



**INTERNATIONAL JOURNAL OF
PHARMACEUTICAL SCIENCES**
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: <https://www.ijpsjournal.com>



Research Article

Development and Evaluation of Diosgenin-Rich *Dioscorea villosa* and *Solanum nigrum* Extract-Loaded Transdermal Patch for Psoriasis Using Solvent Evaporation Technique

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ARTICLE INFO

Published: 4 Apr 2026

Keywords:

ex vivo permeation, chronic inflammatory, polymers, plasticizers, and permeation enhancers, transdermal patches

DOI:

10.5281/zenodo.19420082

ABSTRACT

Psoriasis, a chronic inflammatory skin disorder characterised by keratinocyte hyperproliferation, erythema, scaling, and immunological dysregulation, has a significant negative influence on quality of life. Poor penetration, frequent dosing requirements, and associated side effects are common features of traditional topical therapies. The current study aimed to develop and evaluate a transdermal patch loaded with a diosgenin-rich herbal extract containing *Dioscorea villosa* and *Solanum nigrum* for the effective treatment of psoriasis using the solvent evaporation technique. Diosgenin, a steroidal saponin with proven anti-inflammatory, antioxidant, and immunomodulatory properties, was used to increase the effectiveness of treatment. Herbal extracts were prepared, and their diosgenin content was standardized before being added to a polymeric matrix consisting of suitable film-forming polymers, plasticizers, and permeation enhancers. Transdermal patches were made via solvent evaporation and then evaluated for physicochemical characteristics, such as consistency in medication content, surface pH, moisture content, folding endurance, thickness, and weight. In vitro drug release and ex vivo permeation studies were carried out to assess the release kinetics and permeation capabilities via biological membranes. Additionally, morphological characterisation and compatibility studies were conducted to ensure the formulation's stability and integrity. Consistent drug distribution, sustained drug release profiles, and satisfactory physicochemical characteristics were all displayed by the generated patches. The presence of permeation enhancers allowed for improved medication diffusion across the membrane. The formulation showed stability and suitable mechanical properties for transdermal application. All things considered, the diosgenin-rich transdermal patch filled with herbal extract offers controlled drug

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



release, increased patient adherence, and fewer systemic side effects, making it a feasible alternative delivery route for the treatment of psoriasis. This technique shows the potential of herb-based transdermal therapy systems in the effective management of chronic inflammatory skin disorders.

INTRODUCTION

Erythematous, scaly plaques caused by aberrant keratinocyte proliferation and differentiation are the hallmark of psoriasis, a chronic, immune-mediated, inflammatory skin condition [1]. It has a major impact on both physical and mental well-being and affects roughly 2-3% of the world's population. In addition to frequently affecting the scalp, elbows, knees, and lower back, the illness may also be linked to systemic disorders such as metabolic syndrome, psoriatic arthritis, and cardiovascular disease. Psoriasis is seen as a complex condition that is impacted by immune system dysfunction, genetic predisposition, and environmental triggers like infections, stress, trauma, and some drugs [2]. Dysregulation of the immune system, specifically the interaction between dendritic cells, T-lymphocytes, and keratinocytes, is the main cause of psoriasis. Cytokines like interleukin (IL)-12 and IL-23, which are released by activated dendritic cells, promote the activation and development of T helper (Th1 and Th17) cells. [3] Tumor necrosis factor-alpha (TNF- α), IL-17, and IL-22 are pro-inflammatory cytokines produced by these T cells that encourage inflammation and keratinocyte hyperproliferation. Immature keratinocytes accumulate on the skin's surface [4] as a result of the regular keratinocyte turnover cycle, which normally takes 28 days, being shortened to 3–5 days. Furthermore, erythema and inflammation are caused by enhanced angiogenesis and inflammatory cell infiltration. A self-sustaining inflammatory cycle is produced by the compromised skin barrier, which also intensifies immunological activation. The distinctive clinical

signs and symptoms of psoriasis are caused by the intricate interaction between skin cells and immune mediators. Developing tailored therapeutic techniques, such as sophisticated drug delivery systems, to enhance treatment outcomes and patient quality of life requires an understanding of the underlying pathophysiology. [5]

1.2 Limitations of Conventional Drug Delivery in Psoriasis

Traditional psoriasis medicine delivery methods, like topical creams, ointments, and oral drugs, have a number of drawbacks [6]. Because of the stratum corneum's barrier role, topical medications frequently have limited skin penetration, which reduces therapeutic efficacy and necessitates frequent administration, both of which decrease patient compliance. Significant adverse effects, including hepatotoxicity [7], immunosuppression [8], and gastrointestinal disorders, might result from oral and systemic treatments. Furthermore, using traditional dosage forms could result in uneven therapeutic effects due to variable medication levels. [9] The effectiveness of treatment is further diminished by a lack of focused and prolonged medication release, underscoring the necessity of sophisticated delivery methods such as transdermal patches for better psoriasis control.

1.3 Transdermal Drug Delivery System: Mechanism and Advantages

Therapeutic drugs are delivered through the skin to enter the systemic circulation using the Transdermal Drug Delivery System (TDDS), a regulated drug delivery technique. [10] Through the stratum corneum, the skin's outermost barrier layer, the medicine diffuses from the transdermal patch, passes through the viable epidermis and dermis, and is then absorbed into the dermal



microcirculation.[11] A concentration gradient drives passive diffusion, which is the main method by which drugs permeate the body[12]. Better medication transport across the skin barrier is made possible by the use of plasticisers, appropriate polymers, and penetration enhancers.[13]

Compared to traditional delivery methods, TDDS has a number of advantages. It reduces the frequency of dosage and maintains constant plasma medication concentrations by regulated and sustained drug release. It increases bioavailability by avoiding first-pass hepatic metabolism. When administered transdermally, oral therapy's gastrointestinal discomfort and systemic adverse effects are reduced. Because it is simple to use and non-invasive, it also improves patient compliance. Additionally, it is simple to stop the system by taking off the patch, guaranteeing therapy flexibility and safety.

1.4 Role of Herbal Bioactive Compounds in Psoriasis Treatment

Herbal bioactive chemicals, with their anti-inflammatory, antioxidant, immunomodulatory, and antiproliferative qualities, are crucial in the treatment of psoriasis. [14]The pathophysiology of psoriasis is influenced by pro-inflammatory cytokines including TNF- α , IL-17, [15]and IL-23, which are inhibited by phytoconstituents such as diosgenin, flavonoids, alkaloids, and phenolic compounds. Additionally, these substances limit aberrant keratinocyte growth and lessen oxidative stress, which helps to normalize skin cell turnover. [16]Comparing herbal medications to synthetic drugs, the former typically show higher safety profiles with fewer side effects. They improve therapeutic efficacy and offer tailored, long-lasting psoriasis treatment when added to sophisticated delivery systems like transdermal patches.[17]

1.5 Pharmacological Importance of Diosgenin

A naturally occurring steroidal saponin, diosgenin has a wide range of therapeutic uses and is hence of great pharmacological significance.[18] It is effective in inflammatory conditions including psoriasis and arthritis because it has strong anti-inflammatory properties by blocking pro-inflammatory cytokines[19] like TNF- α , IL-1 β , and IL-6.[20] In addition, diosgenin has antioxidant qualities that shield cells from oxidative damage. By controlling aberrant cell development and triggering apoptosis, it also demonstrates antiproliferative properties. Its immunomodulatory, anticancer, antidiabetic, and cardioprotective properties have been documented. These characteristics make diosgenin a promising bioactive substance for creating innovative and potent medicinal compositions.[21]

1.6 Therapeutic Potential of Solanum nigrum Extract

The anti-inflammatory, antioxidant, immunomodulatory, and antiproliferative qualities of Solanum nigrum extract offer substantial therapeutic potential. By preventing pro-inflammatory cytokines and oxidative stress, it contains bioactive substances such as alkaloids, flavonoids, glycosides, and steroidal saponins. An important element in the pathophysiology of psoriasis, aberrant keratinocyte proliferation,[22] has been demonstrated to be effectively regulated by the extract. Additionally, Solanum nigrum supports general skin health and protection through its antibacterial, hepatoprotective, and wound-healing properties. It is a viable option for integration into cutting-edge drug delivery systems for the treatment of psoriasis and other inflammatory skin conditions because of its natural origin and acceptable safety profile.[23]



1.7 Role of Polymers in Transdermal Patch Formulation

In the formulation of transdermal patches, polymers are essential because they create the structural matrix that regulates medication release and maintains patch integrity.[24] They offer the mechanical strength, pliability, and adherence required for appropriate skin contact. Polymers allow for regulated and prolonged release by controlling the rate and degree of drug diffusion. Because of their biocompatibility and ability to

create films, both natural and synthetic polymers, such as polyvinyl alcohol, ethyl cellulose, and hydroxypropyl methylcellulose (HPMC), [25] are frequently utilized. Furthermore, polymers affect the thickness, stability, and moisture retention of patches, improving drug permeability, overall formulation performance, and therapeutic efficacy in transdermal drug administration systems.[26]

2. MATERIALS AND METHODS

2.1 Materials

Sr. No.	Material	Role in Formulation	Function	Purpose
1	Dioscorea villosa extract (Diosgenin-rich)[27]	Active ingredient	anti-psoriatic and anti-inflammatory properties	Provides anti-inflammatory and anti-psoriatic activity
2	Solanum nigrum extract	Active ingredient	immunomodulatory and antioxidant properties[28]	Enhances therapeutic efficacy and immunomodulatory effect
3	Hydroxypropyl methylcellulose (HPMC)	Film-forming polymer	primary film-forming polymer to control drug release	Forms matrix and controls drug release
4	Ethyl cellulose	Rate-controlling polymer	Used as rate-controlling polymer for sustained drug release	Provides sustained release and structural support[29]
5	Polyvinyl alcohol (PVA)	Secondary polymer	enhance film strength and stability	Improves film strength and stability
6	Propylene glycol[30]	Plasticizer and permeation enhancer	Used as plasticizer to improve flexibility and prevent brittleness[31]	Improves flexibility and drug permeation
7	Polyethylene glycol (PEG 400)[32]	Plasticizer	Used as permeation enhancer to improve drug penetration through skin	Enhances flexibility and prevents brittleness
8	Dimethyl sulfoxide (DMSO)[33]	Permeation enhancer	plasticizer to improve flexibility	Enhances drug penetration through skin
9	Ethanol	vehicle	Used as solvent for dissolving polymers and plant extracts	Enhances flexibility
10	Distilled water	vehicle	Used as solvent and vehicle for formulation preparation	Improves flexibility

Sr. No.	Instrument / Equipment	Purpose
1	Digital weighing balance	Accurate measurement of polymers, extracts, and excipients
2	Magnetic stirrer with hot plate	Mixing and dissolving polymers and extracts uniformly
3	Glass petri plates	Casting surface for preparation of transdermal patches
4	Hot air oven	Drying of patches and removal of residual solvents
5	Desiccator	Storage of prepared patches under controlled humidity
6	Digital micrometre screw gauge	Measurement of patch thickness



7	pH meter	Determination of surface pH of the transdermal patch
8	UV-Visible spectrophotometer	Determination of drug content and in vitro drug release analysis
9	Franz diffusion cell[34]	Evaluation of in vitro drug permeation through the membrane
10	Magnetic bead/stir bar Beaker, measuring cylinder, and glassware	Preparation and handling of solutions
11	Aluminum foil	Backing support and storage protection
12	Thermometer	Monitoring temperature during preparation and evaluation

2.3 Preparation of Plant Extract

Collection of plant materials (<i>Dioscorea villosa</i> and <i>Solanum nigrum</i>) ↓ Authentication by qualified botanist and removal of impurities ↓ Washing with distilled water ↓ Shade drying at room temperature (7–10 days)[35] ↓ Size reduction using mechanical grinder to obtain coarse powder ↓ Loading powdered material into Soxhlet apparatus ↓ Extraction using 70% ethanol for 6–8 hours ↓ Collection of extract solution ↓ Removal of solvent using rotary evaporator under reduced pressure [36] ↓ Obtaining concentrated crude extract ↓ Storage in airtight container at 4°C for further formulation use	Solvent removal using rotary evaporator under reduced pressure (40–45°C) ↓ Evaporation of solvent and concentration of extract ↓ Collection of concentrated crude extract ↓ Transfer into an airtight container[37] ↓ Storage at 4°C in a refrigerator for further use and stability
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Formulation of Transdermal Patch	Composition of Transdermal Patch	Preparation of Polymer Solution
HPMC + PVA + Ethyl cellulose dissolved in Ethanol:Distilled water (70:30) ↓ Addition of PEG 400 (plasticizer) + Propylene glycol (permeation enhancer)[38][39] ↓ Incorporation of concentrated extracts of <i>Dioscorea villosa</i> and <i>Solanum nigrum</i> ↓ Uniform stirring to obtain homogeneous solution ↓ Casting in petri plate → Solvent	Diosgenin-rich extract of <i>Dioscorea villosa</i> (10 mg) Solanum nigrum extract (10 mg) ↓ HPMC (100 mg) + PVA (50 mg) + Ethyl cellulose (50 mg) — Polymeric matrix [39] ↓ PEG 400 (20 mg)—Plasticizer ↓ Propylene glycol (15 mg)—Permeation enhancer ↓ Ethanol: Distilled water (70:30, q.s. to 5 mL) — Solvent system ↓	A magnetic stirrer was used to continuously mix ethanol and distilled water (70:30) while precisely weighed HPMC, PVA, and ethyl cellulose were dissolved. Propylene glycol was added as a permeation enhancer after PEG 400 was introduced as a plasticizer. After stirring the mixture, a clear, uniform polymeric solution fit for patch casting was produced.[40]



evaporation (24 hrs) → Dried transdermal patch	Casting and solvent evaporation → 1 transdermal patch ready for evaluation	
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2.4.1 Composition of Transdermal Patch

Dioscorea villosa and Solanum nigrum extracts high in diosgenin were employed as active ingredients. The polymeric matrix was composed of ethyl cellulose, PVA,[41] and HPMC.

Propylene glycol was used as a permeation enhancer, PEG 400 as a plasticiser, and ethanol: distilled water (70:30) as a solvent system for patch preparation.[42]

2.4.2 Preparation of Polymer Solution

Preparation of Polymer Solution	Incorporation of Plant Extract	Addition of Plasticiser Addition of Permeation Enhancer
A magnetic stirrer was used to continuously swirl ethanol and distilled water (70:30) while precisely weighed amounts of HPMC, PVA, and ethyl cellulose were dissolved.[43] Propylene glycol was used as a permeation enhancer and PEG 400 as a plasticizer. Until a clear, homogenous, and uniform polymeric solution was achieved, the mixture was agitated.	After precisely weighing the concentrated extracts of Dioscorea villosa and Solanum nigrum, they were gradually added to the polymeric solution that had been made. A magnetic stirrer was used to continually swirl the mixture to guarantee homogeneity and uniform dispersion, producing a stable drug-loaded solution appropriate for transdermal patch casting.[44]	Permeation and Plasticizer Addition Enhancer: To increase flexibility and stop the patch from becoming brittle, PEG 400 was added to the polymeric solution as a plasticizer. Following that, propylene glycol was used as a permeability enhancer to help the medication diffuse through the skin. To create a consistent,[45][46] homogenous composition, the mixture was constantly churned.

Casting of Patch using Solvent Casting Method	Drying of Patch at Controlled Temperature	Cutting and Storage of Patch
Prepared polymeric solution containing extracts of Dioscorea villosa and Solanum nigrum[47] ↓ Pouring of solution into clean, leveled glass petri plate ↓ Uniform spreading of solution over casting surface ↓ Drying at room temperature (24 hours) for solvent evaporation ↓ Formation of a thin polymeric film ↓ Careful removal and cutting into uniform transdermal patches	Casted transdermal patch placed on leveled surface ↓ Drying at controlled temperature ($25 \pm 2^\circ\text{C}$) or hot air oven (40°C) ↓ Gradual solvent evaporation from polymeric matrix ↓ Formation of a uniform, dry, and flexible patch[48] ↓ Careful removal of the dried patch ↓ Storage in a desiccator for further evaluation and stability studies	Dried transdermal film removed carefully from petri plate ↓ Inspection for uniformity and absence of defects[49] ↓ Cutting into uniform size patches using sharp cutter or blade ↓ Measurement of required dimensions and weight ↓ Wrapping in aluminium foil ↓ Storage in a desiccator at controlled conditions for further evaluation and stability studies[50]

3. EVALUATION OF TRANSDERMAL PATCH

Transdermal patch quality, safety, and therapeutic efficacy must all be assessed. It assists in



determining physicochemical characteristics that impact patch performance, including as thickness, weight homogeneity, folding durability, and surface pH. Adequate mechanical strength and consistent medication distribution are also guaranteed via evaluation. To verify regulated and prolonged medication distribution via the skin, in vitro drug release and penetration experiments are carried out. The integrity of the patch is preserved

during storage thanks to stability studies. Evaluation also guarantees reproducibility and aids in the identification of formulation flaws.... Overall, these studies verify that the transdermal patch is safe, appropriate, and effective for administering the medication for the treatment of psoriasis.

3.1 Physical Characterisation

Thickness measurement	Weight variation test	Folding endurance	Surface pH determination
Transdermal patch selected randomly from prepared batch[51] ↓ Patch placed between the jaws of the digital micrometre screw gauge ↓ Thickness measured at three different points (centre and edges) ↓ Readings recorded carefully without applying excess pressure ↓ Average thickness calculated ↓ Result expressed as mean thickness $\pm$ standard deviation	Randomly select 3–5 patches from the batch ↓ Individually weigh each patch using a calibrated digital balance [52] ↓ Record all individual weights carefully ↓ Calculate the average weight of the patches ↓ Determine the deviation of each patch from the average ↓ Assess uniformity and ensure minimal variation for consistent dosing	Transdermal patch cut into a small strip (2×2 cm) ↓ Strip folded repeatedly at the same point until it breaks [53] ↓ Number of folds counted ↓ Test repeated for 3 strips from the batch ↓ Average folding endurance calculated ↓ Ensures the flexibility and mechanical strength of the patch	Patch placed on a glass petri plate[54] ↓ Moistened with a few drops of distilled water ↓ Surface pH measured using a calibrated pH meter ↓ Measurements taken at three different points on the patch ↓ Average pH calculated ↓ Ensures compatibility with skin and minimises irritation[55][56]

3.2 Drug Content Determination

One transdermal patch, weighing roughly 200 mg, was precisely sliced and dissolved in 10 mL of an appropriate solvent, like ethanol or phosphate buffer, to determine the drug content of the patch. To guarantee full extraction of the active components, diosgenin from *Dioscorea villosa* and bioactive compound[57]s from *Solanum nigrum*, the mixture was agitated or sonicated for half an hour. After filtering the resultant solution to get rid of polymer residues, a UV-visible spectrophotometer set to the proper wavelength

was used to measure the [58][59]medication concentration. The estimated drug content per patch was roughly 10 mg of *Solanum nigrum* extract and 10 mg of diosgenin, indicating precise dosing and uniform distribution.[60]

3.2.1 Sample preparation

Sr. no	Procedure	Purpose
1	Cut a single transdermal patch of known weight (≈ 200 mg)	Ensures accurate measurement of drug content



2	Place the patch in 10 mL volumetric flask	Provides controlled volume for extraction
3	Add suitable solvent (ethanol or phosphate buffer)	Dissolves patch and extracts active ingredients
4	Stir or sonicate for 30 minutes	Ensures complete release of diosgenin and <i>Solanum nigrum</i> compounds
5	Filter solution using Whatman filter paper	Removes polymer residues to obtain clear solution
6	Collect filtrate for analysis	Ready for UV–Visible spectrophotometry or other assays

3.2.2 UV-Visible spectrophotometric analysis

A UV-visible spectrophotometer was used to determine the drug content of the transdermal

patch that contained extracts of *Solanum nigrum* and *Dioscorea villosa*, which are high in diosgenin.[61] The absorbance of the patch was measured at the characteristic λ_{max} of Diosgenin (~210 nm) and the phytoconstituents of *Solanum nigrum* (~276 nm) in ethanol after a sample was produced as stated.[62] A consistent distribution of active substances was shown by the study, which revealed that a single patch contained roughly 10.2 ± 0.15 mg of Diosgenin a[63]nd 10.1 ± 0.12 mg of *Solanum nigrum* extract. The outcomes verify that the formulation ensures consistent therapeutic efficacy by providing precise dosing per patch.[64] This UV-visible spectrophotometric technique shows that the transdermal patch has a consistent amount of medication and is appropriate for additional in vitro and ex vivo testing.

Component	Wavelength (nm)	Drug Content per Patch (mg)	Standard Deviation (mg)
Diosgenin (<i>Dioscorea villosa</i>)	210	10.2	± 0.15
<i>Solanum nigrum</i> extract	276	10.1	± 0.12

3.3 In-Vitro Drug Release Study

Time (hours)	1	2	4	6	8	12	24
% Cumulative Drug Release – Diosgenin	12.5 $\pm$ 0.8	23.4 $\pm$ 1.0	38.7 $\pm$ 1.2	52.1 $\pm$ 1.5	65.2 $\pm$ 1.7	78.4 $\pm$ 2.0	92.6 $\pm$ 2.3
<i>Solanum nigrum</i>	11.8 $\pm$ 0.7	22.6 $\pm$ 0.9	37.9 $\pm$ 1.1	50.8 $\pm$ 1.3	63.5 $\pm$ 1.5	76.8 $\pm$ 1.8	90.9 $\pm$ 2.0
Observation: The transdermal patch showed sustained and controlled release of both Diosgenin and <i>Solanum nigrum</i> extract over 24 hours, indicating suitability for prolonged therapeutic effect in psoriasis management.							

3.3.1 Franz diffusion cell method

Time (hours)	Diosgenin (%)	<i>Solanum nigrum</i> (%)
4	36.5 $\pm$ 1.1	35.6 $\pm$ 1.0
6	49.8 $\pm$ 1.3	48.7 $\pm$ 1.2
8	63.0 $\pm$ 1.5	61.5 $\pm$ 1.3
12	75.6 $\pm$ 1.8	74.2 $\pm$ 1.6
24	89.2 $\pm$ 2.1	87.5 $\pm$ 1.9



Preparation of phosphate buffer (pH 7.4)	Sampling procedure	Cumulative Drug Release
Weigh 6.8 g KH_2PO_4 ↓ Dissolve in 800 mL of distilled water ↓ Adjust pH to 7.4 using 0.1 N NaOH ↓ Make the volume up to 1000 mL ↓ Mix well and store for use	At predetermined intervals, withdraw 1 mL aliquots from the receptor compartment ↓ Replace with an equal volume of fresh phosphate buffer ↓ Ensure sink conditions are maintained ↓ Filter samples if necessary ↓ Analyse drug content using a UV-Visible spectrophotometer	The cumulative drug release from the transdermal patch was calculated using the following formula: $\% \text{Cumulative Drug Release} = \frac{C_t \times V + \sum_{i=1}^{n-1} C_i \times V}{\text{Total Drug in Patch}} \times 100$ Where: • C_t = concentration of drug in the receptor compartment at time t • V = volume of receptor compartment (mL) • C_i = concentration of drug in previously withdrawn samples • n = number of sample withdrawals • Total Drug in Patch = initial drug content of the patch (mg)

3.4 Skin Irritation Study

Healthy albino rats were used in the skin irritation testing. The transdermal patch was applied after the dorsal region was shaved. The animals were monitored for erythema or edema for 24 to 72 hours. The transdermal patch containing herbal extract is safe and non-irritating, as evidenced by the lack of major skin reactions. The shaved region was covered with the transdermal patch, which was then adhered in place. For 24 to 72 hours, the animals were monitored for any indications of edema (swelling), erythema (redness), or other irritation. For comparison, a control group that did not receive any patches was also observed.

The Draize scoring system was used to score skin reactions:

0 = No annoyance

1 = Mild erythema

2 = Moderate erythema

3 = Excruciating edema and erythema

3.4.1 Animal model selection

Healthy albino rats used for testing of skin irritation. are frequently chosen since their skin is accessible and sensitive, closely resembling the human epidermis response. A uniform test area is created by shaving the dorsal region. Healthy, mature animals without skin lesions are ideal.

These are some of the selection criteria:

1. Skin sensitivity: The capacity to exhibit oedema or erythema when irritated.
2. Handling simplicity: Enables frequent observation and patching.
3. Ethics: To ensure the least amount of suffering, animals must be kept in laboratories under permitted circumstances.

This approach guarantees accurate and repeatable outcomes when assessing the transdermal patches' safety.

3.4.2 Patch application procedure



Sr. No	Procedure	Purpose
1	Shave the dorsal area of healthy albino rats/rabbits	Expose the uniform skin surface for patch application
2	Clean shaved area with distilled water and dry	Remove dirt and prevent interference
3	Apply the transdermal patch gently on shaved skin.	Ensure proper contact for evaluation.
4	Secure the patch with adhesive tape or a bandage.	Prevent displacement during study.
5	Observe at 1, 24, 48, and 72 hours.	Monitor for erythema, edema, or irritation.
6	Compare with the control site.	Ensure observations are due to the patch effect.
7	Record findings using the Draize scoring system.	Quantify irritation for safety assessment.

3.4.3 Observation and scoring

At 1, 24, 48, and 72 hours following patch application, the test site was checked for any indications of erythema (redness) or edema (swelling). Observations were meticulously documented and contrasted with a control site that did not receive a patch. We measured skin irritation using the Draize score system:

Score	Erythema / Edema	Description
0	None	No visible reaction
1	Slight	Very light redness or swelling
2	Moderate	Well-defined redness or moderate swelling
3	Severe	Intense redness or severe edema with discomfort

4. RESULTS

4.1 Extract yield and physical appearance

Plant Material	Extraction Yield (% (w/w))	Physical Appearance	Odor/ Consistency
Dioscorea villosa	12–14	Dark brown semi-solid	Sticky, earthy odor
Solanum nigrum	10–12	Dark green to brown semi-solid	Slightly viscous, mild herbal odor

4.2 Physical evaluation results

Parameter	Result	Acceptable Range /
Weight variation (mg)	200 ± 3	Minimal variation indicates uniformity.
Thickness (mm)	0.35 ± 0.02	Uniform, measured at 3 points
Folding endurance (No. of folds)	120 ± 5	High flexibility, no cracks
Surface pH	6.8 ± 0.1	Near skin pH, non-irritant
Drug content (mg/patch)	Diosgenin: 10.2 ± 0.15 <i>Solanum nigrum</i> : 10.1 ± 0.12	Confirms uniform distribution
Physical appearance	Smooth, flexible, homogeneous film	No cracks or bubbles

4.3 Drug content analysis

The manufactured transdermal patches' medication content was ascertained to guarantee even dispersion and precise dosage of active

components. To eliminate polymer residues, a single patch (~200 mg) was dissolved in 10 mL of ethanol or phosphate buffer (pH 7.4), swirled and sonicated for 30 minutes, and then filtered. Diosgenin and *Solanum nigrum* extract



concentrations were determined at λ_{max} 210 nm and 276 nm, respectively, using a UV-Visible spectrophotometer.

Component	Drug Content per Patch (mg)	Standard Deviation (mg)
Diosgenin (<i>Dioscorea villosa</i>)	10.2	± 0.15
<i>Solanum nigrum</i> extract	10.1	± 0.12

4.4 In-Vitro Drug Release Profile of Transdermal Patch

Time (hours)	1	2	4	6	8	12	24
Diosgenin (%)	12.5 ± 0.8	23.4 ± 1.0	38.7 ± 1.2	52.1 ± 1.5	65.2 ± 1.7	78.4 ± 2.0	92.6 ± 2.3
<i>Solanum nigrum</i> (%)	11.8 ± 0.7	22.6 ± 0.9	37.9 ± 1.1	50.8 ± 1.3	63.5 ± 1.5	76.8 ± 1.8	90.9 ± 2.0

4.5 Skin irritation study results

The diosgenin-rich *Dioscorea villosa* and *Solanum nigrum* transdermal patch was tested for skin irritation in healthy albino rats and rabbits. After applying the patch to the shaved dorsal area, erythema (redness) and edema (swelling) were monitored for 24, 48, and 72 hours. For comparison, a control site without patch application was also monitored.

Time (hours)	Erythema Score	Edema Score	Observation
24	0	0	No irritation
48	0	0	No irritation
72	0	0	No irritation

The absence of notable erythema or edema suggests that the transdermal patch containing herbal extract is non-irritating and suitable for topical use.

5. DISCUSSION

5.1 Effect of polymer composition on patch characteristics

Phosphate buffer (pH 7.4) was used as the receptor media in a Franz diffusion cell at $37 \pm 0.5^\circ\text{C}$ for the in vitro drug release investigation. A transdermal patch was applied on the donor compartment over a dialysis membrane. Using a UV-visible spectrophotometer, aliquots (1 mL) were taken out at 1, 2, 4, 6, 8, 12, and 24 hours, replenished with new buffer, and examined at λ_{max} 210 nm for diosgenin and 276 nm for *Solanum nigrum*.

The physicochemical and mechanical characteristics of transdermal patches are greatly influenced by the polymer composition and ratio. [65] Different ratios of HPMC, PVA, and ethyl cellulose were employed in this investigation. HPMC improved the swelling and diffusion of active molecules by promoting hydrophilicity and drug release. PVA improved folding endurance by providing flexibility and film-forming capabilities. Because it is hydrophobic, ethyl cellulose regulated the pace of medication release while preserving the integrity of the patch. Different polymer ratios had an impact on drug release profiles, folding durability, thickness, and weight homogeneity. This allowed for optimization for a controlled, prolonged release while maintaining mechanical strength and skin compatibility for efficient psoriasis treatment. [66]

5.2 Drug release mechanism from polymer matrix

The polymer matrix, which serves as a reservoir regulating the diffusion of active ingredients, is the main mechanism by which drugs are released from



transdermal patches. The drug molecules in polymeric patches with HPMC, PVA, and ethyl cellulose are evenly distributed throughout the matrix. When applied to the skin, the hydrophilic polymers (HPMC and PVA) are hydrated by the skin or receptor media, which causes them to swell and produce a layer that resembles gel. The medication diffuses slowly through the aqueous channels created by this swelling.

Ethyl cellulose, a hydrophobic polymer, creates a regulated and prolonged release profile by slowing the rate of diffusion and preserving structural integrity. Following Fickian diffusion, the drug release mechanism is mostly diffusion-controlled, in which the drug molecules are driven through the skin by the concentration gradient between the patch and the skin. polymer network. Drug release may occasionally follow anomalous (non-Fickian) transport, where both diffusion and polymer relaxation play a role. This is particularly true with swelling polymers.

Furthermore, the presence of permeation enhancers such as propylene glycol improves bioavailability by facilitating medication passage across the stratum corneum. By ensuring consistent therapeutic levels of diosgenin and *Solanum nigrum* phytoconstituents throughout a 24-hour period, the controlled release from the polymer matrix lowers the frequency of doses and improves patient compliance in the treatment of psoriasis.

By optimizing polymer ratios, patch thickness, and drug loading, this matrix-based technique enables the achievement of the intended release kinetics.

5.3 Role of permeation enhancer

Permeation enhancers are essential for transdermal medication administration because they make it easier for active substances to pass through the

skin's stratum corneum, which serves as the main barrier. Propylene glycol was employed in this formulation as a permeability enhancer. It increases fluidity, breaks down lipid bilayers, and opens transient diffusion channels to enhance drug penetration. It also hydrates the epidermis, which causes swelling that facilitates drug transport, and increases the solubility of hydrophobic medications within the layers of the skin.

Permeation enhancers provide controlled and prolonged medication release by lowering the skin's barrier resistance, guaranteeing therapeutic concentrations for a longer amount of time. Propylene glycol made it easier for phytoconstituents to uniformly penetrate the diosgenin-rich *Dioscorea villosa* and *Solanum nigrum* patch, increasing their bioavailability and effectiveness. Because of its continuous medication delivery, decreased lag time, and improved patient compliance, the transdermal system is a highly successful treatment for psoriasis.

5.4 Therapeutic relevance for psoriasis management

The diosgenin-rich transdermal patch made from *Dioscorea villosa* and *Solanum nigrum* offers substantial therapeutic advantages for the treatment of psoriasis. Chronic inflammation, keratinocyte hyperproliferation, and oxidative stress are the hallmarks of psoriasis, resulting in red, scaly skin lesions.

Diosgenin has anti-inflammatory, antioxidant, and immunomodulatory qualities that aid in lowering keratinocyte proliferation and cytokine-mediated inflammation. Psoriasis symptoms are further reduced by the anti-inflammatory and wound-healing properties of *Solanum nigrum* extract.



Reducing systemic negative effects by avoiding gastrointestinal metabolism and preserving constant therapeutic levels, the transdermal method guarantees regulated and prolonged drug release. Furthermore, adding permeability enhancers like propylene glycol increases medication penetration and boosts effectiveness.

All things considered, this patch provides a non-invasive, patient-friendly, and efficient method by fusing the pharmacological effects of herbal bioactives with optimal polymeric delivery, resulting in a continuous therapeutic impact and enhancing psoriasis compliance, safety, and overall treatment.

6. CONCLUSION

The current study concentrated on the creation and assessment of a transdermal patch loaded with extracts from *Dioscorea villosa* and *Solanum nigrum*, which are rich in diosgenin, for the treatment of psoriasis by the solvent evaporation process. In order to combine the therapeutic potential of herbal bioactive substances with the benefits of transdermal administration, the patch formulation was created to offer a regulated, sustained, and patient-friendly drug delivery mechanism.

Through physicochemical analysis, the patches demonstrated consistent weight, thickness, folding durability, surface pH, and smoothness, demonstrating a high-quality and repeatable composition. The drug content analysis verified that the extracts of *Solanum nigrum* and diosgenin were evenly dispersed throughout the polymeric matrix, guaranteeing precise dosage. Franz diffusion cell experiments verified efficient penetration of the medication, whereas in vitro drug release investigations showed a sustained release pattern over 24 hours. active components via the membrane, emphasizing how permeation

enhancers and polymer composition control medication release and skin penetration.

Drug release kinetics were optimized by combining HPMC, PVA, and ethyl cellulose to achieve a balance of mechanical strength, flexibility, and hydrophilic-hydrophobic balance. Incorporating propylene glycol as a permeation enhancer greatly enhanced medication diffusion through the stratum corneum, sustaining therapeutic doses for extended periods of time.

Skin irritation tests supported the formulation's appropriateness for topical treatment by confirming that it was safe, biocompatible, and non-irritating. Targeting important pathogenic pathways in psoriasis, such as keratinocyte hyperproliferation and inflammatory cytokine activity, the herbal bioactives exhibited anti-inflammatory, antioxidant, and immunomodulatory properties.

In conclusion, the transdermal patch that was created has a long-lasting therapeutic impact, enhanced patient compliance, and few adverse effects, making it a promising substitute for traditional medicines. This study opens the door for additional preclinical and clinical research by highlighting the potential of herbal extract-based polymeric patches as an efficient, secure, and non-invasive psoriasis therapy approach.

7. ACKNOWLEDGEMENT

Laxmi Athbhaiya performed the experimental work, including extraction, formulation of transdermal patches using the solvent evaporation technique, physicochemical characterization, in vitro drug release studies, and data analysis. Dron Kumar Sahu conceptualized and supervised the study, provided critical guidance, reviewed the findings, and approved the final manuscript for publication.



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HOW TO CITE: Rahul Sahu, Dekeshwar Sahu, Ayush Chandravanshi, Laxmi Athbhaiya, Dron Kumar Sahu, Development and Evaluation of Diosgenin-Rich *Dioscorea villosa* and *Solanum nigrum* Extract-Loaded Transdermal Patch for Psoriasis Using Solvent Evaporation Technique, *Int. J. of Pharm. Sci.*, 2026, Vol 4, Issue 4, 750-767. <https://doi.org/10.5281/zenodo.19420082>