar and pestle.
- Measuring utensil or glass holder.
- Measuring barrel.
- Sterile holder for capacity [18].

METHOD OF GARLIC EXTRACT

Ethanolic Garlic Extract (Alcohol-based)

Materials

- New garlic.
- 95% ethanol.
- Blender or mortar and pestle.
- Channel paper.
- Glass jolt or bottle.

Method

- Peel and pulverize 50g of garlic cloves.
- Include a glass jostle with 100 mL of ethanol (50% w/v).
- Seal the jolt and shake well.
- Store in a dim, cool put for 48–72 hours, shaking sometimes.
- Channel the extricate utilizing channel paper.
- Name and store in a cool, dull pit or fridge. Can be final for weeks [19].

METHOD USE TO PREPARE THE TRANSDERMAL PATCH

1. *Dynamic fixing:* Garlic extricates (Allium sativum).
2. *Polymer:* Hydroxypropyl methylcellulose (HPMC).
3. *Plasticizer:* Polyethylene glycol (PEG 400).
4. *Saturation enhancer:* DMSO (Dimethyl sulfoxide).
5. *Dissolvable:* Ethanol.
6. *Backing film:* Polyvinyl liquor (PVA).

Method

1. *Planning of Polymer solution:* Break up the polymer (HPMC) in ethanol with ceaseless mixing.
2. *Joining dynamic fixing:* The concentrated garlic extricate is blended with the polymer solution beneath blending. Include the plasticizer (e.g., glycerol) and saturation enhancer (DMSO) to upgrade sedate discharge.
3. *Casting of the Film:* The arranged mixture is poured into a glass Petri dish and spread equitably. Permit it to dry at room temperature or in a hot discuss stove at 40–50°C for 24 hours.
4. *Last fix mixture:* The dried film is carefully peeled off and cut into uniform patches. The backing film (PVA) is connected to one side (Figure 2) [20].

EVALUATION OF TRANSDERMAL PATCH

Physical Evaluation

Color, odor, thickness, surface, flexibility, transparency, and shape were evaluated (Table 2).

In Vitro Drug Release Study

In vitro sedate discharge consider could be a laboratory-based try utilized to assess the rate and degree at which a medicate is discharged from a defined dose frame (e.g., transdermal fix) into a recreated organic environment, exterior the body. The in-vitro drug diffusion study was carried out using open ended cylinder method with the use of a membrane that is semi permeable. The dialysis

membrane was activated by immersing it into the water. The membrane of appropriate size was tied to one end of the open-ended cylinder which acted as the donor compartment. Then the cylinder was dipped into the diffusion medium which acted as the receptor compartment. Phosphate buffer of pH 6.8 was used as the diffusion medium. Patches of appropriate sizes were then placed in the donor compartment and they were kept separated from the receptor compartment using the dialysis membrane. The temperature was maintained at 37ºC at 50 rpm. 1 ml of the sample was withdrawn after every half an hour for 4 consecutive hours and simultaneously the receptor compartment that is the diffusion medium, was replaced with the fresh buffer. The absorbance was determined using UV spectrophotometer at 272.0 nm (Figure 3) [21].

Figure 2. Patches.

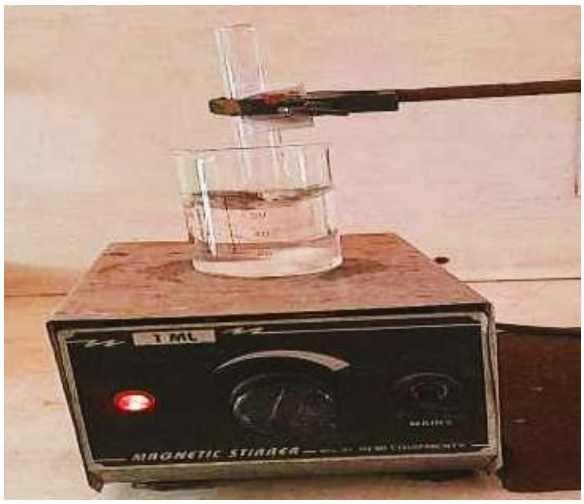

Figure 3. Diffusion assembly.

pH

pH: 5 to 6 pH is determined by using pH paper. The natural pH of healthy hair is slightly acidic, generally between 4.5–5.5 with the scalp being slightly more acidic at 5.5 (Figure 4) [22].

Folding Endurance

After the formulation of patches, the folding endurance study was manually determined. The formulations were turned under repeatedly in the same spot until broken, total number of folding of the patches in the same area repeatedly provides an appropriate number for this study.

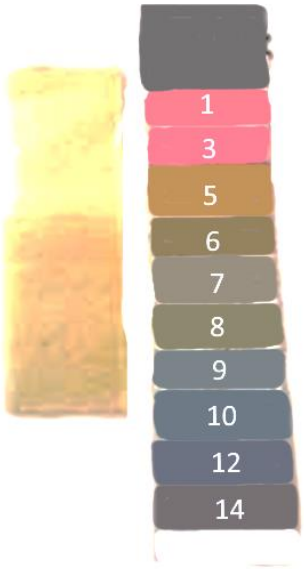

Figure 4. pH paper.

Drug Content

The medicate substance ponder was conducted within the taking after way, 1–2 cm cut of transdermal fixed pieces were taken independently, smashed, and took hold of a volumetric jar (100 ml) which contained phosphate buffer (pH 7.4). An attractive dot was utilized to shake the fluid for five hours. The fixed fluids blend was sifted utilized. The filtrate gotten through Whatman channel paper was examined for sedate substance utilizing spectrophotometry at 272nm, comparing it against a reference (Figures 5 and 6).

Figure 5. UV spectrophotometer.

Table 2. Evaluation of transdermal patches.

Parameter	Result
Color, odor	Pale yellow to light brown, Strong pungent garlic like odor.
Transparency	Translucent to opaque, depending on matrix.
Drug Content Uniformity	95%–105%.
Patch Thickness	100–105.
Weight Variation	2–3%.
Folding Endurance	>400.
Surface pH	5–6.
In-Vitro Drug Release	90%.

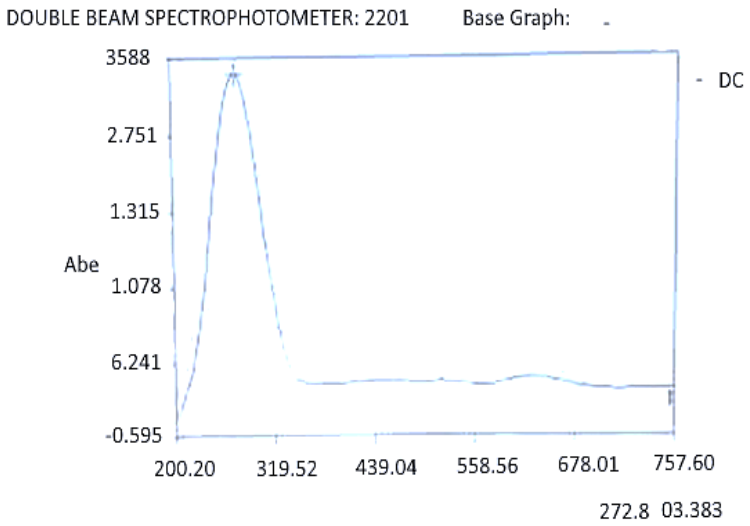

Figure 6. Absorbance graph.

CONCLUSIONS

The current research successfully created and assessed transdermal patches aimed at improving the management of alopecia. These patches were constructed with appropriate polymers and penetration enhancers to guarantee effective drug release and absorption through the skin. Assessment criteria, such as visual characteristics, thickness, transparency, drug content consistency, and in vitro drug release showed that the developed patches were reliable, stable, and effective in transporting the active pharmaceutical ingredient across the skin barrier. In transdermal drug administration represents an encouraging alternative to traditional topical and oral therapies for alopecia, providing controlled delivery, minimized side effects, and improved therapeutic effectiveness.

REFERENCES

1. Prausnitz MR, Mitragotri S, Langer R. Current status and future potential of transdermal drug delivery. Nat Rev Drug Discov. 2004;3(2):115–24. doi:10.1038/nrd1304.
2. Ijaz S, Anwar F, Afzal I, et al. Formulation and evaluation of garlic extract-loaded transdermal patches. Pak J Pharm Sci. 2020;33(1):9–15.
3. Patel DP, Swink SM, Castelo-Soccio L. A review of the use of biologic agents in the treatment of alopecia areata. Am J Clin Dermatol. 2017;18(3):407–23. doi:10.1007/s40257-016-0252-3.
4. Harrison S, Sinclair R. Telogen effluvium. Clin Exp Dermatol. 2002;27(5):389–95. doi:10.1046/j.1365-2230.2002.01056. x.
5. Sharma A, Shukla S, Tiwari S, Gaurav A. Role of garlic (Allium sativum) in various diseases: an overview. J Pharm Res Int. 2021;33(35B):150–8. doi:10.9734/jpri/2021/v33i35B31892.
6. Prausnitz MR, Langer R. Transdermal drug delivery. Nat Biotechnol. 2008;26(11):1261–8. doi:10.1038/nbt.1504.
7. Pathan IB, Setty CM. Chemical penetration enhancers for transdermal drug delivery systems. Trop J Pharm Res. 2009;8(2):173–9. doi:10.4314/tjpr. v8i2.44525.
8. Amagase H. Clarifying the real bioactive constituents of garlic. J Nutr. 2006;136(3 Suppl):716S–25S. doi:10.1093/jn/136.3.716S.
9. Hadgraft J, Guy RH. Transdermal drug delivery: developmental issues and research initiatives. New York: Marcel Dekker; 2003.
10. Aqil M, Ali A, Sultana Y, Najmi AK. Formulation and evaluation of transdermal drug delivery system of ethinylestradiol and levonorgestrel. Indian J Pharm Sci. 2007;69(4):498–504.
11. Jain S, Prajapati S, Singh S, Jain D, Tiwari A. Microwave assisted preparation of transdermal patches. Curr Drug Deliv. 2015;12(1):35–42.
12. Kaur IP, Aggarwal D. Preparation and evaluation of topical application in alopecia. Indian J

Pharm Sci. 2002;64(6):510–4.
13. Jacob SW, Herschler R. Pharmacology of DMSO. JAMA. 1986; and as reviewed in J Pharm Sci. 2015;104(5):1471–80.
14. Liu H, Wang X, Zhang L, et al. The effect of polyethylene glycol on transdermal drug delivery systems: formulation and penetration enhancement 2020.
15. Transdermal delivery of therapeutic agents for the treatment of alopecia: current status and future perspectives. Int J Pharm. 2020;584:119398.
16. Raut DR, Jaiswal SB. Transdermal drug delivery system: an overview. Int J Pharm Sci Rev Res. 2012.
17. Rehman K, et al. A comprehensive review of the therapeutic potential of garlic and its bioactive components. Front Pharmacol. 2020.
18. Sofowora A, Ogunbodede E, Onayade A. The role and place of medicinal plants in the strategies for disease prevention. Afr J Tradit Complement Altern Med. 2013;10(5):210–29.
19. Gamboa-Leon R, et al. In vitro evaluation of the antimicrobial activity of aqueous garlic extract against Escherichia coli. Turk J Med Sci. 2014;44(5):834–40.
20. Kumar S, Sharma R, Choudhury P, Nayak BS. Development and evaluation of garlic-based transdermal patches for alopecia treatment. Int J Pharm Sci Res. 2021;12(3):789–97.
21. Bhatia J, Aggarwal G, Harikumar SL. A review on transdermal drug delivery system (TDDS): design and evaluation with herbal and allopathic approaches 2023.
22. Ahad HA. Transdermal drug delivery system: a review. ResearchGate. 2021. Available from: https://www.researchgate.net/publication/348874654.

