Journal of Applied Pharmaceutical Research
Volume 13 Issue 6, Year of Publication 2025, Page 22 – 32
DOI: https://doi.org/10.69857/joapr.v13i6.1203

Check for updates

Research Article

JOURNAL OF APPLIED PHARMACEUTICAL RESEARCH | JOAPR
www.japtronline.com ***ISSN: 2348 – 0335***

FORMULATION AND IN-VITRO EVALUATION OF OXAPROZIN TRANSDERMAL PATCHES FOR SUSTAINED ANTI-INFLAMMATORY THERAPY

Mansi Gupta, Priya Tiwari*

Article Information
Received: 14th July 2025
Revised: 5th November 2025
Accepted: 1st December 2025
Published: 25th December 2025

Keywords
Oxaprozin (OXA), Transdermal Patches, NSAIDs, Rheumatoid Arthritis, Box-Behnken Design, Drug Release

ABSTRACT

Background: Inflammation is characterized by pain, altered membrane permeability, increased vascular activity, and protein denaturation. Oxaprozin, a BCS Class II NSAID, is often used to manage inflammation and pain but is limited by poor solubility and extensive first-pass metabolism, which reduces its effectiveness when administered orally. This study aimed to develop and evaluate oxaprozin-loaded transdermal patches as a patient-friendly alternative for sustained anti-inflammatory therapy. **Methodology:** Transdermal patches were formulated using the solvent-casting technique with hydroxypropyl methylcellulose (HPMC) and polyvinylpyrrolidone (PVP K-30) as film-forming polymers, along with plasticizers and permeation enhancers (propylene glycol and DMSO). A Box-Behnken design (13 runs) was employed to optimize the effects of polymer concentrations on adhesion strength and % cumulative drug release. The patches were characterized for thickness, folding endurance, surface pH, moisture content, drug content, and *in vitro* drug release. **Result and Discussion:** Pre-formulation studies confirmed drug-excipient compatibility and stability. P1 exhibited optimal performance with a thickness (0.123±0.34 mm), weight variation (94.5±0.56 %), drug content (94.47 %), folding endurance (25±0.1), and *in vitro* drug release (81.14±6.08 % over 24 hours). The release followed Korsmeyer-Peppas kinetics (R^2 = 0.9677), indicating a diffusion-controlled release mechanism. Statistical analysis confirmed significant differences among formulations ($p < 0.05$) & stability studies showed no changes after 3 months. **Conclusion**: The optimized oxaprozin transdermal patches, particularly formulation P1, demonstrated uniformity, stability, and controlled drug release, establishing their potential as an effective alternative to oral NSAID therapy. Future *in vivo* studies are recommended to confirm therapeutic efficacy and clinical applicability.

INTRODUCTION

The transdermal drug delivery system (TDDS) is a widely utilized method for administering medications. A transdermal patch, sometimes referred to as a skin patch, is a medicated adhesive pad applied to the skin that delivers a specific dose of drugs into the bloodstream through the skin. One of the main

*Moradabad Educational Trust, Group of Institutions, Faculty of Pharmacy, Moradabad, UP, India, 244001.

***For Correspondence:** **tiwari93priya@gmail.com**

advantages of TDDS is its controlled drug release, which can occur either through a permeable membrane covering a drug reservoir or by the drug melting due to body heat from a thin layer embedded in the adhesive. This method bypasses the liver's first-pass metabolism and avoids gastrointestinal issues and poor absorption often seen with oral medications. Since most drugs pass through the skin via intercellular pathways, the use of permeation enhancers is essential in TDDS. These agents temporarily reduce the barrier function of the stratum corneum without damaging the underlying living tissues [1].

The process of inflammation follows an infection or tissue damage. To maintain homeostasis, an inflammatory response is necessary. This may lead to the formation of fibrous tissue, increased levels of several white blood cells, and overproduction of cytokines, including interleukin-6, interleukin-8, and tumor necrosis factor-α. Inflammation is a key physiological process that triggers the immune response. Inflammation and tissue swelling are frequently associated with superficial pain, which is mediated by noxious receptors in the skin. NSAIDs can inhibit the production of prostaglandins (e.g., PGE2) and thromboxanes by blocking the action of COX-1 and COX-2, which are involved in pain and inflammation. PGE2 and thromboxanes are thought to mediate hypersensitivity reactions, including inflammation and vasospasm. On the other hand, excessive oral use over a longer duration of time may result in intestinal blood loss, heart attacks, and strokes [2].

Oxaprozin is a non-narcotic, non-steroidal anti-inflammatory drug (NSAID) commonly used to manage inflammation, swelling, stiffness, and joint pain associated with osteoarthritis and rheumatoid arthritis. Oxaprozin exerts its anti-inflammatory effect primarily by inhibiting platelet cyclooxygenase, which reduces prostaglandin synthesis. Additionally, its antipyretic activity may influence the hypothalamus, promoting increased blood flow to the skin, vasodilation, and enhanced heat loss. The structural formula of oxaprozin ($C_{18}H_{15}NO_3$) is depicted in Table 3 [3]. Oxaprozin supports infrequent dosing since it exhibits strong protein binding with a very low free fraction [4]. It is also a promising option for transdermal delivery due to its low water solubility, lipophilicity (log P ~3–4), and molecular weight (~293.3 Da) [5].

These characteristics imply that a transdermal patch would minimize the gastrointestinal side effects associated with oral treatment while maintaining consistent therapeutic levels.

MATERIALS AND METHODS

Materials

Oxaprozin was obtained from Yarrow Chem. Products, Maharashtra, India. The polymers- Hydroxy propyl methyl cellulose (HPMC) (Ozone International Mumbai), PVP (Sisco Research Laboratories Pvt. Ltd.), plasticizer-propylene glycol (Nice Chemicals Pvt. Ltd.), permeation enhancer-dimethyl sulfoxide (Avantor Performance Materials India Pvt. Ltd.), and solvent-methanol (Thermo Fisher Scientific India Pvt. Ltd.), provided by the institute were of reagent grade.

Methodology

Preliminary studies of Oxaprozin

Pre-formulation testing is the first step in dosage form development. It involves studying the physical and chemical characteristics of the drug, both in its pure form and in combination with various excipients. The main goal of this process is to provide essential data that helps the formulator to create a stable and effective formulation. This preliminary stage is referred to as pre-formulation [6].

Organoleptic Characteristics of Oxaprozin

The organoleptic properties of oxaprozin, including its color, odor & appearance, were assessed through visual inspection [7].

Examination of Oxaprozin's Melting Point

A small quantity of oxaprozin was loaded into a capillary tube and placed in a melting point apparatus (Harrisons Pharma Machinery Private Limited) to determine its melting point. The temperature at which the drug melted was then recorded [8].

Solubility study of Oxaprozin

Oxaprozin's solubility in several buffers and solvent systems was assessed. 10 ml of each solvent was combined with an excess of the drug in screw-capped glass tubes, which were then shaken on a continuous water bath shaker at 25 °C for 24 hours. The tubes were then visually inspected to determine whether the drug was present [9].

Spectrophotometric Analysis of Oxaprozin

10 mg of accurately weighed oxaprozin was added to 10 ml of methyl alcohol to make a 1000 µg/ml solution. For solution strengths of 2, 4, 6, 8, and 10 µg/ml, appropriate dilutions were prepared. Using a Shimadzu-1900i double-beam Ultraviolet (UV)-visible spectrophotometer (Japan), the solution's UV spectrum was scanned between 200 and 400 nm, and λ_{max} was determined [10].

Fourier-Transform Infrared (FT-IR) Spectroscopy

Oxaprozin, either alone or in combination with the polymers under research, was assembled into tiny discs using KBr, and the 4000-400 cm^{-1} frequency band was used to get the spectra in FT-IR (Perkin Elmer Spectrum IR version 10.7.2) [11].

Drug–excipient compatibility studies

Any chemical or physical interaction between drugs and excipients can affect the drug's stability and bioavailability. We prepared a small mixture of drugs and excipients (1:1). The mixture was placed in vials. The rubber closures were placed on the vials & sealed them hermetically. The drug-excipient compatibility was analyzed at 4 weeks of storage at ambient conditions. The samples were also analyzed by FT-IR [12].

Preparation of different placebo patches

The trial-and-error method was used to develop a range of placebo patches comprising combinations of hydrophilic and hydrophobic polymers. The combination of these placebo patches, selected for their suitability as transdermal drug-delivery systems, is used to incorporate the drug. Various polymer combinations, like HPMC and PVP in a 1:3 ratio, produced a smooth, transparent, consistent, and flexible film. In contrast, HPMC and EC at 1:1 formed an inconsistent film, while PVA and PVP at 1:4 yielded a tough, hard film [13].

DEVELOPMENT OF TRANSDERMAL PATCHES

Box-Behnken Design (BBD) for Development of Formulations

BBD is one of the best-known methods for improving patch composition. We conduct and examine it using experimental approaches, thereby distinguishing it from other established methods. Our initial statistical bio-methodological analysis helped us identify the independent and dependent variables and set their respective limits. To improve the transdermal patch, BBD was used to identify independent factors (HPMC [A] and PVP [B]) and response characteristics (adhesion strength [R1] and % medication release [R2]) across multiple possible outcomes (Table 1). The response surface methodology is a statistical method used to examine how alternative formulations and/or processing factors directly affect one or more response variables. It helps to select the optimal design to improve the formulation process. We used Design-Expert® version 12.0.3.0 to evaluate patches containing oxaprozin. The results showed that 13 distinct formulations can be produced using two different center positions.

Table 1: Levels of two independent variables used in (BBD) Patch Formulation

Factor	Name (mg)	Type	Minimum	Maximum	Coded Low	Coded High
A	HPMC	Numeric	27.57	112.43	-1 ↔ 40.00	+1 ↔ 100.00
B	PVP	Numeric	11.72	68.28	-1 ↔ 20.00	+1 ↔ 60.00

Table 2: Different Formulations of Oxaprozin Transdermal Patch

Formulation Code	Drug(mg)	HPMC(mg)	PVP(mg)
P1	10	70	20
P2	10	70	40
P3	10	100	40
P4	10	100	60
P5	10	70	40
P6	10	100	40
P7	10	70	40
P8	10	70	40
P9	10	70	60
P10	10	70	40
P11	10	40	60
P12	10	100	40
P13	10	40	20

Development of transdermal patches

A sufficient quantity of polyvinylpyrrolidone and hydroxypropyl methyl cellulose was weighed according to the specified ratio. These polymers were then dissolved in a solvent system that contained water and methanol in a 3:1 ratio. The polymer solution was supplemented with a drug solution containing a plasticizer and a penetration enhancer at appropriate concentrations. The resulting polymer solution was then spread onto a 6 cm-diameter Petri dish previously treated with castor oil, a lubricant. After 48 hours at 25 ± 2 °C and 50 ± 5% relative humidity, the patches were removed and placed in a desiccator until needed. These patches were found to be flexible, smooth, and uniform [13].

Assessment of transdermal patches

Physical aspect: Each created patch was observable for color, transparency, smoothness, and plasticity [14].

Thickness: The thickness of each patch was determined at multiple locations using a screw micrometer, and the mean value was then calculated [15].

% Weight variation: % Weight variation is done with a digital balance. An average weight was determined after the test was run on five patches [16].

Folding Endurance: A 2 cm^2 strip was cut and repeatedly folded at the same place until it broke. The number of folds before breaking was recorded as the folding endurance value. The count's film was folded at the specified area without breaking and was used to calculate the folding endurance value [17].

Flatness: A flatness evaluation was performed to ensure that the developed transdermal patches maintained a smooth surface and wouldn't shrink over time. 3 longitudinal strips were taken from different areas of the film, and their lengths were measured. The degree of flatness was assessed by calculating the % of constriction, where 0% constriction indicated complete flatness [18].

$$\boldsymbol{Flatness}\ (\%) = \frac{\boldsymbol{L1-L2}}{\boldsymbol{L1}} \times \mathbf{100}$$

Where, L1=Initial length and L2= Final length

Surface pH

In closed Petri dishes containing 5 mL of distilled water, the transdermal patches were placed. To swell and absorb water, the patches were submerged in the solution for 30 min. After the water was absorbed, the pH was measured with a pH meter. The water's pH mirrored the patch's surface pH after the patch was soaked in it. A neutral pH provides tolerability and compatibility (≅ 7) or a surface pH that is nearly equal to the skin's pH [19].

% Drug content determination: A precisely measured 100 mg portion of the transdermal patch was dissolved in 100 ml of phosphate buffer with a pH of 7.4. The mixture was continuously agitated in a shaker incubator (Hi-Tech Lab Products) for 24 hrs, followed by 15 min. of sonication. After filtration & appropriate dilution, the concentration of the drug in the resulting solution was determined using a UV-visible spectrophotometer at 285 nm [20].

% moisture absorption: The patches that maintained 80–90% relative humidity were precisely weighed and placed in desiccators containing 100 ml of saturated KCl solution. 3 days later, the patches were removed & weighed. The research was carried out at room temperature [21].

$$\boldsymbol{Moisture\ absorption}\ (\%) = \frac{(\boldsymbol{Final\ Weight\ -Initial\ Weight})}{\boldsymbol{Initial\ Weight}}\ \boldsymbol{X}\ \mathbf{100}$$

In Vitro Drug Release Study

In a Franz diffusion cell, the vitelline membrane served as the skin, and the pores of the egg membrane were activated by soaking the egg membrane in PBS (pH 7.4) for 24 hours. The membrane separates the donor and receiver compartments. 20 ml of PBS (pH 7.4) in the receiver compartment was maintained at 37 ± 0.2 °C. A magnetic stirrer was used to maintain hydrodynamic conditions. A single 2 cm^2 patch was moistened with a trace amount of PBS (pH 7.4) before being placed in the donor compartment. An equal volume of PBS (pH 7.4) was replaced after each 1 ml sample was withdrawn from the receiver compartment at 1, 2, 4, 6, 8, 12, and 24 hours. The absorbance at λ_{max} of 285 nm of a UV-visible spectrophotometer was used to calculate the % of drug that had permeated [22].

Release kinetics [23]

A range of kinetic models was employed to define release kinetics and evaluate *in vitro* release data. The zero-order rate denotes a drug's release rate that is invariant irrespective of concentration. The release process, in which concentration dictates the release rate, is consistent with a first-order system. Higuchi posits that drug release from an insoluble matrix follows Fickian diffusion and is proportional to the square root of time. The following data processing techniques are employed to present the *in vitro* release profile outcomes for each batch:

a) Zero – order kinetic model: This model illustrates the graph of % CDR vs time.

b) First – order kinetic model: This model presents a graph depicting the logarithm of the cumulative percentage of medication left vs time.

c) Higuchi model: In the Higuchi model, the graph is displayed with % CDR against √T.

d) Korsmeyer-Peppas model: This model is shown by a graph plotting Log % CDR against log time.

a) Zero-order kinetics: The following formula would anticipate a zero-order release: $\boldsymbol{Q}_t = \boldsymbol{Q}_0 + K_0 t$

b) First-order kinetics: The following formula could be utilized to anticipate a first-order release: $\boldsymbol{Q}_t = \boldsymbol{Q}_0 \boldsymbol{e}^{-kt}$

c) Higuchi model: Higuchi's classical diffusion equation has been utilized to describe drug release from matrix devices by diffusion: $\boldsymbol{Q}_t = \boldsymbol{K}_H \boldsymbol{t}^{1/2}$

d) Korsmeyer-Peppas model: $\boldsymbol{Q}_t/\boldsymbol{Q}_\infty = \boldsymbol{K}_k \boldsymbol{t}^n$

Stability studies

The optimized transdermal patch was exposed to 40°C & a 75% relative humidity for 3 months in a stability chamber (Lab India

Instruments). The patches were examined for drug content & physical alterations after 90 days [24].

Statistical Analysis

Statistical analysis was performed using GraphPad Prism (Version All 10.6.0). The data are expressed as mean ± standard deviation (SD) from n=3. Data were analyzed using one-way ANOVA, followed by Tukey's multiple comparisons test, with $P < 0.05$ considered statistically significant.

RESULTS AND DISCUSSION

Preliminary Studies of Oxaprozin

The pre-formulation study disclosed the chromaticity and odor of the OXA, which was a white crystalline powder and odorless. The other parameters, such as melting point, λ_{max}, and FTIR, were consistent with reference standards. The wavelength (λ_{max}) of oxaprozin was 285 nm, which is consistent with the reference values shown in Table 3.

Solubility study of Oxaprozin

Oxaprozin is a Biopharmaceutical Classification System class 2 drug; therefore, it is merely soluble in polar solvents and highly soluble in non-polar solvents, e.g., DMSO, ethanol, methanol, and 7.4 PBS. The data are illustrated in Table 4.

Spectrophotometric Analysis of Oxaprozin: The UV spectra of OXA are shown in Figure 1. The absorbance was 285 nm, which is consistent with the reference (USP 285 nm).

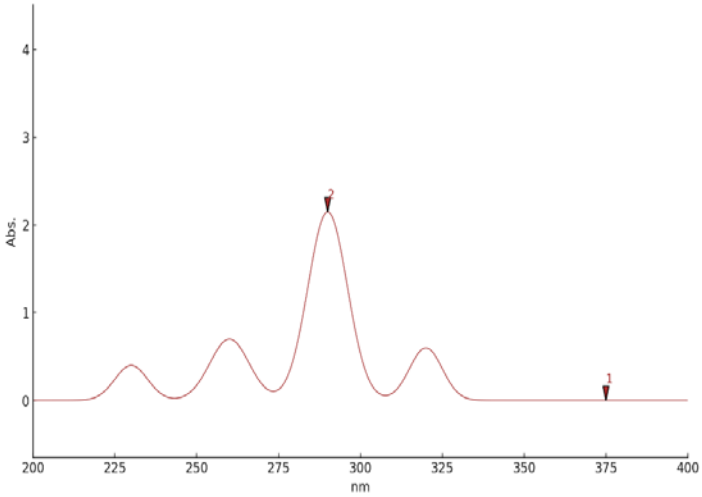


Figure 1: UV spectra of Oxaprozin

FTIR Spectroscopy

The identity and structural integrity of oxaprozin were confirmed by its FTIR spectrum (Figure 2 and Table 5). The FTIR spectra are presented at higher resolution and annotated with specific peak labels for clarity. The prominent absorption peak indicates the O–H stretching at 3226.63 cm^{-1}, which the carboxylic acid group may cause. C=O stretching is represented by a strong peak at 1707.89 cm^{-1}. The aromatic character of the chemical is indicated by the peaks in 1600–1500 cm^{-1}, which are ascribed to the aromatic ring's C=C stretching vibrations, along with CH_2 bending at 1442 cm^{-1}. Spectral matching confirms that the formulation procedure is appropriate for preserving the chemical stability of oxaprozin in the transdermal patch. The results validate the drug's identification and structural soundness.

Table 3: Pre-formulation Parameters

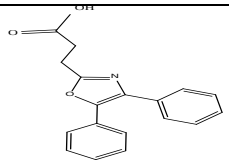
Structural Formula	
Variables	**Resultant**
Organoleptic characteristics	
Color	White Powder
Odor	Odorless
Appearance	White Crystalline Powder
Melting Point	159-160 ºC
λ_{max}	285 nm

Table 4: Solubility of Oxaprozin

Solvent	**Solubility**
Water	Insoluble
DMSO	Homogeneous
Ethanol	Homogeneous
Methanol	Homogeneous
PBS (pH 7.4)	Sparingly Soluble

Drug–excipient compatibility studies

To evaluate potential interactions and compatibility, the FTIR spectra of oxaprozin in combination with DMSO, HPMC, propylene glycol, and PVP were recorded. Oxaprozin's distinctive peaks, including the broad O–H stretch at 3226 cm^{-1}, the C=O stretch near 1700 cm^{-1}, and the aromatic C=C vibrations near 1600 cm^{-1}, were retained in the Oxaprozin + DMSO spectrum (Figure 2(a) and Table 5), suggesting no discernible shift or disappearance. This implies that DMSO does not chemically interact with oxaprozin and is compatible with it. The FTIR spectra of Oxaprozin + HPMC (Figure 2(b) and Table 5) similarly showed all of Oxaprozin's major functional group peaks with just minor changes. The lack of notable changes or the development of new peaks indicates that Oxaprozin and HPMC are physically mixing without chemically interacting.

The main Oxaprozin functional peaks were likewise retained in the Oxaprozin + Propylene Glycol spectrum displayed (Figure 2(c) and Table 5). The compatibility of the excipient was confirmed by the absence of any new peaks or notable changes, despite slight fluctuations in intensity. Once more demonstrating the lack of chemical interaction, the spectrum of Oxaprozin + PVP (Figure 2(d) and Table 5) retained the distinctive peaks of Oxaprozin, specifically the C=O, O–H, and aromatic vibrations. The preservation of these bands confirms PVP's status as a chemically inert excipient in the formulation. Due to the absence of significant shifts, disappearances, or formations of new peaks, the FTIR spectra (Table 5) indicate that Oxaprozin retains its chemical stability and exhibits physical compatibility with all examined excipients, including DMSO, HPMC, Propylene Glycol, and PVP, thereby affirming the lack of substantial chemical interactions and endorsing the formulation of a stable and effective transdermal delivery system.

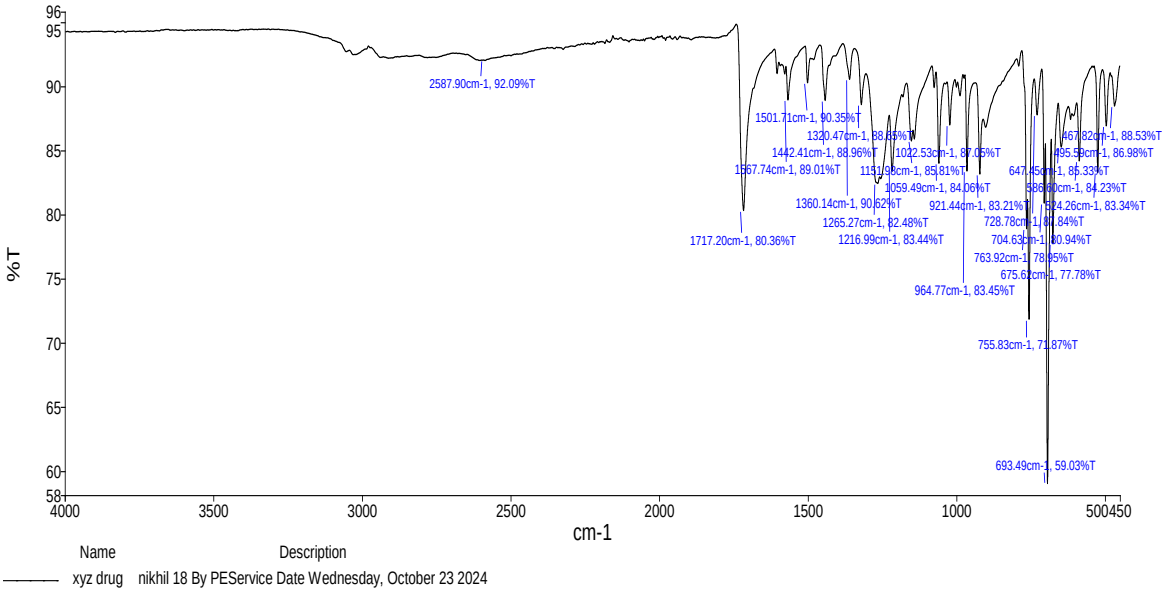


Figure 2: FTIR spectrum of Oxaprozin. Major functional peaks are directly labeled on the spectra, including O–H stretching (~3226 cm⁻¹), C=O stretching (~1717 cm⁻¹), aromatic C=C vibrations (1600–1500 cm⁻¹), and CH_2 bending (~1442 cm⁻¹)

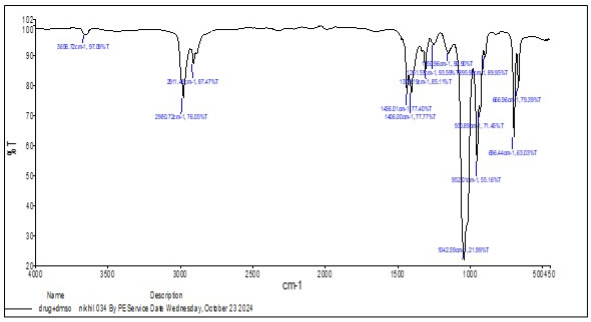


Figure 2 (a): FTIR spectrum of Oxaprozin + DMSO

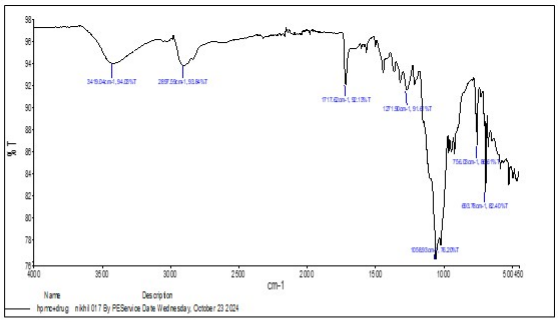


Figure 2 (b): FTIR spectrum of Oxaprozin + HPMC

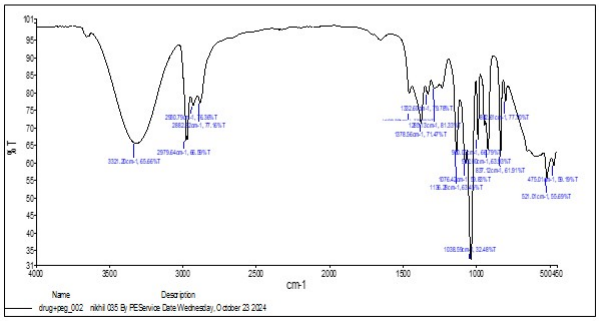


Figure 2 (c): FTIR spectrum of Oxaprozin + Propylene Glycol

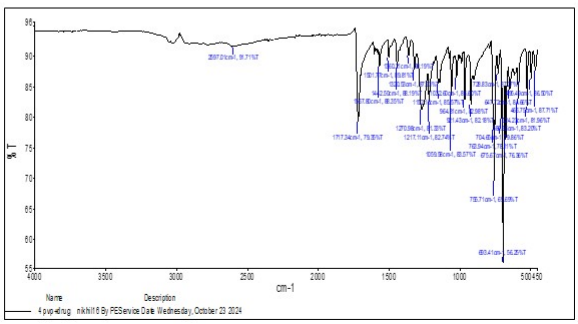


Figure 2 (d): FTIR spectrum of Oxaprozin + PVP

Figure 2: FTIR spectrum: (a). DMSO with oxaprozin, (b). HPMC with oxaprozin, (c). Propylene glycol with oxaprozin and (d). PVP with oxaprozin.

Table 5: FTIR spectra characterization of drug and drug with excipients

Characterization	Observed Peak (cm^{-1})	Interpretation	Shift compared to standard
Oxaprozin	2587.9	C-H stretch (alkanes)	Reference
	1717.2	C=O stretch	Reference
	1501.71	C=C stretch (aromatics)	Reference
	1442.41	CH_2 bend	Reference
Oxaprozin with HPMC	3419.04	Broad O-H stretching	Slight shift
	2897.59	C-H stretching	Minor shift
	1717.62	C=O stretching vibration	Negligible shift
	756.03	Aromatic C-H bending	New excipient band
Oxaprozin with PVP	1717.34	C=O stretching	Negligible shift
	1567.8	N-H Bending	New excipient band
	1442.5	CH2 bending	Negligible shift
	763.94	Aromatic C-H bending	Minor shift
Oxaprozin with DMSO	3658.72	O-H stretching	Shift due to excipient
	2980.72	C-H stretching	Slight shift
	1042.59	S=O stretching	New excipient band
Oxaprozin with PG	3321.2	O-H stretching	Slight shift
	2979.64	C-H stretching	Negligible shift
	1076.42	C-O stretching	New excipient band

Experimental Design for the Formulation

The solvent casting process was employed to develop transdermal patches containing oxaprozin, and the Box-Behnken Design (BBD) was used to optimize their performance. The BBD tool has two independent variables and one dependent variable. The findings from the BBD tool indicate that the independent factors (HPMC and PVP) have a substantial effect on the dependent variables (Adhesion Strength and % CDR), and vice versa. When the response values were entered into first-order, second-order, and quadratic models, the quadratic model fit best. The R2 values for adhesion strength and % CDR were 0.8263 and 0.7517, respectively. The response surface plot (Figure 3) shows that adhesion strength is directly proportional to the amounts of HPMC and PVP.

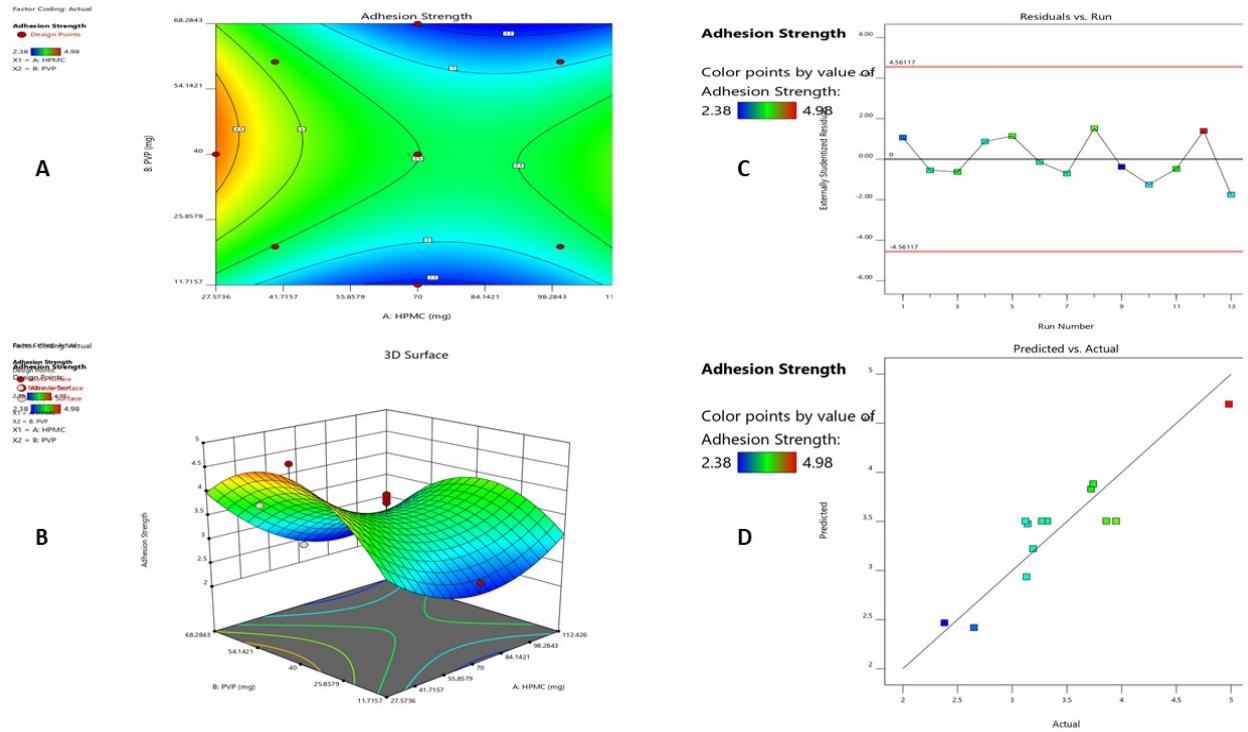


Figure 3: Shows the Response Surface Methodology (RSM) study of how the concentrations of HPMC and PVP affect the strength of adhesion. (A) Contour plot, (B) 3D surface plot, (C) Residuals vs. run plot, and (D) Predicted vs. actual plot

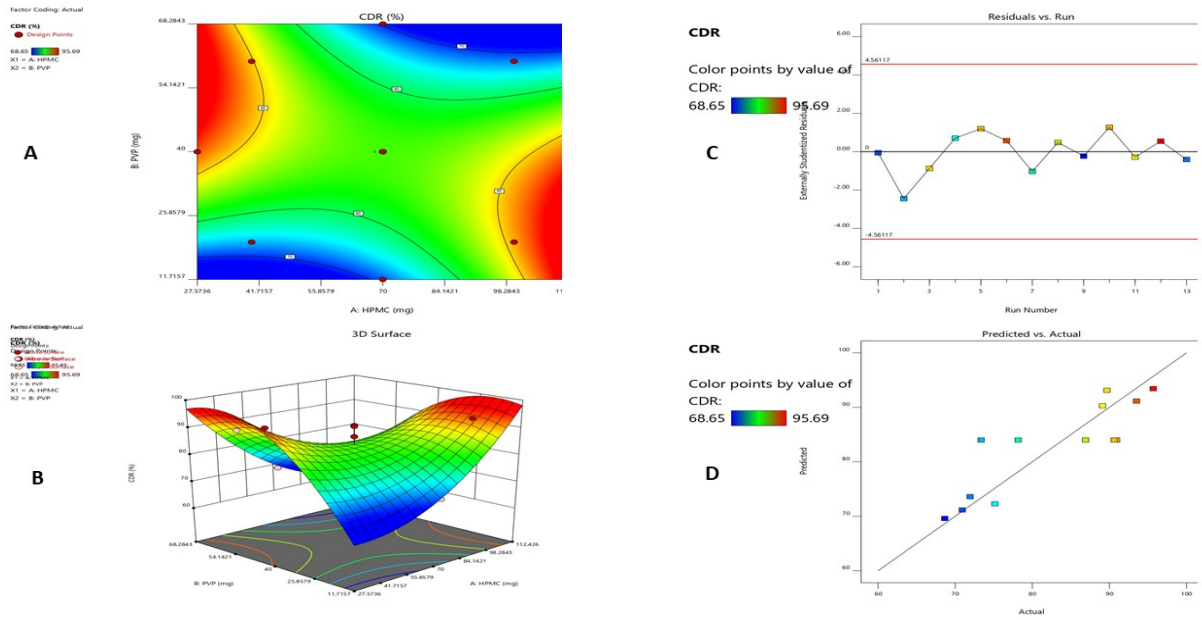


Figure 4: Shows the Response Surface Methodology (RSM) study of how the concentrations of HPMC and PVP affect % CDR. (A) Contour plot, (B) 3D surface plot, (C) Residuals vs. run plot, and (D) Predicted vs. actual plot.

Assessments of Transdermal Patch

Physical aspects

The transparent, clear, smooth, and flexible transdermal patch of oxaprozin was obtained.

Various assessment parameters of the oxaprozin transdermal patch

The data on the assessment parameters of the prepared patches are presented in Table 6.

In Vitro Drug Release

Statistical analysis confirmed significant differences among formulations. One-way ANOVA revealed a robust treatment effect ($F = 6.311$, $p < 0.0001$). Further post hoc evaluation using Tukey's multiple comparisons test identified which pairs of formulations showed significant differences. Notably, formulation P1 exhibited consistently higher drug release than several others. Among these formulations, P1 exhibited the best performance, attributable to its specific combination of HPMC and PVP at varying concentrations. This formulation successfully sustained drug release over a 24-hour period, achieving the targeted sustained-release profile (% drug released within 24 hours). The in vitro drug-release profiles for these formulations are shown in Figure 5.

Table 6: Resultative value of all formulations. Values represent mean ± SD (n=3). Statistical significance was determined using one-way ANOVA followed by Tukey's post-hoc test ($p < 0.05$).

Formulation	Thickness (mm)	% Weight variation	Folding endurance	Flatness	Surface pH	% Drug content	% Moisture absorption	*In vitro* Diffusion study
P1	0.123±0.34	94.5±0.56	25±0.12	100%	7.0±0.1	94.47	1.49±1.31	81.14±6.08
P2	0.166±0.087	89.7±0.53	24±0.54	100%	7.0±0.2	93.54	2.68±2.12	78.33±9.07
P3	0.647±0.0084	98.5±0.57	15±0.05	100%	7.1±0.3	91.85	3.79±1.51	76.32±7.95
P4	0.835±0.0405	87.7±0.88	18±0.0041	100%	6.9±0.5	89.15	3.40±1.30	73.81±10.25
P5	0.745±0.0412	75.1±1.7	20±0.003	100%	6.9±0.4	74.14	3.7±1.65	76.32±7.96
P6	0.565±0.025	93.8±0.62	22±0.14	100%	7.0±0.2	85.34	2.85±1.40	74.28±8.41
P7	0.612±0.031	96.2±0.74	19±0.11	100%	6.8±0.3	82.97	2.22±1.18	72.15±6.97
P8	0.678±0.027	91.5±0.60	17±0.07	100%	6.9±0.2	79.82	3.98±1.23	70.92±7.65
P9	0.589±0.033	95.6±0.65	21±0.10	100%	7.1±0.1	88.40	2.13±1.75	77.36±6.83
P10	0.498±0.029	90.2±0.58	23±0.12	100%	7.0±0.2	91.22	3.52±1.44	79.41±7.21
P11	0.452±0.026	86.9±0.70	24±0.09	100%	7.0±0.1	92.75	3.10±1.39	80.63±5.98
P12	0.598±0.032	87.5±0.80	16±0.06	100%	6.9±0.2	77.85	4.01±1.56	71.43±8.37
P13	0.722±0.035	96.8±1.00	18±0.08	100%	6.8±0.4	75.92	3.85±1.33	73.55±7.59

Statistical analysis (one-way ANOVA with Tukey's post-hoc test) confirmed that variations among formulations were significant ($p < 0.05$), with formulation P1 showing significantly higher drug release compared to others ($p < 0.01$).

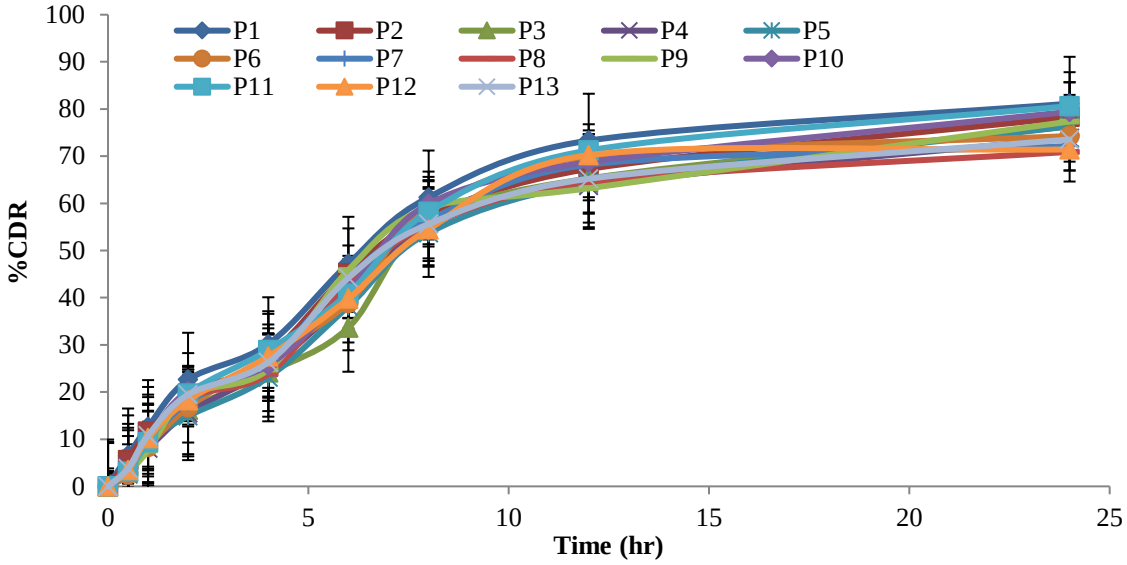


Figure 5: *In Vitro* Drug Release of all formulations. Data are expressed as mean ± SD (n=3)

Release Kinetics of Optimized Formulation

The release kinetics of the medication from the transdermal patch of the enhanced formulation (P1) were assessed using kinetic models to examine the cumulative release data.

Table 7: Models and their R^2 values of optimized formulation (P1)

Formulation	Zero order (R2)	First order (R2)	Higuchi (R2)	Korsmeyer Peppas(R2)
P1	0.7969	0.909	0.935	0.9677

Stability Studies

The formulated patch was subjected to specified conditions for a set period, after which it was tested against the criteria listed in Table 8.

Table 8: Stability Study of Optimized Oxaprozin Transdermal Patch (P1)

Formulation	Duration	Appearance	Surface pH	% DC
P1	3 months	No change	7.2	94.45

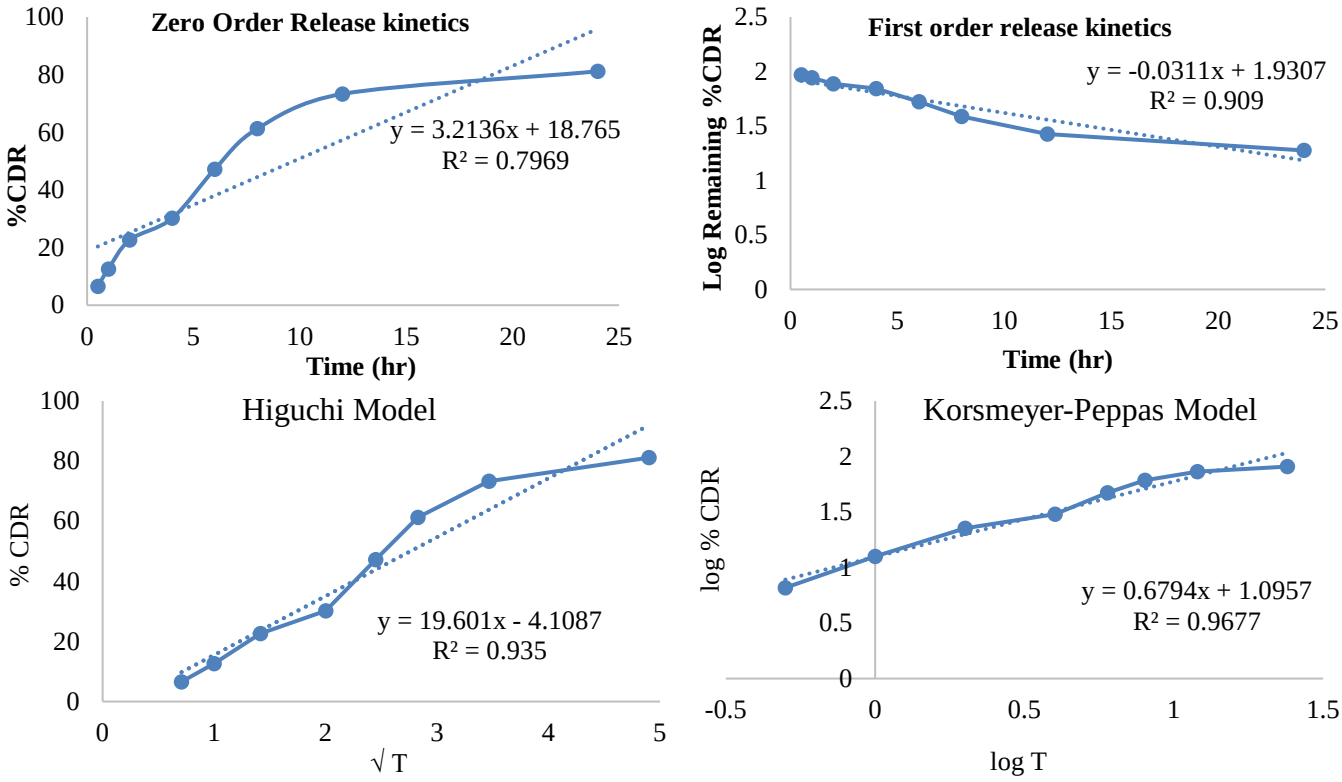


Figure 6: *In vitro* release kinetics of Optimized Formulation (P1)

CONCLUSION

Comprehensive preformulation and formulation studies of the anti-inflammatory drug oxaprozin have demonstrated its compatibility, stability, and suitability for transdermal delivery. The drug, classified as BCS Class II, showed favorable physicochemical properties and solubility in various solvents. FTIR analysis confirmed the absence of significant interactions with excipients, thereby validating the use of polymers such as HPMC and PVP. The prepared transdermal patches, produced by the solvent casting method, were thoroughly evaluated and found to exhibit uniformity in thickness, weight, surface pH, drug content, and physical properties. Among the tested formulations, P1 was the most effective, exhibiting optimal drug-release characteristics. These findings firmly establish that oxaprozin-loaded transdermal patches, particularly the P1 formulation, offer a promising, controlled, and stable therapeutic system for the effective management of inflammation. Future studies should include *in vivo* evaluation to establish clinical relevance.

FINANCIAL ASSISTANCE

NIL

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

The study was conceptualized and designed by Mansi Gupta, who also conducted the experimental procedures, collected and analyzed the data, and drafted the initial manuscript. Priya Tiwari supported the development of the methodology, oversaw the project's progress, contributed to data interpretation, and thoroughly revised the manuscript for critical intellectual content. Both authors have reviewed and approved the final manuscript and take full responsibility for the integrity and accuracy of the work.

ABBREVIATIONS

OXA: Oxaprozin; HPMC: Hydroxypropylmethyl cellulose; UV: Ultra-violet Spectroscopy; FTIR: Fourier-Transform Infrared Spectroscopy; EC: Ethyl cellulose; PVP: Polyvinylpyrrolidone; DMSO: Dimethyl sulfoxide; PG: Propylene glycol; BCS: Biopharmaceutical Classification System; COX: Cyclooxygenase enzyme; RH: Relative humidity; R^2: Correlation coefficient.

REFERENCES

[1] Chavan YS. Development and Optimization of Transdermal Patches of Losartan Potassium. *Asian J. Pharm. Technol*., **15**, 119–26 (2025) https://doi.org/10.52711/2231-5713.2025.00020.

[2] Choudhury D, Dutta KN, Kalita R. A review on transdermal patches used as an anti-inflammatory agent. *Asian J Pharm Clin Res*, **14**, 21–6 (2021) http://dx.doi.org/10.22159/ajpcr.2021v14i12.43277.

[3] Anubha Dhuriya and Aaditya Singh. Evalaution of Antidepressant and Anxiolytic Activity of Oxaprozin in Swiss Albino Mice. *Int. J. Adv. Res.*, **11**, 295–304 (2023) https://dx.doi.org/10.21474/IJAR01/16880.

[4] Karim A, Noveck R, McMahon FG, Smith M, Crosby S, Adams M, Wilton J. Oxaprozin and piroxicam, nonsteroidal antiinflammatory drugs with long half-lives: effect of protein-binding differences on steady-state pharmacokinetics. *J. Clin. Pharmacol.*, **37**, 267–78 (1997) https://doi.org/10.1002/j.1552-4604.1997.tb04302.x.

[5] Aitipamula S, Wong ABH, Chow PS, Tan RBH. Novel solid forms of oxaprozin: cocrystals and an extended release drug–drug salt of salbutamol. *RSC Adv.*, **6**, 34110–9 (2016) https://doi.org/10.1039/C6RA01802E.

[6] Koli, Ramachandra, Phoolsingh Yaduwanshi. Jyotiram Sawale RS. Design And Evaluation Of Transdermal Drug Delivery System Of Selected Cardiovascular Drug. *African J. Biomed. Res.*, **26**, 457–66 (2023) https://doi.org/10.53555/AJBR.v26i3.7173.

[7] Wable SA, Pingale PL, Shinkar DM, Boraste SS, Amrutkar S V. Formulation, Optimization, and Evaluation of Transdermal Patches of Clotrimazole and Betamethasone Dipropionate for Candidiasis. *Res. J. Pharm. Technol.*, **17**, 4267–74 (2024) https://doi.org/10.52711/0974-360X.2024.00660.

[8] Purohit P V, Pakhar PS, Pawar VB, Dandade SS, Waghmare MS, Shaikh FA, Kale RH. Formulation and Comparative Evaluation of Naproxen-Based Transdermal Gels. *J. Pharm. Sci. Comput. Chem*, **1**, 83–105 (2025) https://doi.org/10.32553/ijmbs.v8i1.2765.

[9] Arya U, Malik JK. Preformulation studies of aceclofenac: Major part of formulation strategy. *EAS J Pharm Pharmacol*, **4**, 91–5 (2022) https://doi.org/10.36349/easjpp.2022.v04i06.001.

[10] Chopra N, Chaudhuri A, Kumar H, Gurjar A, Sharma N. Development and Characterization of Self-healing Transdermal Patch of Lidocaine for the Management of Pain. *Curr. Res. Pharm. Sci.*, 108–17 (2023) https://doi.org/10.24092/CRPS.2023.130204.

[11] Shehata TM, Mohafez O, Hanieh HN. Pharmaceutical formulation and biochemical evaluation of atorvastatin transdermal patches. *Indian J. Pharm. Educ. Res*, **52**, 54–61 (2018) https://doi.org/http://dx.doi.org/10.5530/ijper.52.1.6.

[12] Patel P, Ahir K, Patel V, Manani L, Patel C. Drug-Excipient compatibility studies: First step for dosage form development. *Pharma Innov.*, **4**, 14 (2015).

[13] Bhatia C, Sachdeva M, Bajpai M. Formulation and evaluation of transdermal patch of pregabalin. *Int. J. Pharm. Sci. Res.*, **3**, 569 (2012) http://dx.doi.org/10.13040/IJPSR.0975-8232.3(2).569-75.

[14] Jajoo VS, Shrirame DS, Sawale A V, Atram SC. Formulation and evaluation of Transdermal Patch for the treatment of Migraine. *J. Drug Deliv. Ther.*, **13**, 47–52 (2023) http://dx.doi.org/10.22270/jddt.v13i5.6072.

[15] Shelke P V, Rachh PR, Mankar SD, Gorde PL. Optimization and evaluation of transdermal delivery system for nebivolol hydrochloride. *J. Appl. Pharm. Res.*, **12**, 21–37 (2024) https://doi.org/10.69857/joapr.v12i3.580.

[16] Mo L, Lu G, Ou X, Ouyang D. Formulation and development of novel control release transdermal patches of carvedilol to improve bioavailability for the treatment of heart failure. *Saudi J. Biol. Sci.*, **29**, 266–72 (2022) https://doi.org/10.1016/j.sjbs.2021.08.088.

[17] Karnakoti A, Borade A, Birajdar P, Bodke V, Dagale M, Badekar R. Formulation and Evaluation of Transdermal Patch. *Int. J. Sci. Res. Technol.*, (2025) https://doi.org/10.5281/zenodo.14837862.

[18] Jacob L, Salim MS, Saju J. Formulation and evaluation of transdermal patches of selegiline. *Asian J. Pharm. Technol.*, **12**, 96–100 (2022) https://doi.org/10.52711/2231-5713.2022.00016.

[19] Sk V, Pashikanti S. Design , Development , and Evaluation of Transdermal Patches Containing Donepezil Hydrochloride. *Int. J. Drug Deliv. Technol.*, **13**, 576–83 (2023) https://doi.org/10.25258/ijddt.13.2.18.

[20] Nandi S, Mondal S. Fabrication and evaluation of matrix type novel transdermal patch loaded with tramadol hydrochloride. *Turkish J. Pharm. Sci.*, **19**, 572 (2022) https://doi.org/10.4274/tjps.galenos.2021.43678.

[21] Kumar M, Bose P, Singh AP, Singh AP. Formulation And Evaluation of Betulinic Acid Loaded Transdermal Patches. *J. Drug Deliv. Ther.*, **15**, 52–8 (2025) http://dx.doi.org/10.22270/jddt.v15i1.6951.

[22] Dhaval J. Patel, Saurav M. Patel, Sanjesh G. Rathi SKS. Formulation and Evaluation of Transdermal Patch of Blonanserin. *Int. J. Pharm. Sci. Rev. Res.*, **69**, 69–74 (2021) https://doi.org/10.47583/ijpsrr.2021.v69i02.011.

[23] Shoaib MH, Tazeen J, Merchant HA, Yousuf RI. Evaluation of drug release kinetics from ibuprofen matrix tablets using HPMC. *Pak. J. Pharm. Sci.*, **19**, 119–24 (2006).

[24] Ashok BK, Sominath WJ. Formulation and Evaluation of Transdermal Patches of Tridax Procumbenes for Anti-Inflammatory Activity. *Int. J. Pharm. Res. Appl.*, **9**, 1784–97 (2024) https://doi.org/10.35629/7781-090217841797.