

FORMULATION AND EVALUATION OF CURCUMIN TOPICAL HYDROGEL FOR SKIN DISEASE**Mohit Dangi, Reena Shende*, Satkar Prasad****RKDF School of Pharmaceutical Sciences, BHABHA University, Madhya Pradesh, India. 462026***Corresponding Author's E mail: emi_ryadav@yahoo.com

Received 4 Sept. 2025; Revised 6 Sept. 2025; Accepted 8 Oct. 2025, Available online 15 Oct. 2025



Cite this article as: Dangi M, Shende R and Prasad S. Formulation and evaluation of curcumin topical hydrogel for skin disease. Asian Journal of Pharmaceutical Education and Research. 2025; 13(4): 80-96.

<https://dx.doi.org/10.38164/AJPER/14.4.2025.80-96>

ABSTRACT

Curcumin, a natural polyphenolic compound derived from *Curcuma longa*, possesses well-documented anti-inflammatory, antioxidant, antimicrobial, and wound healing properties. However, its clinical utility is significantly limited by poor water solubility, low chemical stability, and minimal bioavailability. To address these challenges, this study explores the formulation of a curcumin-loaded hydrogel for effective topical delivery. The aim of this research was to develop and evaluate a hydrogel-based delivery system capable of enhancing the solubility, stability, and localized skin delivery of curcumin for potential therapeutic use in inflammatory and infectious skin conditions. A hydrogel formulation containing 0.75, 1.0 and 1.25% carbopol 940 was prepared using Carbopol 940, incorporating curcumin. The formulation was characterized for its physicochemical properties, including pH, viscosity, spreadability, extrudability and drug content. In vitro drug release and skin permeation studies were conducted using Franz diffusion cells. The optimized curcumin hydrogel demonstrated favorable physicochemical properties, sustained drug release over 8 h, and enhanced skin permeation compared to curcumin suspension. The developed curcumin-loaded hydrogel offers a promising platform for topical delivery, overcoming the inherent limitations of curcumin and providing controlled release and targeted action. This formulation may serve as an effective therapeutic strategy for treating skin disorders.

Keywords: Curcumin; Topical hydrogel; Skin disease; Skin permeation.

INTRODUCTION

Curcumin, the principal bioactive compound derived from the rhizome of *Curcuma longa*, has been extensively studied for its diverse pharmacological properties, including anti-inflammatory, antioxidant, antimicrobial, and anticancer effects. Despite its broad therapeutic potential, the clinical application of curcumin remains limited due to its poor aqueous solubility, low chemical stability, and rapid metabolic degradation, resulting in minimal systemic bioavailability¹⁻³.

Topical drug delivery offers a promising alternative to oral administration, particularly for the management of localized skin disorders. However, delivering lipophilic compounds like curcumin through the skin barrier presents significant formulation challenges. To overcome these limitations, hydrogels have emerged as a versatile platform for topical drug delivery. Hydrogels are three-dimensional, hydrophilic polymeric networks capable of absorbing substantial amounts of water or biological fluids without dissolving. Their high biocompatibility, non-greasy texture, ease of application, and ability to provide a moist wound environment make them particularly suitable for dermatological use^{4,5}.

Incorporating curcumin into a hydrogel matrix not only enhances its solubility and stability but also facilitates controlled and sustained drug release at the site of action. This can significantly improve therapeutic efficacy while minimizing systemic exposure and side effects. Recent advances in hydrogel technology—such as bioadhesive, stimuli-responsive, and nanostructured hydrogels—further enhance their potential for effective dermal delivery of curcumin⁶.

This research aims to develop and characterize a curcumin-loaded hydrogel formulation intended for topical application in the treatment of inflammatory and infectious skin conditions. The study focuses on evaluating the physicochemical properties, in vitro drug release profile, skin permeation, and biological efficacy of the formulation, offering a potential strategy to maximize the therapeutic benefits of curcumin through a novel delivery system.

MATERIALS AND METHODS

Materials

Curcumin ($\geq 94\%$ pure) was purchased from Sigma-Aldrich, USA, while Carbopol 940 and Triethanolamine (TEA) were obtained from Himedia; ethanol (analytical grade), from [Supplier Name]. Glycerin, distilled water, and phosphate-buffered saline (PBS, pH 7.4) as well as the dialysis membrane (MWCO 12–14 kDa), were all sourced from SD Fine.

Methods

Preformulation studies

Organoleptic properties

Organoleptic features of drug Curcumin were differentiated according to their odor, color, and description⁸.

Determination of melting point

Melting point equipment was used to measure the melting point of Curcumin. A little quantity of medication was inserted in a capillary tube, sealed on one end, and then placed in a melting point device, and the melting point temperature was recorded⁹.

Analytical method validation

Preparation of stock solution

A precise amount of 100 mg of curcumin was accurately weighed and transferred into a 100 mL volumetric flask. Methanol was added up to the mark to prepare a stock solution with a concentration of 1 µg/mL. From this stock, aliquots of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, and 0.7 mL were withdrawn and each was diluted to 10 mL with methanol to obtain standard solutions with final concentrations of 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, and 0.07 µg/mL, respectively¹⁰⁻¹².

Preparation of standard dilutions

An accurately weighed 1 mg of curcumin was transferred into a 100 mL volumetric flask, and methanol was added up to the calibration mark to prepare the solution. The resulting solution was then used for further analysis¹⁰⁻¹².

Determination of absorption maxima (λ max)

For determination of λ max 0.5 µg/ml solution of curcumin was scanned in the 800–200 nm wavelength range using methanol as a blank in a UV spectrophotometer. The wavelength of 424 nm was found to correlate to curcumin's maximum absorbance in methanol¹⁰⁻¹².

Preparation of standard calibration curve of curcumin by UV visible Spectroscopy

The standard calibration curve of curcumin was obtained by measuring the absorbance of curcumin solution in concentration range (0.01-0.07µg/mL) prepared from stock solutions in methanol at 424 nm in triplicate. Calibration curve of curcumin was then plotted with absorbance on y-axis and curcumin concentration on x-axis¹⁰⁻¹².

Solubility and partition coefficient analysis

A little amount of the sample was weighed out and put in a test tube, and then a known volume of the solvent was added to the tube to determine the sample's solubility. After each addition, the system is shaken violently and checked visually for any particles of undissolved solute¹⁴.

Drug excipients interaction study by FTIR

an accurately weighed 10 mg of KBr was added with the medication and excipients and mashed them up in a mortar to see if the drug and polymer used to form the hydrogel would be compatible. An FTIR Spectrophotometer was used to measure a small sample of the triturated material that was placed on the sample holder and measured between 4000 and 400 cm^{-1} . By comparing the spectra to the peaks found in the FTIR analysis of the pure drug sample, interactions between the drug and the excipient was examined¹³.

Preparation of hydrogels

The hydrogel uses Carbopol 940 as cross-linker & gelling agent was prepared using chemical cross-linking method. Dissolve 0.5 g of curcumin powder in 5 mL of ethanol to make a concentrated solution. Dissolve 5 g of Carbopol 940 in 100 mL of distilled water while stirring. The curcumin solution was mixed with Carbopol 940 solution thoroughly. 0.1 mL of triethanolamine was added drop wise into the mixture with continuous stirring to crosslink the polymer chains and forms a hydrogel. The hydrogel was washed several times with distilled water to remove any residual crosslinking agent. Air drying of the hydrogel in a sterile environment was done. The different formulation was prepared using different concentration of curcumin drug¹⁵.

Evaluation parameters of test drug.

Physical appearance

The color of the formulations was checked against black and white background. The odor of the hydrogels was checked by mixing a little amount of gel in water and by taking smell of it. Consistency of the formulations was checked by applying the hydrogel on to the skin. All the formulations was tested for occurrence of any aggregate by visual inspection after the gels have been set in the container. Greasiness was checked by applying the formulations on to the skin¹⁶.

pH determination-

pH of the formulations was determined by using digital pH meter. The formulation was taken into the beaker, then pH meter is immersed into the formulation and reading were recorded. Same process was repeated three times with the same formulations and average of three was taken as pH. Similar procedure was used for the determination of pH of all formulations¹⁷.

Viscosity and rheological behavior

Brookfield viscometer was used to determine the viscosity of gel formulations at 50rpm for 3 minutes with spindle 6 and results were noted in mPaS¹⁸.

Spreadability

Spreadability was determined by apparatus suggested by Mutimer *et al.* 1956 with slight modification, which is suitably modified in the laboratory and used for the study. It consists of a wooden block, which is provided by a pulley at one end. By this method, spreadability is measured on the basis of 'Slip' and 'Drag' characteristics of gels. A ground glass slide is fixed on this block. An excess of Gel (about 2 gm) under study is placed on this ground slide. The Hydrogel was sandwiched between this slide and another glass slide having the dimension of fixed ground slide and provided with the hook. A 1 Kg weight was placed on the top of the two slides for 5 minutes to expel air and to provide a uniform film of the Gel between the slides. Excess of the Gel was scrapped off from the edges. The top plate was subjected to pull of 80 gm. With the help of string attached to the hook and the time (in seconds) required by the top slide to cover a distance of 7.5 cm be noted. A shorter interval indicates better spreadability. Spreadability was calculated by using the formula¹⁹.

$$S = M.L / T$$

Where, S = spreadability, M = Weight tied to upper slide, L = Length of glass slides, T = Time taken to separate the slides completely from each other.

Extrudability

Accurately weighed quantity (20 g) of the hydrogel packed in a closed collapsible tube and pressed at the crimped end firmly using a clamp in order to prevent roll back. The cap was opened and the release of the hydrogel was allowed for extrudability. The extruded gel was collected and analyzed for its weight. The extrudability in % was calculated²⁰.

Drug content

0.1 ml of formulation was dissolved in 10 ml of ethanol completely to obtain the stock solution. 1ml from the stock solution is further diluted with ethanol up to 10ml and absorbance was measured spectrophotometrically at 424 nm. Drug content was then calculated²¹.

In vitro Drug release study

In vitro release study of formulated hydrogel was carried out using Franz Diffusion cell with effective diffusional surface area of 1.71 cm² and a receptor cell volume of 25 ml. The receptor compartment was filled with dissolution medium consisting of phosphate buffer pH 5.5 and 1.5% polysorbate 80, and temperature was maintained at 32 °C (in-simulation to skin pH and temperature). The cellulose acetate membrane (Sigma Aldrich, Germany) with a pore size of 0.45 µm will be fixed between the donor and receptor compartment. The donor compartment was charged with 1mg of hydrogel. 2 mL volume of sample was collected from the receptor compartment at predetermined time intervals, i.e., 0, 0.5, 1, 2, 4, 8, 12, 16, 20 and 24 h. The amount of Curcumin in the samples was analyzed using a UV–Visible spectrophotometer UV 1800, Shimadzu at a wavelength of 424 nm. The experiment was performed in duplets and the results were averaged²².

Stability study testing:

The International Conference on Harmonisation has established specific requirements and protocols for conducting short-term studies. The accelerated stability testing study for the topical hydrogel formulations was done for duration of 3 months as per ICH guidelines. Accurately weighed quantities of 5.0 g of the 1% curcumin topical hydrogel formulations were packed in an amber colored bottle. The bottles were charged in humidity cum stability chamber (3 in one units in one with individual humidity and temperature controller, Technico, India) at 40±2 °C and 75±5% RH. Sampling was done at 0, 15, 30 and 90 days interval and tested for appearance, spreadability, drug assay²³.

RESULTS AND DISCUSSION

Preformulation studies

Analytical method validation

With the use of a UV-Visible Spectrophotometer, the wavelength of maximum absorbance, or λ_{max} , for drug curcumin in methanol was identified. A prepared solution that had a concentration of 10 µg/mL was scanned between 200 - 400 nm. The 424 nm maximum was noted (Figure 1). For subsequent investigation of absorption for concentrations ranging from 0.01 to 0.07 µg/mL (Table 1), observed absorption maxima, or max 424 nm, were employed. The concentration range for the linear plot was 0.02 to 0.07 µg/mL, and the correlation coefficient (r^2) value was shown to be 0.9978 (Figure 2).

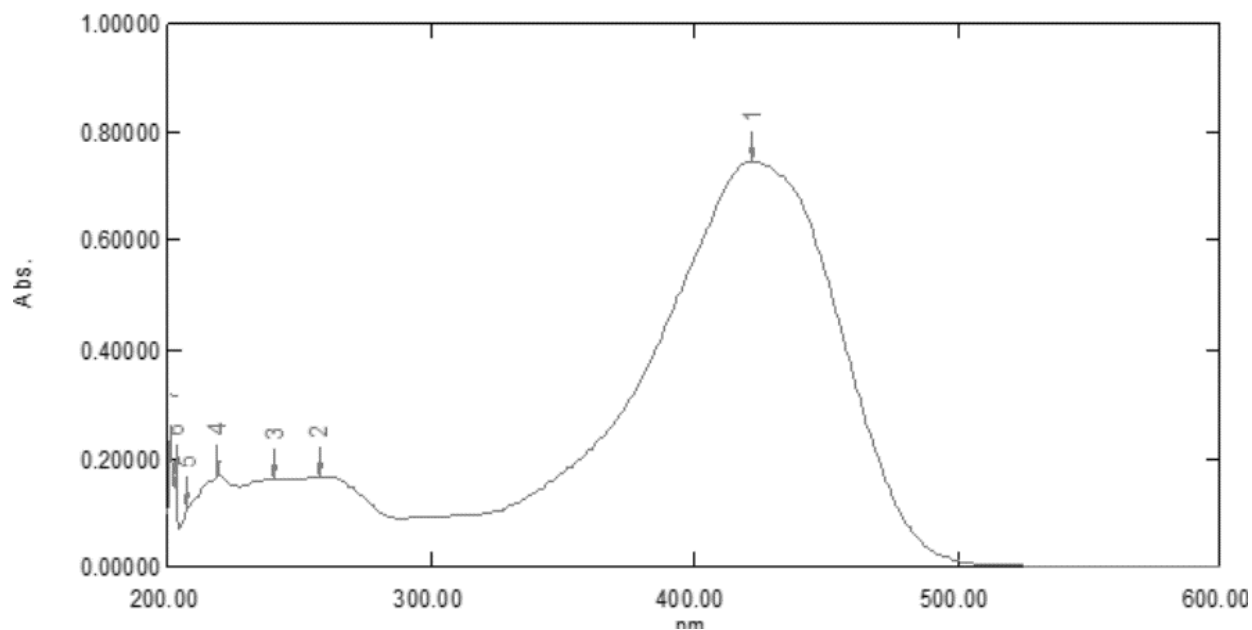


Figure 1: Absorbance of curcumin at 425 nm

Table 1: Absorbance of Curcumin at different concentrations

Sr.no	Concentration (µg/ml)	Absorbance
1.	0	0
2.	0.01	0.1
3.	0.02	0.214
4.	0.03	0.323
5.	0.04	0.428
6.	0.05	0.522
7.	0.06	0.61
8.	0.07	0.692
9.	0.08	0.785

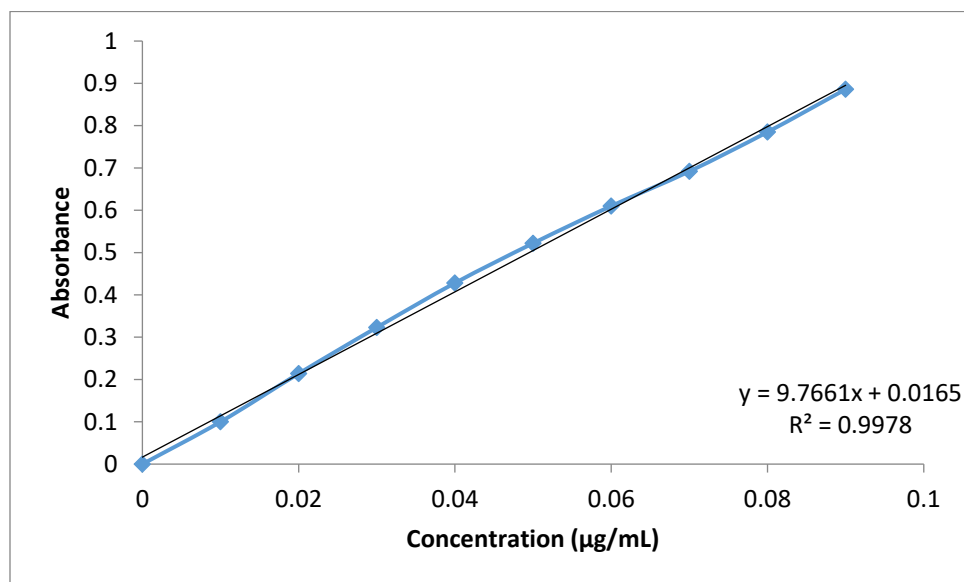


Figure 2: Calibration curve of Herbal drug Curcumin

Melting point, solubility and partition coefficient

The melting point of the sample was determined using the capillary method and found to be **177 °C (Table 2)**, which is consistent with the reported melting point range of curcumin, indicating purity and crystalline nature of the compound. Curcumin exhibited poor solubility in aqueous media, consistent with its hydrophobic nature. The partition coefficient (log P) of curcumin was determined using the shake-flask method between n-octanol and water and was found 2.95 (Table 2). This value indicates that curcumin is lipophilic, favoring partitioning into lipophilic (oil-based) phases, which affects its absorption and bioavailability.

Table 2: Observation table for melting point determination of phytochemicals

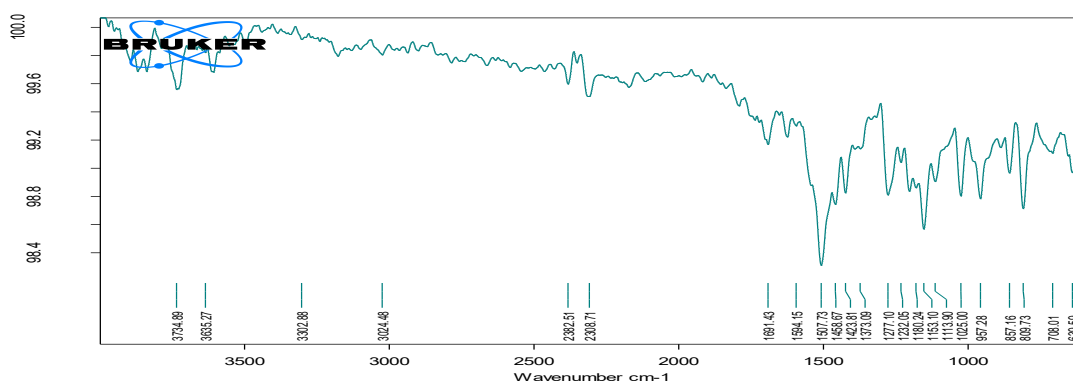
S. No.	Phytochemical	Melting Point (°C)	Standard deviation	Reported MP (°C)	Avg (µg/mL)	Reported value (µg/mL)	P avg.	Reported value
1	Curcumin	177	± 0.94	170-180 ²¹	0.218±0.006	<0.6 ²²	2.95±0.15	3.25 ²³

Drug-excipient interaction study

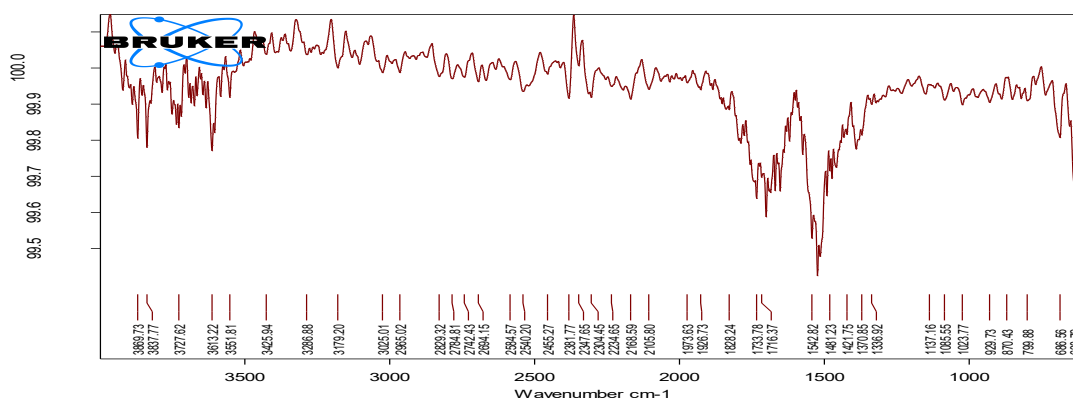
Key peaks expected for curcumin near $\sim 3500\text{--}3200\text{ cm}^{-1}$ for broad peak due to --OH stretching (phenolic hydroxyl groups); $\sim 1625\text{--}1600\text{ cm}^{-1}$: $\text{C}=\text{C}$ and $\text{C}=\text{O}$ stretching from the conjugated diketone and aromatic system; $\sim 1500\text{--}1420\text{ cm}^{-1}$: Aromatic $\text{C}\text{--}\text{C}$ stretching; $\sim 1275\text{--}1200\text{ cm}^{-1}$: $\text{C}\text{--}\text{O}$ stretching (phenolic and methoxy groups); $\sim 1020\text{--}1000\text{ cm}^{-1}$: $=\text{C}\text{--}\text{H}$ bending and $\text{C}\text{--}\text{O}\text{--}\text{C}$ symmetric stretching.

Whereas, for Carbopol (a crosslinked polyacrylic acid) shows peak near $\sim 3400\text{--}3200\text{ cm}^{-1}$: Broad O–H stretching (from carboxylic acid groups); $\sim 1700\text{--}1725\text{ cm}^{-1}$: Sharp peak due to C=O stretching of –COOH; $\sim 1450\text{--}1400\text{ cm}^{-1}$: C–H bending; $\sim 1250\text{--}1150\text{ cm}^{-1}$: C–O stretching (Figure 3a & 3b).

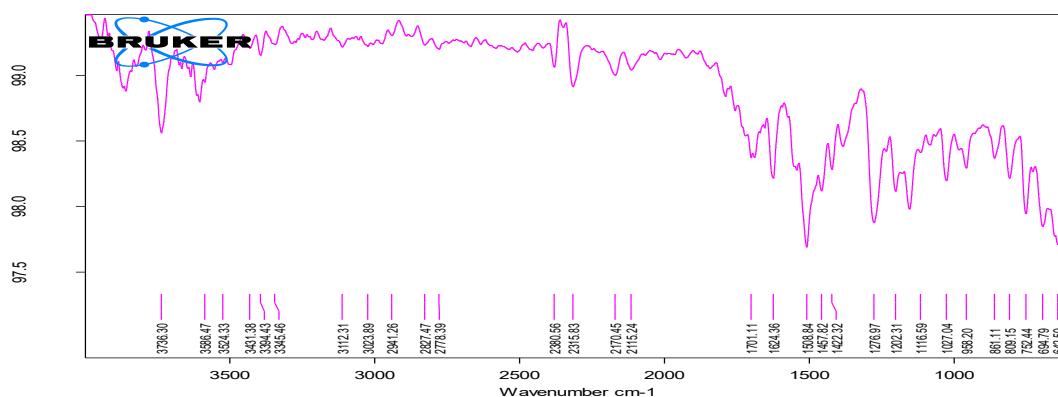
When curcumin is mixed with Carbopol it shift in O–H stretching region ($\sim 3200\text{--}3500\text{ cm}^{-1}$): A shift to lower wavenumbers or broadening may indicate hydrogen bonding between the hydroxyl groups of curcumin and the carboxylic groups of Carbopol. Reduction or broadening of C=O peak ($\sim 1700\text{ cm}^{-1}$): Suggests interaction between curcumin's keto groups and Carbopol's carboxyl groups. Decrease in the intensity of curcumin's aromatic C=C or C=O peaks may indicate molecular dispersion or complexation within the polymer matrix (Figure 3c). No new peaks appear and only shifts or intensity changes were observed, it suggested physical interaction (e.g., hydrogen bonding or dispersion), not covalent bond formation. The FTIR spectrum of the curcumin-Carbopol mixture likely indicates hydrogen bonding interactions between the hydroxyl/keto groups of curcumin and the carboxylic acid groups of Carbopol. This can improve curcumin's stability and dispersibility within the polymer matrix, which is important for drug delivery applications.



a.



b



c

Figure 3: FTIR spectrum of a. curcumin, b. carbopol 940 and c. physical mixture of curcumin and carbopol 940

Preparation and optimization of topical hydrogel

Table 3 shows the results of various physicochemical properties of the blank polymeric hydrogels made with different concentrations (0.25%–2.0%) of polymers. Among all tested polymer proportions, 0.75, 1.0, and 1.25% w/w of Carbopol 940, were determined as the optimized amounts for preparing blank polymeric hydrogel, as it demonstrated improved physicochemical properties.

Formulation of hydrogels loaded with curcumin was executed with the optimized concentrations of polymers as found during the formulation optimization. Methanol was used to dissolve the phytochemicals before adding to final formulation. Triethanolamine was used as a neutralizing agent for the hydrogel made with carbopol 940, while methyl and propyl paraben were utilized as preservatives. Propylene glycol was used to enhance solvent property for hydrogels prepared with carbopol 940 (Table 4)

Table 3: Optimization of polymeric concentration for blank hydrogel.

S. No.	Concentration	Sensitivity	Homogeneity	Grittiness	Appearance	pH ±SD	Viscosity (%torque)	Spreadability ±SD
1	0.25	non irritant	present	absent	Less opaque, translucent, viscous gel	8.3 ±0.12	61.6	7.2±0.5
2	0.5	non irritant	Present	absent	Less opaque, translucent,	6.04±0.03	30.3	12.3±0.1

3	0.75	non irritant	Present	absent	viscous gel Colorless, translucent, viscous gel	6.1± 0.17	42.8	10.7± 0.2
4	1.0	non irritant	Present	absent	Colorless, translucent, viscous gel	6.31± 0.58	47.0	9.1± 0.6
5	1.25	non irritant	Present	absent	Colorless, translucent, viscous gel	5.15± 0.04	51.0	6.0± 0.05
6	1.50	non irritant	Present	absent	Colorless, clear translucent, viscous gel	6.19± 0.04	70.8	6.8± 0.8
7	1.75	non irritant	Present	absent	Colorless, clear translucent, viscous gel	4.52± 0.03	58.8	7.6± 0.25
8	2.0	non irritant	present	absent	Colorless, clear translucent, viscous gel	5.02± 0.02	64.10	8.3± 0.236

Table 4: Formula for preparation of topical hydrogel.

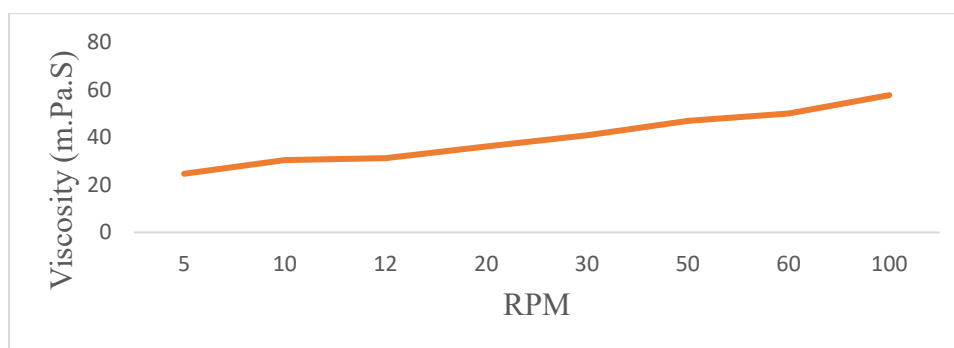
S.No	Ingredient	THGL1	THGL2	THGL3
1	Curcumin	10mg	10mg	10mg
2	Carbopol 940	750mg	1000mg	1250mg
3	Triethanolamine	q.s	q.s	q.s
4	Methyl paraben	0.1	0.1	0.1
5	Propyl paraben	0.02	0.02	0.02
6	Ethanol	5 ml	5 ml	5 ml
7	Purified water	100gm	100gm	100gm

Table 5: pH determination

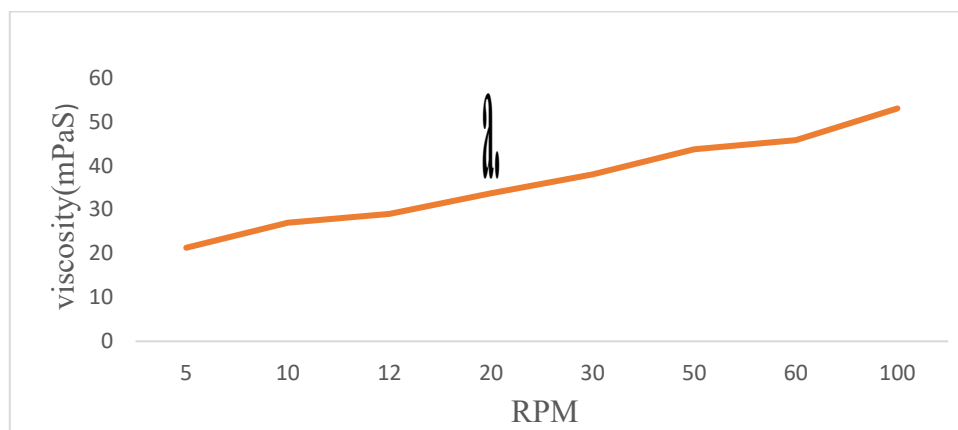
Formulation code	Appearance	Sensitivity	Homogeneity	Grittiness	pH	Viscosity (mPaS)	Spreadability(cm)	Extrudability
THGL1	colorless, less translucent	non irritating	present	Absent	6.21±0.5	34240	8.8±0.4	72.25±1.5
THGL2	colorless	non irritating	present	absent	6.67±0.5	37600	6.2±0.6	65.45±0.75
THGL3	colorless	non irritating	present	absent	5.19±0.5	40800	6.8±0.5	62.21±0.52

Rheological study

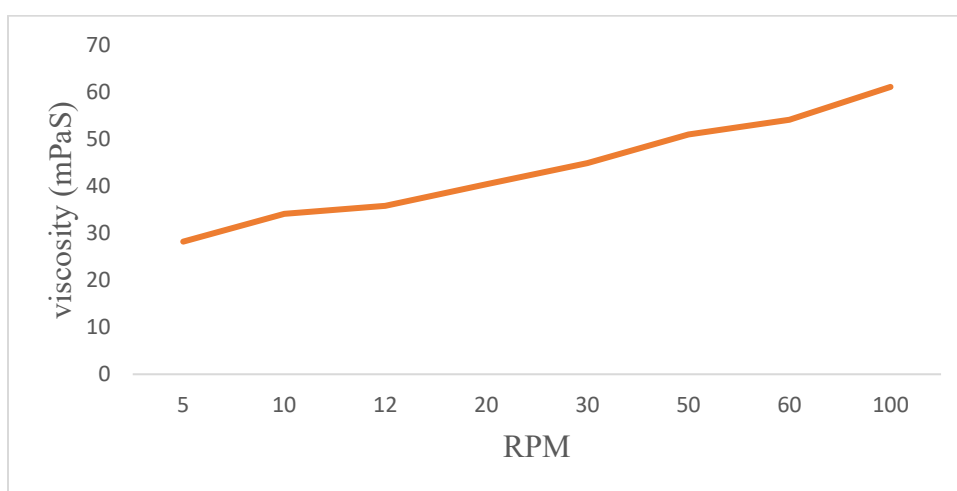
The hydrogel exhibited non-Newtonian, pseudoplastic (shear-thinning) behavior, as evidenced by a decrease in viscosity with increasing shear rate (Figure 4). This behavior is typical of Carbopol-based hydrogels and is desirable for topical formulations, as it allows easy spreading under applied force while maintaining structure at rest.



a.



b.



c.

Figure 4: Rheological curves for the topical hydrogel formulation a. THGL1, b. THGL2 and c. THGL3

In-vitro drug release study:

The cumulative amount of curcumin permeated through the dialysis membrane over 8 hours was measured and plotted as a function of time (Figure 5). The curcumin-loaded hydrogel demonstrated a sustained and efficient permeation profile across the membrane, with release governed primarily by diffusion-controlled mechanisms. These results support its potential for topical therapeutic applications.

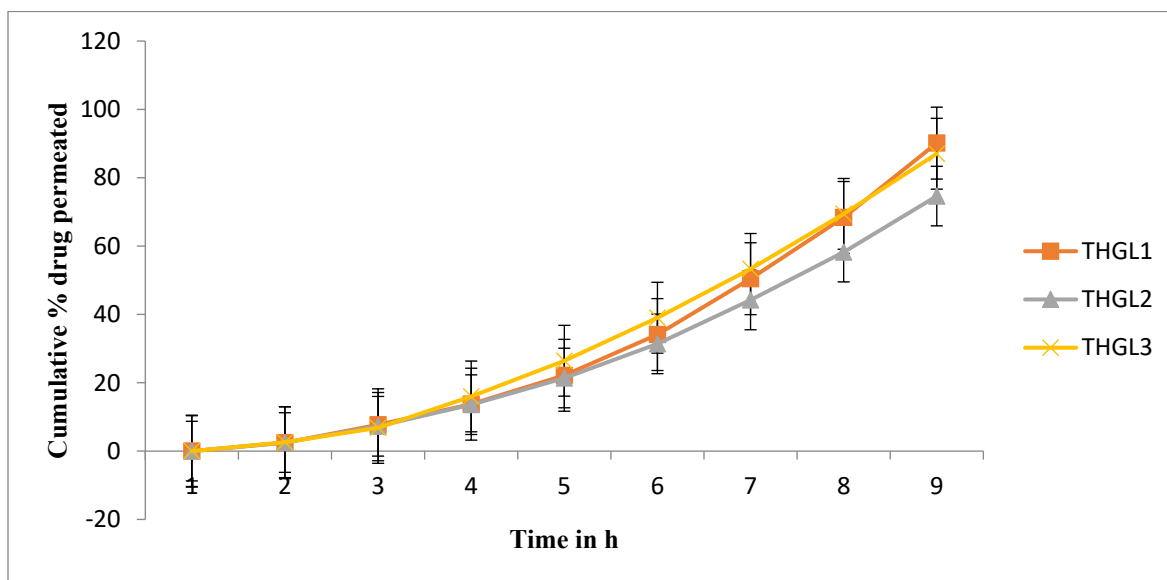


Figure 5: In-vitro drug release profile for the formulations THGL1 (0.75% carbopol), THGL2 (1.0% carbopol) and THGL3 (1.25% carbopol)

Stability study

The topical hydrogel formulation remained physically and chemically stable over 3 months at refrigerated and room temperature conditions, with minor changes in pH, viscosity, and drug content (Table 6). However, accelerated conditions (40 °C) led to noticeable degradation, suggesting that cool storage is optimal for maintaining formulation stability.

Table 6: Study of accelerated stability testing of THGL 2

Time (Days)	Appearance	Homogeneity	Grittiness	pH (±SD)	Viscosity (mPaS) (±SD)	Spreadability (±SD)	Assay (±SD)
0	Translucent viscous gel	Present	Absent	6.82±0.05	31423±114.90	17.51±0.30	99.13±0.33
10	Translucent viscous gel	Present	Absent	6.84±0.07	31696±383.14	17.36±0.49	97.29±0.34
15	Translucent viscous gel	Present	Absent	6.75±0.03	31667.67±222.82	16.88±0.57	95.33±0.74
30	Translucent viscous gel	Present	Absent	6.89±0.03	31803±168.25	16.20±0.57	93.32±0.63
90	Translucent viscous gel	Present	Absent	6.94±0.05	31670±111.86	15.83±0.58	91.32±0.49

CONCLUSION

The present study successfully formulated and evaluated a topical hydrogel containing curcumin using Carbopol 940 as the gelling agent. The hydrogel exhibited desirable physicochemical properties, including suitable pH, homogeneity, spreadability, and viscosity, making it appropriate for topical application. In vitro drug release and permeation studies demonstrated a sustained release profile and efficient skin permeation, indicating potential for prolonged therapeutic action. The rheological analysis confirmed non-Newtonian, pseudoplastic behavior, which is favorable for ease of application and retention on the skin. Furthermore, the stability study over a period of three months confirmed that the formulation remained physically and chemically stable under refrigerated and room temperature conditions, with only minor changes observed under accelerated conditions. The formulated hydrogel shows promise as a stable, effective, and patient-friendly delivery system for curcumin in topical therapeutic applications, warranting further in vivo and clinical evaluations.

ACKNOWLEDGEMENTS

Authors are thankful to the RKDF School of Pharmaceutical Sciences, BHABHA University, Madhya Pradesh, India for providing the necessary facilities for the current research work.

References

1. Algahtani MS, Ahmad MZ, Nouredin IH, Albarqi HA, Alyami HS, Alyami MH, Alqahtani AA, Alasiri A, Algahtani TS, Mohammed AA, Ahmad J. Preparation and characterization of curcumin nanoemulgel utilizing ultrasonication technique for wound healing: In vitro, ex vivo, and in vivo evaluation. *Gels*. 2021 Nov 14;7(4):213.
2. Kesharwani P, Jain A, Srivastava AK, Keshari MK. Systematic development and characterization of curcumin-loaded nanogel for topical application. *Drug development and industrial pharmacy*. 2020 Sep 1;46(9):1443-57.
3. Terzopoulou Z, Michopoulou A, Palamidi A, Koliakou E, Bikiaris D. Preparation and evaluation of collagen-based patches as curcumin carriers. *Polymers*. 2020 Oct 17;12(10):2393.
4. Jeengar MK, Rompicharla SV, Shrivastava S, Chella N, Shastri NR, Naidu VG, Sistla R. Emu oil based nano-emulgel for topical delivery of curcumin. *International journal of pharmaceutics*. 2016 Jun 15;506(1-2):222-36.

5. Khawar MI, Mahmood A, Nabi D. Exploring the role of octanol-water partition coefficient and Henry's law constant in predicting the lipid-water partition coefficients of organic chemicals. *Scientific Reports*. 2022 Sep 2;12(1):14936.
6. Navdeep S, Kamya G, Shivi S, Shammy J. Development and characterization of Barbaloin Gel for the safe and effective treatment of Psoriasis. *Journal of Drug Delivery & Therapeutics*. 2020;10(5):188-97.
7. Veseli A, Kristl A, Akelj S. Proof-of-concept for a miniaturized shake-flask biopharmaceutical solubility determination by sonic mixing. *Die Pharmazie-An International Journal of Pharmaceutical Sciences*. 2020 Dec 1;75(12):626-31.
8. Plöger GF, Hofsäss MA, Dressman JB. Solubility determination of active pharmaceutical ingredients which have been recently added to the list of essential medicines in the context of the biopharmaceutics classification system–biowaiver. *Journal of Pharmaceutical Sciences*. 2018 Jun 1;107(6):1478-88.
9. Yalkowsky SH, Alantary D. Estimation of melting points of organics. *Journal of pharmaceutical sciences*. 2018 May 1;107(5):1211-27.
10. Baluja S, Kulshrestha A, Movalia J. 1-Octanol-water partition coefficient of some cyanopyridine and chalcone compounds. *Revista Colombiana de Ciencias Químico-Farmacéuticas*. 2017 Dec;46(3):342-56.
11. Rizvi DA, Fatima Z, Kaur CD. Antipsoriatic and anti-inflammatory studies of *Berberis aristata* extract loaded nanovesicular gels. *Pharmacognosy magazine*. 2017 Sep 8;13(Suppl 3):S587.
12. Ali Karami M, Sharif Makhmalzadeh B, Pooranian M, Rezai A. Preparation and optimization of silibinin-loaded chitosan–fucoidan hydrogel: An in vivo evaluation of skin protection against UVB. *Pharmaceutical Development and Technology*. 2021 Feb 7;26(2):209-19.
13. Chidambaram M, Krishnasamy K. Drug-drug/drug-excipient compatibility studies on curcumin using non-thermal methods. *Advanced pharmaceutical bulletin*. 2014 Feb 7;4(3):309.
14. Narang AS, Rao VM, Raghavan KS. Excipient compatibility. In: *Developing solid oral dosage forms* 2009 Jan 1 (pp. 125-145). Academic Press.
15. Dejeu IL, Vicaş LG, Vlaia LL, Jurca T, Mureşan ME, Pallag A, Coneac GH, Olariu IV, Muţ AM, Bodea AS, Dejeu GE. Study for evaluation of hydrogels after the incorporation of liposomes embedded with caffeic acid. *Pharmaceuticals*. 2022 Jan 31;15(2):175.
16. Narayana S, Nasrine A, Ahmed MG, Sultana R, Gowda BJ, Surya S, Almuqbil M, Asdaq SM, Alshehri S, Hussain SA. Potential benefits of using chitosan and silk fibroin topical hydrogel for

- managing wound healing and coagulation. *Saudi Pharmaceutical Journal*. 2023 Mar 1;31(3):462-71.
17. Woodruff CM, Botto N. The role of patch testing in evaluating delayed hypersensitivity reactions to medications. *Clinical reviews in allergy & immunology*. 2022 Jun;62(3):548-61.
 18. Nair AB, Shah J, Aljaeid BM, Al-Dhubiab BE, Jacob S. Gellan gum-based hydrogel for the transdermal delivery of nebivolol: Optimization and evaluation. *Polymers*. 2019 Oct 16;11(10):1699.
 19. Khanna K, Sharma D, Khar RK, Karwasra R, Sharma N, Nishad DK, Bhatnagar A, Popli H. A comparative study of chitosan gel and soframycin in the management of wounds. *The International Journal of Lower Extremity Wounds*. 2020 Jun;19(2):148-57.
 20. Osmani RA, Aloorkar NH, Ingale DJ, Kulkarni PK, Hani U, Bhosale RR, Dev DJ. Microsponges based novel drug delivery system for augmented arthritis therapy. *Saudi pharmaceutical journal*. 2015 Oct 1;23(5):562-72.
 21. Lee SC, Gillispie G, Prim P, Lee SJ. Physical and chemical factors influencing the printability of hydrogel-based extrusion bioinks. *Chemical reviews*. 2020 Aug 20;120(19):10834-86.
 22. Ghazwani M, Vasudevan R, Kandasamy G, Hani U, Niharika G, Naredla M, Devanandan P, Puvvada RC, Almehizia AA, Hakami AR, Dhurke R. Development and In Vitro Characterization of Antibiotic-Loaded Nanocarriers for Dental Delivery. *Molecules*. 2023 Mar 24;28(7):2914.
 23. Maske PP, Lokapure SG, Nimbalkar D, Malavi S, D'souza JI. In vitro determination of sun protection factor and chemical stability of *Rosa kordesii* extract gel. *Journal of Pharmacy Research*. 2013 Jun 1;7(6):520-4.