IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

Development and Evaluation of A Herbal Transdermal Patch Containing Plumbago Zeylanica Extract for the Management of Arthralgia

Sachiv Thakur[1], Dr. Abhishek Soni[2], Kiran[3]
[1] Student, [2] Dean, [3] Professor
School of Pharmacy Abhilashi University Chail-Chowk, Mandi, Himachal Pradesh, India

Abstract: *Herbal medicines have attracted considerable attention owing to their therapeutic efficacy, safety, and reduced incidence of adverse effects compared with many synthetic drugs. Among various novel drug delivery systems, transdermal patches offer sustained drug release, improved patient compliance, and avoidance of first-pass hepatic metabolism. The present study aimed to develop and evaluate a herbal transdermal patch containing Plumbago zeylanica extract for the management of arthralgia and inflammatory conditions.*

The roots of Plumbago zeylanica were subjected to hydroalcoholic extraction using the Soxhlet extraction method. The obtained extract was incorporated into a polymeric matrix prepared using Polyvinyl Alcohol (PVA) and Hydroxypropyl Methylcellulose (HPMC), while polyethylene glycol was employed as a plasticizer. The formulated patches were evaluated for various physicochemical parameters including film thickness, weight variation, moisture content, percentage elongation, flatness, and mechanical properties.

The prepared formulations demonstrated satisfactory physical characteristics, uniform drug distribution, and good mechanical strength. The optimized formulations exhibited excellent flexibility, dimensional stability, and low moisture uptake, indicating their suitability for transdermal drug delivery. The findings suggest that Plumbago zeylanica possesses significant potential for incorporation into herbal transdermal systems for the management of pain and inflammation. However, further pharmacological and clinical investigations are required to establish its therapeutic efficacy and safety in humans.

Keywords: Plumbago zeylanica, Herbal transdermal patch, Arthralgia, Drug delivery system, Anti-inflammatory activity, Herbal formulation.

I. INTRODUCTION

Herbal medicines have been used for centuries in traditional systems of medicine and continue to play an important role in modern healthcare. The growing interest in plant-based therapeutics is primarily due to their diverse pharmacological activities, natural origin, and relatively lower incidence of adverse effects. Consequently, researchers are increasingly exploring medicinal plants as potential sources for the development of novel pharmaceutical formulations.

Transdermal drug delivery systems (TDDS) represent an advanced approach for the administration of therapeutic agents through the skin into the systemic circulation. Unlike conventional oral dosage forms, transdermal patches bypass first-pass hepatic metabolism, provide sustained and controlled drug release, reduce fluctuations in plasma drug concentration, and improve patient compliance. These advantages make transdermal patches particularly suitable for the management of chronic conditions requiring prolonged therapy.

Despite these benefits, only a limited number of drugs possess the physicochemical properties necessary for effective transdermal delivery. Therefore, extensive research is being conducted to identify new bioactive compounds and suitable formulation strategies that can enhance skin permeation while maintaining therapeutic efficacy.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 4, June 2026 Impact Factor: 8.2

Plumbago zeylanica Linn., commonly known as **Chitrak** or **White Leadwort**, belongs to the family **Plumbaginaceae** and is widely distributed in tropical and subtropical regions. The plant has been extensively used in traditional Ayurvedic medicine for the treatment of inflammatory disorders, pain, digestive ailments, skin diseases, and wound healing. Its pharmacological activities are primarily attributed to **plumbagin**, a biologically active naphthoquinone that exhibits anti-inflammatory, analgesic, antioxidant, antimicrobial, and anticancer properties.

Arthralgia, commonly referred to as joint pain, affects millions of individuals worldwide and significantly reduces quality of life. Conventional therapies often provide symptomatic relief but may produce undesirable side effects following long-term use. Herbal transdermal formulations offer a promising alternative by delivering bioactive compounds directly through the skin, thereby providing sustained therapeutic action while minimizing systemic adverse effects.

Therefore, the present study was undertaken to formulate and evaluate a herbal transdermal patch containing *Plumbago zeylanica* extract and to assess its physicochemical characteristics for potential application in the management of arthralgia and inflammatory conditions.

II. MORPHOLOGY OF *PLUMBAGO ZEYLANICA*

Plumbago zeylanica Linn., commonly known as **White Leadwort** or **Chitrak**, belongs to the family **Plumbaginaceae**. It is an important medicinal plant widely utilized in traditional systems of medicine due to its diverse pharmacological properties. The plant is a perennial undershrub characterized by a well-developed root system and numerous branches.

Habit

Plumbago zeylanica is a perennial herbaceous undershrub or semi-climbing shrub that generally attains a height of **1-2 m**. The plant exhibits profuse branching with slender, spreading stems, enabling it to grow under a wide range of environmental conditions.

Root

The root is thick, cylindrical, and extensively branched with a reddish-brown outer surface. It possesses a characteristic pungent taste and is considered the most medicinally valuable part of the plant. The roots are rich in bioactive constituents, particularly **plumbagin**, which is responsible for many of its therapeutic activities.

Stem

The stem is herbaceous in the upper region and becomes woody toward the base as the plant matures. It is smooth or slightly striated and varies in color from green to light brown. The stem provides mechanical support and serves as a transport pathway for water and nutrients.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

Leaves

The leaves are simple, alternate, and exstipulate, with an ovate, elliptic, or oblong shape. They generally measure **5-10 cm** in length and possess a smooth, glabrous surface. Depending on the variety, the leaves may be sessile or attached by a short petiole. Their green coloration reflects active photosynthetic function.

Inflorescence

The inflorescence consists of terminal or axillary spikes bearing numerous flowers arranged in elongated clusters. This arrangement contributes to efficient pollination and seed production.

Flowers

The flowers are white, bisexual, and regular in symmetry. The calyx is tubular and covered with sticky glandular hairs that aid in protecting the reproductive structures. The corolla consists of five fused petals, and five stamens are attached to the corolla tube. The ovary is superior and unilocular, producing a single style and stigma.

Fruit

The fruit is a small membranous capsule enclosed within the persistent calyx. Upon maturity, it contains the seed required for propagation.

Seed

The seed is solitary, oblong in shape, and dark brown in color. It possesses good viability under favorable environmental conditions and serves as one of the natural methods of plant propagation.

Floral Formula

K(5) C(5) A5 $\bar{G}$(1)

where:

K(5): Five united sepals (gamosepalous calyx)

C(5): Five united petals (gamopetalous corolla)

A5: Five stamens

$\bar{G}$(1): Superior ovary consisting of one carpel

Diagnostic Characteristics

The important diagnostic characteristics of *Plumbago zeylanica* include:

White salver-shaped flowers arranged in elongated spikes.

Tubular calyx bearing sticky glandular hairs.

Thick reddish-brown medicinal roots with a characteristic pungent odor and taste.

Simple alternate leaves with smooth surfaces.

Presence of the bioactive compound **plumbagin**, which serves as the principal phytochemical marker of the species.

III. GEOGRAPHICAL DISTRIBUTION AND HABITAT OF *PLUMBAGO ZEYLANICA*

Geographical Distribution

Plumbago zeylanica Linn. is a widely distributed medicinal plant belonging to the family **Plumbaginaceae**. It is predominantly found in tropical and subtropical regions of the world and has adapted to a variety of ecological conditions. Owing to its medicinal significance and environmental adaptability, the plant is naturally distributed across Asia, Africa, Australia, and parts of the Americas.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

Distribution in Asia

The plant is extensively distributed throughout **India, Sri Lanka, Bangladesh, Nepal, China, Myanmar, Thailand, and other Southeast Asian countries**. It grows abundantly in open fields, forest margins, and wastelands where climatic conditions are favorable.

Distribution in Africa

In Africa, *Plumbago zeylanica* occurs widely in tropical and subtropical regions. It is commonly found in grasslands, woodland margins, and disturbed habitats where adequate sunlight and drainage are available.

Distribution in Australia

The species is reported from the tropical northern regions of Australia, where it grows naturally under warm climatic conditions and well-drained soils.

Distribution in the Americas

The plant is also found in several parts of **Central America, the Caribbean Islands, and tropical regions of South America**. In these regions, it occurs either as a wild species or as a cultivated medicinal plant.

Distribution in India

India is considered one of the major natural habitats of *Plumbago zeylanica*. The plant is widely distributed throughout tropical and subtropical regions of the country and is frequently observed in:

- Forest clearings and open woodlands
- Roadside vegetation
- Wastelands and uncultivated fields
- Hedgerows and scrub forests
- Agricultural boundaries

It generally occurs from sea level up to an altitude of approximately **1,500 meters**, although its abundance varies depending on local climatic conditions.

Habitat and Ecological Requirements

Plumbago zeylanica thrives under warm and humid environmental conditions and demonstrates remarkable adaptability to different soil types. However, its optimum growth is observed under the following conditions:

- Warm tropical and subtropical climate
- Well-drained sandy or loamy soil
- Moderate rainfall with adequate sunlight
- Soil rich in organic matter
- Open habitats with good air circulation

The species exhibits considerable tolerance to environmental stress and can survive in relatively poor soils, making it suitable for cultivation in diverse agro-climatic regions.

Medicinal Importance of Its Distribution

The extensive geographical distribution of *Plumbago zeylanica* has contributed significantly to its widespread use in traditional systems of medicine, particularly **Ayurveda, Siddha, and folk medicine**. The availability of the plant across different regions facilitates its utilization for the preparation of herbal formulations possessing anti-inflammatory, analgesic, antimicrobial, antioxidant, and wound-healing properties.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 4, June 2026 Impact Factor: 8.2

Its broad ecological adaptability and rich phytochemical composition make *Plumbago zeylanica* an important medicinal resource for the development of novel herbal pharmaceutical formulations, including transdermal drug delivery systems.

IV. CHEMICAL CONSTITUENTS OF *PLUMBAGO ZEYLANICA*

Chemical Constituents

Plumbago zeylanica Linn. is a medicinally important plant that contains a wide variety of bioactive phytochemicals responsible for its numerous pharmacological activities. Different parts of the plant, including the roots, leaves, stems, and aerial portions, possess several secondary metabolites such as **naphthoquinones, flavonoids, phenolic compounds, sterols, triterpenoids, glycosides, alkaloids, saponins, and coumarins**. These constituents contribute to the plant's anti-inflammatory, analgesic, antimicrobial, antioxidant, anticancer, and wound-healing properties.

4.1 Naphthoquinones

Naphthoquinones are the major biologically active constituents of *Plumbago zeylanica*. Among them, **plumbagin (5-hydroxy-2-methyl-1,4-naphthoquinone)** is considered the principal marker compound and is responsible for many of the plant's therapeutic effects. Another important constituent identified in the plant is **3-chloroplumbagin**.

Plumbagin has been extensively investigated for its:

- Anti-inflammatory activity
- Analgesic activity
- Antioxidant property
- Antimicrobial effect
- Anticancer potential
- Immunomodulatory action

Because of these biological properties, plumbagin is regarded as the characteristic phytochemical marker of *Plumbago zeylanica*.

4.2 Flavonoids

Flavonoids constitute another important group of phytochemicals present in the plant. Various flavonoids and flavonoid glycosides have been isolated from different parts of *Plumbago zeylanica*.

These compounds possess several pharmacological activities, including:

- Antioxidant activity
- Free radical scavenging activity
- Anti-inflammatory effects
- Cytoprotective properties

Flavonoids help protect biological tissues from oxidative stress and contribute significantly to the therapeutic value of the plant.

4.3 Triterpenoids and Sterols

The plant contains several naturally occurring sterols and triterpenoids, including:

- **β-Sitosterol**
- **Stigmasterol**
- Other triterpenoid compounds
- These constituents are known for their:
- Anti-inflammatory effects
- Cholesterol-lowering properties
- Immunomodulatory activity

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

- Tissue protective effects

Their presence enhances the medicinal importance of the plant and supports its traditional use in inflammatory disorders.

4.4 Phenolic Compounds

Phenolic compounds are widely distributed throughout the plant and include:

- Phenolic acids
- Tannins
- Other polyphenolic substances

These compounds exhibit potent antioxidant and antimicrobial activities by neutralizing free radicals and inhibiting microbial growth. Their presence contributes to the plant's wound-healing and protective effects.

4.5 Glycosides

Various glycosidic compounds have been reported in different parts of *Plumbago zeylanica*. Glycosides are known to influence several biological processes and may contribute to the pharmacological actions of the plant through synergistic interactions with other phytochemicals.

4.6 Alkaloids

Small quantities of alkaloids have also been detected in the plant. Although present in relatively low concentrations, these compounds may contribute to its biological activities, including analgesic and antimicrobial effects.

4.7 Other Phytoconstituents

In addition to the major constituents, *Plumbago zeylanica* contains several other bioactive compounds such as:

- Fatty oils
- Fatty acids
- Carbohydrates
- Proteins
- Amino acids
- Coumarins
- Saponins

These constituents collectively enhance the nutritional and medicinal value of the plant and may act synergistically to produce therapeutic effects.

Distribution of Phytochemicals in Different Plant Parts

The concentration of phytochemicals varies among different parts of the plant:

Plant Part	Major Constituents
Roots	Rich in plumbagin, naphthoquinones, and phenolic compounds
Leaves	Flavonoids, tannins, sterols, and plumbagin
Stem and Aerial Parts	Phenolic compounds, sterols, and traces of plumbagin

The roots contain the highest concentration of plumbagin and therefore represent the most pharmacologically valuable portion of the plant.

Marker Compound: Plumbagin

Plumbagin is considered the principal bioactive marker compound of *Plumbago zeylanica*. Chemically, it is identified as **5-hydroxy-2-methyl-1,4-naphthoquinone**.

DOI: 10.48175/IJARSCT-36558

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

Chemical Properties

Property	Description
Chemical Name	5-Hydroxy-2-methyl-1,4-naphthoquinone
Molecular Formula	$C_{11}H_8O_3$
Molecular Weight	188.18 g/mol
Chemical Class	Naphthoquinone

Plumbagin has attracted significant scientific interest because of its broad spectrum of biological activities, including antioxidant, anti-inflammatory, antimicrobial, anticancer, and analgesic effects. These pharmacological properties make *Plumbago zeylanica* a promising medicinal plant for the development of novel herbal formulations, including transdermal drug delivery systems aimed at the management of arthralgia and other inflammatory disorders.

V. MATERIALS AND METHODS

5.1 Study Design

The present study was undertaken to develop and evaluate a herbal transdermal patch containing ***Plumbago zeylanica*** root extract for the management of arthralgia. The work involved extraction of the plant material, formulation of transdermal patches using suitable polymers, and evaluation of the prepared formulations for their physicochemical and mechanical characteristics.

5.2 Collection and Authentication of Plant Material

Fresh roots of ***Plumbago zeylanica*** Linn. were collected from the local region and authenticated based on their morphological characteristics and botanical features. The collected plant material was thoroughly washed under running tap water to remove soil, dust, and other impurities before further processing.

5.3 Preparation of Plant Material

The cleaned roots were shade-dried at room temperature for approximately **14 days** to preserve their phytochemical constituents and prevent degradation due to direct sunlight. After complete drying, the roots were coarsely powdered using a mechanical grinder. The powdered material was stored in an airtight container in a cool and dry place until extraction.

5.4 Extraction of *Plumbago zeylanica*

Hydroalcoholic extraction was carried out using the **Soxhlet extraction method**. Approximately **1 kg** of the dried root powder was packed into the extraction chamber and extracted with a **hydroalcoholic solvent system consisting of ethanol and distilled water (70:30 v/v)**.

The extraction process was continued until complete exhaustion of the plant material. The resulting extract was concentrated using a water bath maintained at **65–70°C** and further evaporated under reduced pressure using a rotary evaporator to remove the solvent completely. The concentrated semi-solid extract was collected and stored in airtight containers under refrigerated conditions until further use in formulation studies.

5.5 Formulation of Herbal Transdermal Patch

The herbal transdermal patches were prepared by the **solvent casting technique**.

Polyvinyl Alcohol (**PVA**) was used as the backing membrane, while **Hydroxypropyl Methylcellulose (HPMC 50 CPS)** served as the primary film-forming polymer. The required quantity of *Plumbago zeylanica* extract was incorporated into the polymer solution and mixed under continuous magnetic stirring for approximately **one hour** to obtain a homogeneous dispersion.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

Polyethylene glycol (**PEG**) was added as a plasticizer to improve the flexibility and mechanical strength of the film. The mixture was stirred for an additional hour to ensure uniform distribution of all components.

Approximately **5 mL** of the prepared formulation was poured onto the PVA backing membrane placed on a clean glass surface. The solvent was allowed to evaporate slowly under controlled conditions by covering the casting surface with an inverted funnel to minimize rapid evaporation and bubble formation.

The prepared films were allowed to dry at room temperature for **24 hours**, after which the patches were carefully peeled off and stored in airtight containers for further evaluation.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

5.6 Decoction Preparation (Traditional Extraction Method)

For the preparation of the herbal decoction, **10 g** of powdered *Plumbago zeylanica* root was mixed with **160 mL** of distilled water in a round-bottom flask. The mixture was heated until the volume was reduced to approximately **40 mL**, thereby concentrating the active constituents.

The concentrated extract was filtered through suitable filter paper to remove insoluble materials and allowed to cool before incorporation into the formulation process.

5.7 Evaluation of Transdermal Patches

The prepared herbal transdermal patches were evaluated for various physicochemical and mechanical parameters to assess their quality, uniformity, and suitability for transdermal drug delivery.

5.7.1 Moisture Content

The prepared films were individually weighed and placed in desiccators containing fused calcium chloride for **24 hours**. After the specified period, the films were reweighed, and the percentage moisture content was calculated.

Lower moisture content indicates better stability and reduced susceptibility to microbial growth and degradation during storage.

5.7.2 Film Thickness

Film thickness was measured using a calibrated screw gauge at different locations on each patch. The average value was recorded to assess the uniformity of film preparation. Uniform thickness is essential for ensuring consistent drug distribution and controlled drug release.

5.7.3 Weight Variation Test

Patches of identical dimensions were cut from different regions of the prepared film and weighed individually using a digital analytical balance. The average weight and variation among the samples were determined.

A low variation in weight indicates uniform distribution of polymer and herbal extract throughout the formulation.

5.7.4 Percentage Elongation at Break

The mechanical flexibility of the prepared patches was evaluated by determining the percentage elongation at break. The increase in length before rupture was recorded and expressed as a percentage of the original length.

Higher elongation values indicate greater elasticity and improved handling characteristics.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

5.7.5 Flatness Test

Three strips were cut from different portions of each film, namely the center, left side, and right side. The strips were examined for any contraction or shrinkage after drying.

The absence of dimensional changes indicates excellent flatness and uniformity of the prepared transdermal patches.

5.8 Statistical Analysis

The experimental observations were recorded systematically, and the results were expressed as mean values where applicable. The evaluated parameters were compared to assess the overall quality, mechanical strength, and suitability of the formulated herbal transdermal patches for potential therapeutic application.

VI. CONCLUSION

The present investigation successfully demonstrated the development and evaluation of a herbal transdermal patch containing *Plumbago zeylanica* root extract for the management of arthralgia. The study was designed to explore the feasibility of incorporating a traditionally important medicinal plant into a modern transdermal drug delivery system capable of providing sustained therapeutic action.

The hydroalcoholic extract of *Plumbago zeylanica* was successfully formulated into polymeric films using Polyvinyl Alcohol (PVA) and Hydroxypropyl Methylcellulose (HPMC) through the solvent casting technique. The prepared patches were subjected to various physicochemical and mechanical evaluations, including moisture content, film thickness, weight variation, percentage elongation at break, and flatness.

The experimental findings revealed that the formulated patches possessed satisfactory physical appearance, good mechanical strength, acceptable flexibility, uniform thickness, and excellent dimensional stability. The moisture content remained low, suggesting improved storage stability and reduced susceptibility to degradation. Similarly, the weight variation and film thickness studies confirmed the uniform distribution of the herbal extract throughout the polymeric matrix.

Among the prepared formulations, those containing **4% Polyvinyl Alcohol (PVA) and 3–4% Hydroxypropyl Methylcellulose (HPMC)** demonstrated superior characteristics with respect to flexibility, integrity, and overall formulation performance.

The study therefore concludes that *Plumbago zeylanica* possesses considerable potential for incorporation into herbal transdermal drug delivery systems. Such formulations may serve as an effective alternative approach for the management of arthralgia and inflammatory disorders while improving patient compliance and minimizing systemic adverse effects associated with conventional dosage forms.

However, additional investigations including **drug release studies, skin permeation studies, pharmacokinetic evaluation, pharmacodynamic assessment, toxicity studies, and clinical trials** are necessary before the developed formulation can be considered for therapeutic application.

VII. FUTURE SCOPE

The present research provides a foundation for the development of herbal transdermal drug delivery systems based on *Plumbago zeylanica*. Future studies may focus on:

Optimization of polymer composition to improve drug release and skin permeation.

In vitro diffusion and permeation studies using biological membranes.

Pharmacokinetic and pharmacodynamic evaluation in suitable experimental models.

Long-term stability studies under accelerated and real-time storage conditions.

Toxicological and skin irritation studies to establish safety.

Clinical evaluation in patients suffering from arthralgia and other inflammatory disorders.

Comparative studies with marketed transdermal formulations to assess therapeutic efficacy.

Isolation and standardization of plumbagin and other active phytoconstituents for enhanced formulation development.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 4, June 2026 Impact Factor: 8.2

Further research in these areas may facilitate the commercialization of a safe, effective, and patient-friendly herbal transdermal therapeutic system.

VIII. ACKNOWLEDGEMENT

The authors express their sincere gratitude to **Dr. Abhishek Soni**, Dean, School of Pharmacy, Abhilashi University, for providing the necessary facilities, guidance, and encouragement throughout the course of this research work.
The authors also extend their heartfelt appreciation to **Mrs. Kiran**, Professor, School of Pharmacy, for her continuous support, valuable suggestions, and scientific guidance during the planning and execution of this project.
Finally, the authors acknowledge the faculty members, laboratory staff, and the School of Pharmacy, Abhilashi University, Chail-Chowk, Himachal Pradesh, for providing the infrastructure and academic environment necessary for the successful completion of this work.

REFERENCES

1. Acharya BR, Bhattacharyya B, Chakrabarti G. The natural naphthoquinone plumbagin exhibits antiproliferative activity and disrupts the microtubule network through tubulin binding. **Biochemistry**. 2008;47(30):7838-7845.
2. Unnikrishnan R, Anjana RM, Mohan V. Diabetes mellitus and its complications in India. **Nature Reviews Endocrinology**. 2016.
3. Khandelwal KR. **Practical Pharmacognosy**. Pune: Nirali Prakashan; 2008.
4. Thangaraj P. Extraction of bioactive compounds. **Progress in Drug Research**. 2016.
5. Tilak JC, Adhikari S, Devasagayam TPA. Antioxidant properties of *Plumbago zeylanica* and its active ingredient plumbagin. **Redox Report**. 2004;9(4):219-227.
6. Velnar T, Bailey T, Smrkolj V. The wound healing process. **Journal of International Medical Research**. 2009;37(5):1528-1542.
7. Hewlings SJ, Kalman DS. Curcumin: A review of its effects on human health. **Foods**. 2017;6(10):92.
8. World Health Organization. **WHO Traditional Medicine Strategy 2014-2023**. Geneva: WHO; 2013.
9. Gupta SC, Patchva S, Aggarwal BB. Therapeutic roles of curcumin. **AAPS Journal**. 2013;15(1):195-218.
10. Boateng JS, Matthews KH, Stevens HNE, Eccleston GM. Wound healing dressings and drug delivery systems: A review. **Journal of Pharmaceutical Sciences**. 2008;97(8):2892-2923.
11. Barry BW. **Novel mechanisms and devices to enable successful transdermal drug delivery**. European Journal of Pharmaceutical Sciences. 2001;14(2):101-114.
12. Prausnitz MR, Langer R. **Transdermal drug delivery**. Nature Biotechnology. 2008;26(11):1261-1268.
13. Patel RP, Patel G, Baria AH. **Formulation and evaluation of transdermal patches: A review**. International Journal of Pharmaceutical Research. 2009;1(1):1-7.
14. Jain NK. **Controlled and Novel Drug Delivery**. 1st ed. New Delhi: CBS Publishers & Distributors; 2008.
15. Chien YW. **Novel Drug Delivery Systems**. 2nd ed. New York: Marcel Dekker Inc.; 1992.
16. Kokate CK, Purohit AP, Gokhale SB. **Pharmacognosy**. 56th ed. Pune: Nirali Prakashan; 2021.
17. Trease GE, Evans WC. **Trease and Evans Pharmacognosy**. 16th ed. London: Saunders Elsevier; 2009.
18. Harborne JB. **Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis**. 3rd ed. London: Chapman and Hall; 1998.
19. Sofowora A. **Medicinal Plants and Traditional Medicine in Africa**. 3rd ed. Ibadan: Spectrum Books; 2008.
20. World Health Organization. **WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants**. Geneva: WHO; 2003.
21. World Health Organization. **WHO Monographs on Selected Medicinal Plants**. Vol. 1. Geneva: WHO; 1999.
22. Kirtikar KR, Basu BD. **Indian Medicinal Plants**. 2nd ed. Dehradun: International Book Distributors; 1999.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

23. Nadkarni KM. **Indian Materia Medica**. 3rd ed. Mumbai: Popular Prakashan; 2007.
24. Rang HP, Ritter JM, Flower RJ, Henderson G. **Rang & Dale's Pharmacology**. 9th ed. Elsevier; 2020.
25. Brunton LL, Hilal-Dandan R, Knollmann BC. **Goodman & Gilman's The Pharmacological Basis of Therapeutics**. 13th ed. McGraw-Hill; 2018.
26. Allen LV, Popovich NG, Ansel HC. **Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems**. 10th ed. Philadelphia: Lippincott Williams & Wilkins; 2014.
27. Remington JP. **Remington: The Science and Practice of Pharmacy**. 22nd ed. Pharmaceutical Press; 2013.
28. Bhowmik D, Chiranjib B, Chandira RM. **Recent advances in transdermal drug delivery systems**. International Journal of Pharmaceutical Sciences Review and Research. 2010;3(2):68-77.
29. Patel D, Chaudhary SA, Parmar B, Bhura N. **Transdermal drug delivery system: A review**. The Pharma Innovation Journal. 2012;1(4):66-75.
30. Sharma PP. **Cosmetics: Formulation, Manufacturing and Quality Control**. 5th ed. New Delhi: Vandana Publications; 2018.
31. Kumar V, Abbas AK, Aster JC. **Robbins and Cotran Pathologic Basis of Disease**. 10th ed. Elsevier; 2021.
32. Evans WC. **Pharmacognosy**. 16th ed. London: Saunders Elsevier; 2009.
33. Wagner H, Bladt S. **Plant Drug Analysis: A Thin Layer Chromatography Atlas**. 2nd ed. Springer; 2009.
34. Indian Pharmacopoeia Commission. **Indian Pharmacopoeia**. Ghaziabad: IPC; Latest Edition.
35. United States Pharmacopeia Convention. **United States Pharmacopeia–National Formulary (USP–NF)**. Rockville, MD: USP Convention; Latest Edition.