iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VII **Month of publication:** July 2026

DOI: https://doi.org/10.22214/ijraset.2026.84168

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

Formulation, Optimization and Evaluation of a pH-Sensitive Mucoadhesive Hydrogel for Ocular Delivery of Nepafenac

Ashwini Kolbhure[1], Dr. Vaishali Kate[2]
[1]*Student M.Pharm 2 yr, Department of Pharmaceutics, Dr. Vedprakash Patil Pharmacy College, Chh. Sambhajinagar, Maharashtra, India*
[2]*Assistant Professor, Department of Pharmaceutics, Dr. Vedprakash Patil Pharmacy College, Chh. Sambhajinagar, Maharashtra, India*

Abstract: ***Background: Conventional Nepafenac ophthalmic suspensions are limited by rapid tear turnover, blinking and nasolacrimal drainage, which shorten precorneal residence time and reduce ocular bioavailability. Objective: The present study aimed to formulate and evaluate a pH-sensitive mucoadhesive hydrogel of Nepafenac for prolonged ocular retention and sustained anti-inflammatory delivery. Methods: Nepafenac hydrogels were prepared using Carbopol 934P as a pH-responsive gelling polymer and HPMC K15M as a viscosity-enhancing mucoadhesive polymer. A two-factor, three-level experimental design was applied with Carbopol 934P and HPMC K15M as independent variables, and sol and gel viscosity as dependent responses. Formulations were evaluated for preformulation characteristics, UV analytical suitability, FTIR, DSC, pH, gelation time, viscosity, mucoadhesive strength, drug content, in vitro drug release, HET-CAM ocular irritation and short-term stability. Results: Nepafenac was a white, odorless, slightly bitter crystalline powder with a melting range of 178-182°C and UV absorption maximum at 238 nm. The calibration curve was linear over 2-10 µg/mL with a calculated equation of y = 0.04935x - 0.01390 (R^2 = 0.9833). FTIR peaks of the drug were retained in the mixture and the DSC endothermic peak shifted only slightly, supporting drug-excipient compatibility. The optimized batch F9 contained 100 mg Nepafenac, 350 mg Carbopol 934P and 500 mg HPMC K15M per 100 mL and showed pH 7.3, gelation time 30 s, sol viscosity 503 cps, gel viscosity 706 cps, mucoadhesive strength 615, drug content 97.3% and 98% cumulative drug release at 8 h. The formulation remained stable for 3 months and was non-irritant in the HET-CAM test. Conclusion: The optimized pH-sensitive Nepafenac hydrogel exhibited suitable physicochemical properties, sustained release, stability and ocular tolerability, suggesting its potential as an improved ophthalmic delivery system.***

Keywords: Nepafenac; pH-sensitive hydrogel; Mucoadhesive ocular delivery; Carbopol 934P; HPMC K15M; In situ gel; HET-CAM; Sustained release.

I. INTRODUCTION

Ocular drug delivery is a therapeutically important route for treating local eye conditions such as postoperative inflammation, pain and allergic or infectious disorders. Topical ophthalmic dosage forms are convenient and non-invasive, but their effectiveness is frequently limited by the protective anatomy and physiology of the eye. Tear turnover, blinking and nasolacrimal drainage dilute and eliminate a large fraction of the instilled dose within a short period, while the multilayered cornea provides both lipophilic and hydrophilic barriers to drug penetration [1-4].

Conventional eye drops and suspensions therefore often exhibit low ocular bioavailability and require repeated dosing. Frequent administration may reduce patient adherence, particularly in chronic therapy or postoperative care. In the case of non-steroidal anti-inflammatory drugs (NSAIDs), repeated dosing can also increase the risk of local irritation and systemic exposure through nasolacrimal drainage [5-8]. These limitations have encouraged the development of polymer-based in situ systems that can be administered as liquids and then transform into gels after contact with ocular fluids.

In situ hydrogels are three-dimensional hydrophilic polymer networks capable of absorbing aqueous fluid while maintaining a semi-solid structure. pH-sensitive systems are especially suitable for ocular use because they remain fluid before instillation and rapidly gel at tear pH. Carbopol, a cross-linked polyacrylic acid polymer, undergoes swelling and chain expansion at physiological pH, while HPMC improves viscosity, mucoadhesion and formulation stability. The combination of a pH-responsive polymer with a mucoadhesive viscosity enhancer can improve precorneal residence time and support sustained drug release [9-12].

©IJRASET: All Rights are Reserved

Nepafenac is an ophthalmic NSAID prodrug that penetrates ocular tissues and is converted to amfenac, an active metabolite that inhibits COX-mediated prostaglandin synthesis. It is commonly used for ocular pain and inflammation, particularly after cataract surgery. However, the poor residence time of conventional topical formulations can restrict local availability. The present work was therefore designed to formulate, optimize and evaluate a pH-sensitive mucoadhesive hydrogel of Nepafenac using Carbopol 934P and HPMC K15M as critical formulation variables.

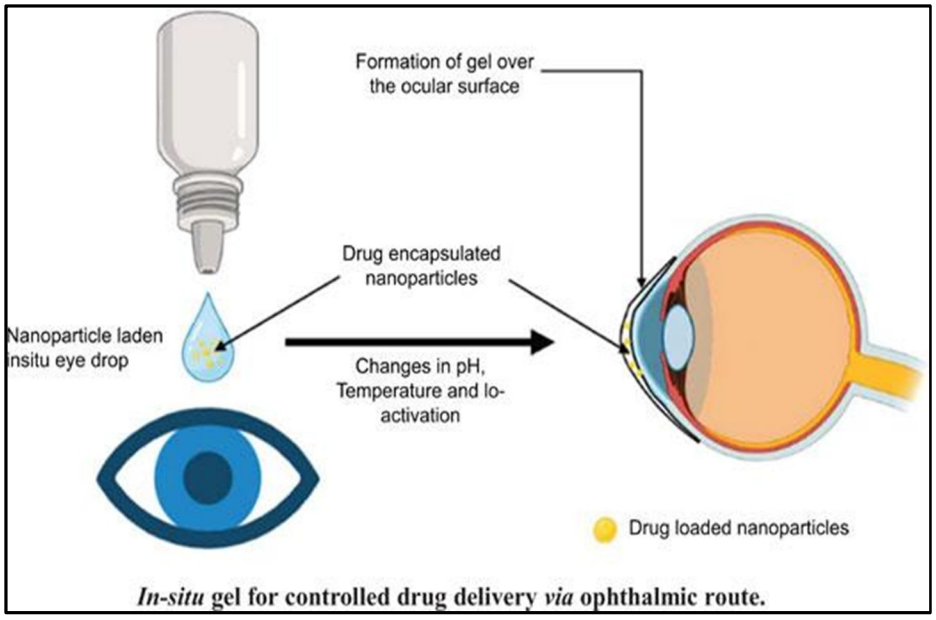


Figure 1. Principle of pH-sensitive in situ ocular hydrogel formation and controlled delivery.

II. MATERIALS AND METHODS

A. *Materials*

Nepafenac was used as the active pharmaceutical ingredient. Carbopol 940/934P was selected as the pH-sensitive gelling polymer and HPMC K15M as the viscosity-enhancing mucoadhesive polymer. Sodium chloride was used for tonicity adjustment, benzalkonium chloride as preservative and distilled water as vehicle. The thesis source listed Nepafenac as pharmaceutical grade from Shree Chemical, Khamgaon; Carbopol and sodium chloride from Loba Chem. Pvt. Ltd., Mumbai; and HPMC K15M from Fine Chem. Pvt. Ltd., Mumbai.

B. *Preformulation and Analytical Studies*

Nepafenac was examined for organoleptic properties, melting point and solubility in water, ethanol, methanol and phosphate buffer pH 7.4. For UV analysis, 10 mg Nepafenac was dissolved in methanol and diluted to obtain a 100 µg/mL stock solution. A 10 µg/mL working solution was scanned from 200 to 400 nm against methanol as blank to determine λmax. Calibration standards of 2, 4, 6, 8 and 10 µg/mL were prepared and analyzed at 238 nm.

C. *Drug-excipient Compatibility*

FTIR spectroscopy was performed for pure Nepafenac and physical mixtures of Nepafenac with selected excipients using KBr pellet method over the scanning range of 4000-400 cm^{-1}. Characteristic functional group peaks were compared to identify shifts, disappearance or new peak formation. DSC analysis was performed for pure drug and drug-excipient mixture in sealed aluminium pans under nitrogen at a heating rate of 10°C/min over 30-300°C.

D. *Experimental Design and Formulation Development*

A two-factor, three-level design was used to examine the effect of Carbopol 934P (X1) and HPMC K15M (X2) on the viscosity of sol and gel formulations. The tested Carbopol 934P concentrations were 250, 300 and 350 mg per 100 mL, and HPMC K15M concentrations were 400, 450 and 500 mg per 100 mL. Nine formulations (F1-F9) were prepared.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

Table 1. Composition of Nepafenac hydrogel formulations.

Batch	Nepafenac (mg)	Carbopol 934P (mg)	HPMC K15M (mg)	BAK (mg)	NaCl (mg)	Distilled water
F1	100	250	400	10	900	q.s. to 100 mL
F2	100	250	450	10	900	q.s. to 100 mL
F3	100	250	500	10	900	q.s. to 100 mL
F4	100	300	400	10	900	q.s. to 100 mL
F5	100	300	450	10	900	q.s. to 100 mL
F6	100	300	500	10	900	q.s. to 100 mL
F7	100	350	400	10	900	q.s. to 100 mL
F8	100	350	450	10	900	q.s. to 100 mL
F9	100	350	500	10	900	q.s. to 100 mL

E. Preparation of hydrogel

Carbopol 934P was slowly dispersed in distilled water under continuous stirring and allowed to hydrate for 24 h. HPMC K15M was separately dispersed in warm distilled water and allowed to swell completely. Nepafenac was dissolved in a small quantity of suitable co-solvent and added gradually to the polymeric dispersion with constant stirring. Benzalkonium chloride and sodium chloride were dissolved in distilled water and incorporated into the formulation. The pH was adjusted to 6.8-7.4 using triethanolamine, and the final volume was made up with distilled water. The prepared hydrogels were stored in sterile airtight containers for further evaluation.

F. Evaluation of hydrogel

Formulations were visually inspected for appearance, clarity, homogeneity and phase separation. pH was measured using a calibrated digital pH meter after dispersing hydrogel in simulated tear fluid. Sol and gel viscosity were determined using a Brookfield viscometer before and after gelation in simulated tear fluid. Gelation time was recorded by exposing formulations to simulated tear conditions. Mucoadhesive strength was determined using the interaction between mucin solution and formulation based on viscosity difference. Drug content was estimated after appropriate dilution and UV analysis at 238 nm.

In vitro drug release was studied using Franz diffusion cells with dialysis membrane and simulated tear fluid pH 7.4 as receptor medium at 37°C. Samples were withdrawn at predefined intervals up to 8 h and replaced with fresh medium. The HET-CAM assay was used to evaluate ocular irritation potential by observing hemorrhage, vascular lysis and coagulation after application of the optimized formulation to the chorioallantoic membrane. Stability studies were performed for the optimized formulation in sealed amber vials, and samples were evaluated for appearance, pH, viscosity, drug content and drug release over 3 months.

III. RESULTS AND DISCUSSION

A. Preformulation and Analytical Suitability

Nepafenac appeared as a white, odorless, slightly bitter crystalline powder. The melting point was observed in the range of 178-182°C. The drug was practically insoluble in water, slightly soluble in ethanol and phosphate buffer pH 7.4, and soluble in methanol. This solubility pattern justified the use of methanol for analytical stock preparation and the need for a polymeric ocular system to improve residence and release characteristics.

The UV spectrum showed a λmax at approximately 238 nm in methanol. The calibration response increased with concentration in the range of 2-10 µg/mL, and the calculated linear equation was $y = 0.04935x - 0.01390$ with $R^2 = 0.9833$, indicating acceptable linearity for drug content and release analysis.

Table 2. Preformulation, analytical and compatibility observations.

Parameter	Observation/result
Organoleptic properties	White, odorless, slightly bitter crystalline powder
Melting point	178-182°C
Solubility	Practically insoluble in water; slightly soluble in ethanol and phosphate buffer pH 7.4; soluble in methanol

UV λmax	238 nm in methanol
Calibration range	2-10 µg/mL; absorbance increased from 0.095 to 0.505
FTIR main peaks	3300 cm^{-1} (N-H), 3050 cm^{-1} (aromatic C-H), 1700 cm^{-1} (amide C=O), 1600 cm^{-1} (aromatic C=C), 1540 cm^{-1} (amide II), 1178 cm^{-1} (C-O)
DSC thermal event	Pure Nepafenac peak at 185.78°C; drug-excipient mixture peak at 189.18°C

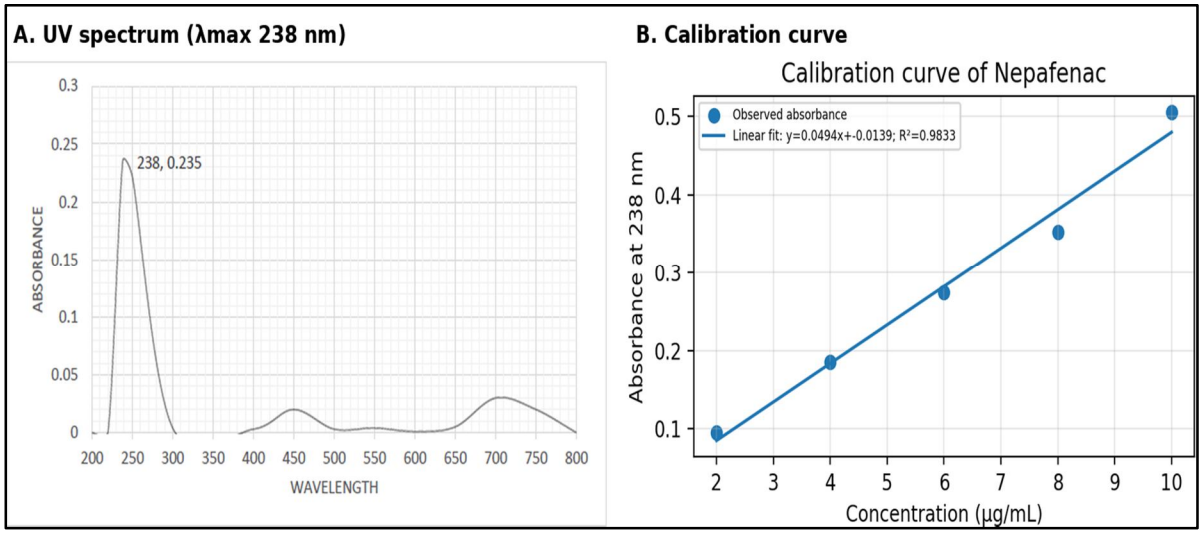


Figure 2. UV spectrum and calibration curve of Nepafenac.

B. Drug-excipient compatibility

FTIR spectra of Nepafenac showed characteristic bands corresponding to amide N-H stretching, aromatic C-H stretching, amide C=O stretching, aromatic C=C stretching, C-N stretching and C-O stretching. These characteristic peaks were retained in the drug-excipient mixture without the appearance of major new bands, indicating absence of significant chemical interaction. DSC thermograms supported the FTIR observation. The pure drug displayed a sharp endothermic peak at 185.78°C, while the physical mixture showed a broad but identifiable peak at 189.18°C. The minor shift and broadening were attributed to excipient dilution and heat distribution rather than incompatibility.

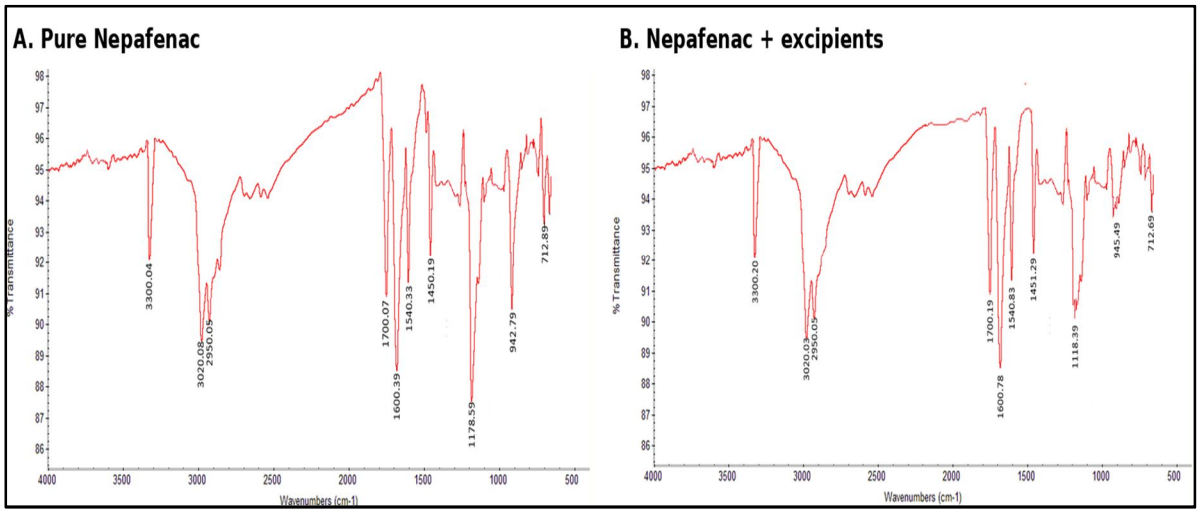


Figure 3. FTIR spectra of pure Nepafenac and Nepafenac-excipient mixture.

©IJRASET: All Rights are Reserved

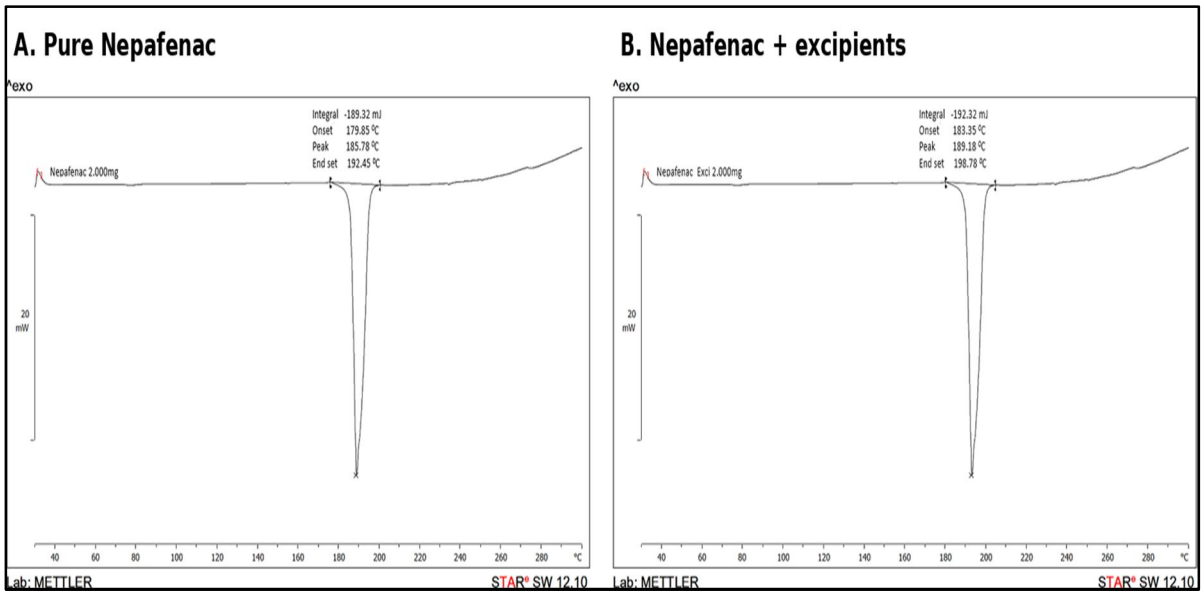


Figure 4. DSC thermograms of pure Nepafenac and Nepafenac-excipient mixture.

C. Preliminary and design-of-experiments optimization

Preliminary trials demonstrated a progressive increase in sol and gel viscosity with increasing polymer concentration. Sol viscosity increased from 390 cps in Run 1 to 610 cps in Run 5, while gel viscosity increased from 550 cps to 780 cps. This confirmed the viscosity-enhancing contribution of HPMC K15M and the gel-structuring effect of Carbopol 934P.

Table 3. Summary of DOE model interpretation.

Response	Model	Model statistics	Significant terms	Interpretation
Viscosity (sol)	Quadratic model	$F = 455.17$; $p < 0.0001$	A-Carbopol 934P, A^2 and B^2 significant	Carbopol had the dominant influence on sol viscosity
Viscosity (gel)	Linear model	$F = 8.80$; $p = 0.0076$	A-Carbopol 934P significant	Carbopol primarily controlled gel viscosity; HPMC supported consistency
Practical selection	Batch evaluation	F9 showed highest overall performance	Carbopol 350 mg + HPMC 500 mg	Selected for final evaluation based on viscosity, mucoadhesion, drug content and release

The response surface plots revealed that increasing Carbopol 934P markedly increased sol viscosity and contributed to gel viscosity. HPMC K15M gave an additional viscosity-building and stabilizing effect. A practical optimum was selected based on a balance between syringeable sol viscosity, post-gelation strength, mucoadhesive behavior and sustained drug release.

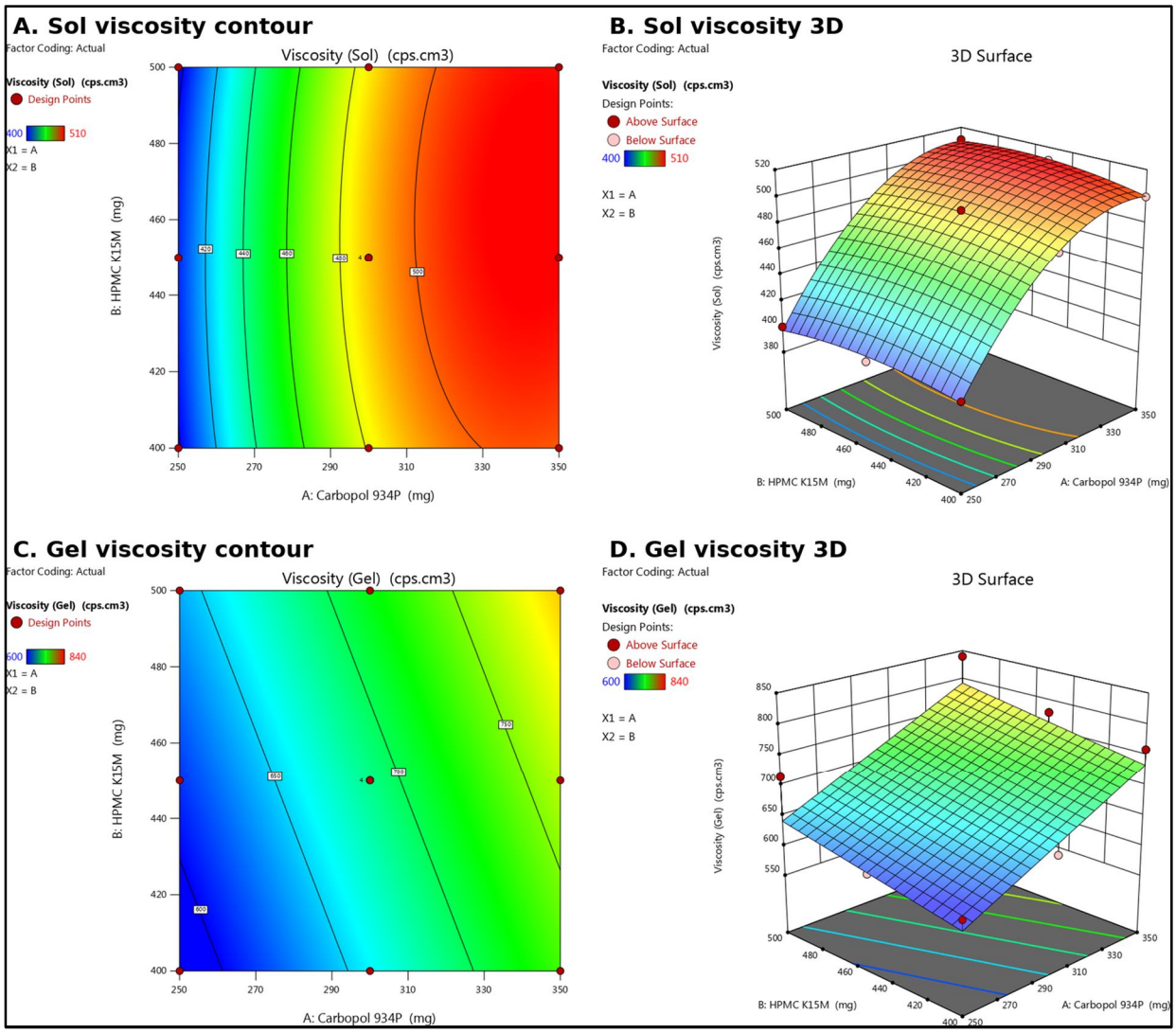


Figure 5. Contour and three-dimensional response surface plots for sol and gel viscosity.

D. Evaluation of Nepafenac hydrogel formulations

All formulations were clear, colorless, homogeneous and free from phase separation, showing good physical acceptability for ocular use. pH values ranged from 6.9 to 7.3, which is close to ocular physiological pH and may minimize irritation. Gelation time ranged from 22 to 30 s, indicating rapid transformation from sol to gel under simulated tear conditions. Viscosity data showed acceptable sol viscosity for administration and higher gel viscosity after gelation, which is essential for precorneal retention.

The evaluation data of batches F1–F9 shows that all formulations had acceptable physicochemical characteristics for ocular in situ hydrogel delivery of Nepafenac. The pH of the formulations ranged from 6.9 to 7.3, which is close to the physiological pH of tear fluid and therefore suitable for ocular application without causing significant irritation. Gelation time increased gradually from 22 seconds in F1 to 30 seconds in F9, indicating that the formulations were able to convert from sol to gel within a short time after administration. This rapid gelation is important because it helps the formulation remain on the ocular surface and reduces drainage through tear fluid.

The sol viscosity ranged from 425 to 503 cps, showing that the formulations remained pourable and easy to instill before gel formation. After gelation, viscosity increased from 615 to 706 cps, confirming formation of a stronger gel matrix. Higher gel viscosity helps prolong precorneal residence time and supports sustained drug release. Mucoadhesive strength also increased from 400 in F1 to 615 in optimized F9, suggesting improved adhesion of the gel to the ocular mucosal surface. This property is beneficial for reducing dosing frequency and improving drug absorption. Drug content was found between 90% and 97.3%, indicating good drug uniformity among the prepared batches.

The percentage drug release at 8 hours increased from 86% in F1 to 98% in F9, showing that formulation optimization improved release performance. Among all batches, F9 was selected as the optimized formulation because it showed suitable pH, acceptable gelation time, highest sol and gel viscosity, maximum mucoadhesive strength, highest drug content, and maximum drug release. Overall, the results confirm that optimized batch F9 has desirable characteristics for sustained ocular delivery of Nepafenac.

Table 4. Physicochemical and release evaluation of Nepafenac hydrogel formulations.

Batch	pH	Gelation time (s)	Sol viscosity (cps)	Gel viscosity (cps)	Mucoadhesive strength	Drug content (%)	Release at 8 h (%)
F1	6.9	22	480	652	400	90	86
F2	7.0	23	485	615	420	91	88
F3	7.0	25	490	650	460	92	90
F4	7.1	24	490	670	510	91	91
F5	7.1	26	500	688	500	94	92
F6	7.2	27	450	685	515	95	93
F7	7.2	28	425	632	525	94	94
F8	7.1	29	487	695	558	95	95
F9 optimized	7.3	30	503	706	615	97.3	98

The optimized F9 formulation exhibited the highest mucoadhesive strength (615), highest drug content (97.3%) and maximum 8 h drug release (98%). The increased polymer concentration in F9 provided sufficient gel structure for retention while still allowing efficient drug diffusion. The release profile suggested sustained delivery over 8 h, which may reduce dosing frequency compared with conventional ophthalmic suspensions.

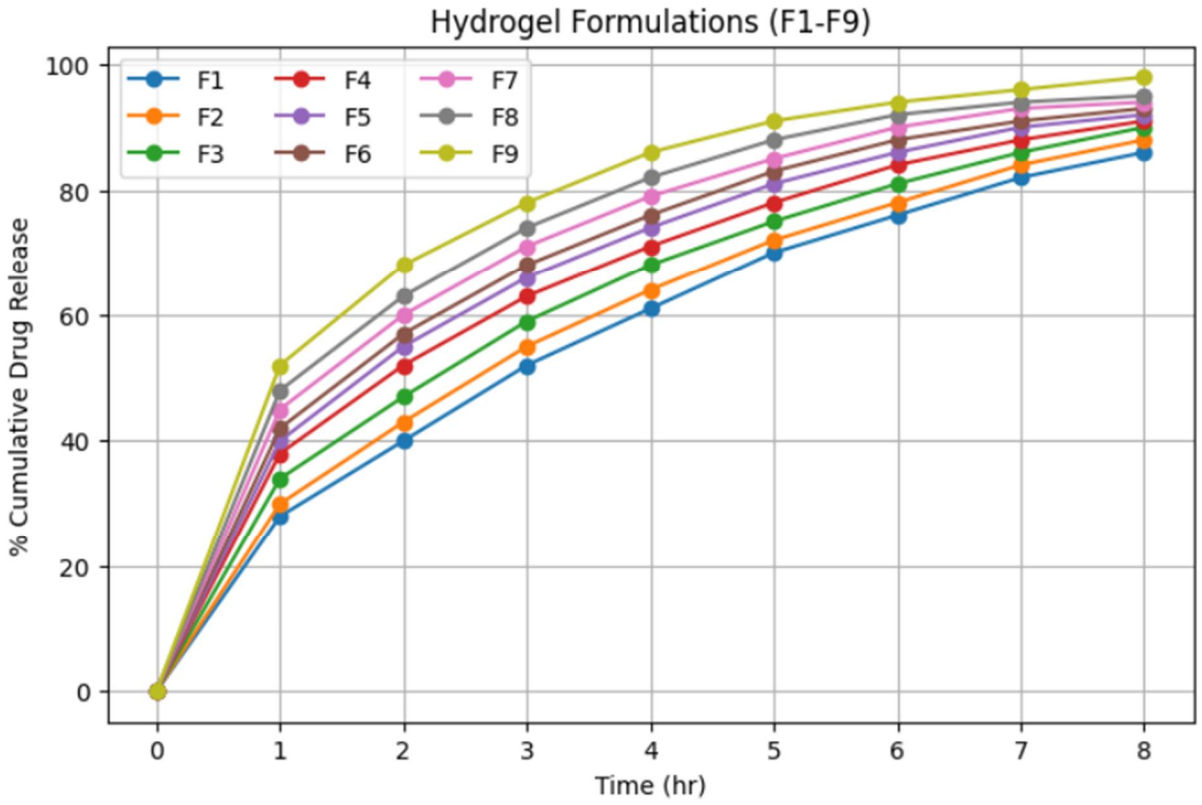


Figure 6. In vitro cumulative drug release profiles of Nepafenac hydrogel formulations.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

E. Ocular irritation and stability

The HET-CAM assay showed that the optimized Nepafenac hydrogel produced no hemorrhage, lysis or coagulation on the CAM surface. The formulation was classified as non-irritant with a score of 0.0-0.9, whereas the positive control produced severe irritation. This result supports the ocular compatibility of the pH-adjusted hydrogel matrix.

Table 5. HET-CAM ocular irritation observations.

Sample	Hemorrhage	Lysis	Coagulation	Response	Score	Classification
Positive control (0.1 N NaOH)	Severe	Severe	Severe	Strong irritation	15.0-21.0	Severe irritant
Optimized Nepafenac ocular hydrogel	Absent	Absent	Absent	No irritation	0.0-0.9	Non-irritant

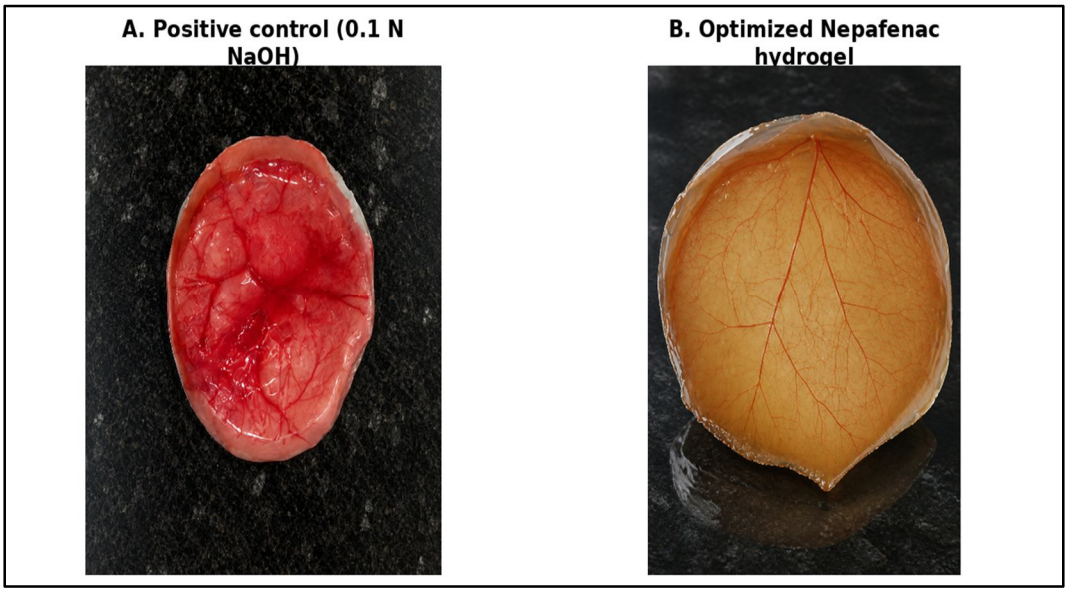


Figure 7. HET-CAM observation of positive control and optimized Nepafenac hydrogel.

Table 6. Short-term stability data of optimized Nepafenac hydrogel.

Parameter	1 month	2 months	3 months
Physical appearance	Clear, colorless	Clear, colorless	Clear, colorless
pH	7.32	7.31	7.30
Viscosity (cps)	503	502	500
Drug content (%)	97.1	97.7	97.0
Drug release (%)	99.98	99.8	99.8
Odor/color change	None	None	None
Overall stability	Stable	Stable	Stable

The optimized formulation remained physically stable during the stability study. pH decreased only slightly from 7.32 to 7.30, viscosity remained close to 500 cps and drug content remained around 97%. No odor, color change or phase separation was observed. The formulation therefore maintained its physicochemical and release performance under the tested conditions.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

F. Comparison with marketed formulation

Table 7. Comparative evaluation of prepared Nepafenac hydrogel and marketed preparation.

Parameter	Prepared Nepafenac hydrogel	Marketed preparation (Nevanac®)	Comparative observation
Dosage form	Hydrogel	Ophthalmic suspension	Hydrogel showed improved gel consistency and retention potential
Appearance	Clear, transparent, colorless	Slightly translucent suspension	Hydrogel exhibited better clarity
pH	7.30	7.28	Both were ocular-compatible
Viscosity	500 cps	495 cps	Slightly higher viscosity may improve residence time
Drug content	97.0%	96.5%	Prepared hydrogel showed good uniformity
Drug release	99.8%	98.9%	Hydrogel exhibited sustained release behavior
Phase separation	Absent	Slight settling possible	Hydrogel showed better physical stability
Therapeutic implication	Sustained and prolonged effect	Conventional release	Hydrogel may reduce dosing frequency

The comparative evaluation indicates that the prepared Nepafenac hydrogel showed better performance than the marketed preparation, Nevanac® ophthalmic suspension, particularly in terms of clarity, physical stability, retention potential, and sustained drug release. The prepared formulation was a clear, transparent, colorless hydrogel, whereas the marketed preparation was a slightly translucent suspension. This suggests that the hydrogel had better visual clarity, which is important for ocular preparations because it may reduce discomfort and blurring after instillation.

Both formulations showed ocular-compatible pH values, with the prepared hydrogel having a pH of 7.30 and Nevanac® showing 7.28. These values are close to tear fluid pH and indicate that both formulations are likely to be well tolerated by the eye. The viscosity of the prepared hydrogel was 500 cps, slightly higher than the marketed preparation at 495 cps. This small increase in viscosity may be beneficial because it can improve the residence time of the formulation on the ocular surface and reduce rapid drainage through tears.

The drug content of the prepared hydrogel was 97.0%, compared with 96.5% for the marketed formulation, indicating good uniformity and efficient drug incorporation. Drug release from the hydrogel was 99.8%, slightly higher than the marketed preparation at 98.9%. More importantly, the hydrogel showed sustained release behavior, which may help maintain therapeutic drug levels for a longer duration. The absence of phase separation in the hydrogel also confirms better physical stability, while the suspension may show slight settling during storage. Overall, the prepared Nepafenac hydrogel demonstrated improved clarity, stability, drug uniformity, and sustained release compared with Nevanac®. These properties suggest that the hydrogel formulation may provide prolonged ocular retention, better therapeutic efficacy, and reduced dosing frequency.

IV. CONCLUSION

A pH-sensitive mucoadhesive hydrogel of Nepafenac was successfully formulated using Carbopol 934P and HPMC K15M. The optimized F9 formulation showed acceptable ocular pH, rapid gelation, suitable sol and gel viscosity, strong mucoadhesion, high drug content and sustained in vitro drug release. FTIR and DSC studies confirmed compatibility between Nepafenac and selected excipients. HET-CAM testing indicated that the optimized formulation was non-irritant, while stability testing showed maintenance of appearance, pH, viscosity, drug content and release performance for 3 months. The developed formulation may serve as a promising ocular delivery platform for prolonged Nepafenac therapy. Further work should include sterility assurance, preservative efficacy testing, ex vivo corneal permeation, in vivo ocular residence studies, pharmacokinetic assessment and clinical evaluation.

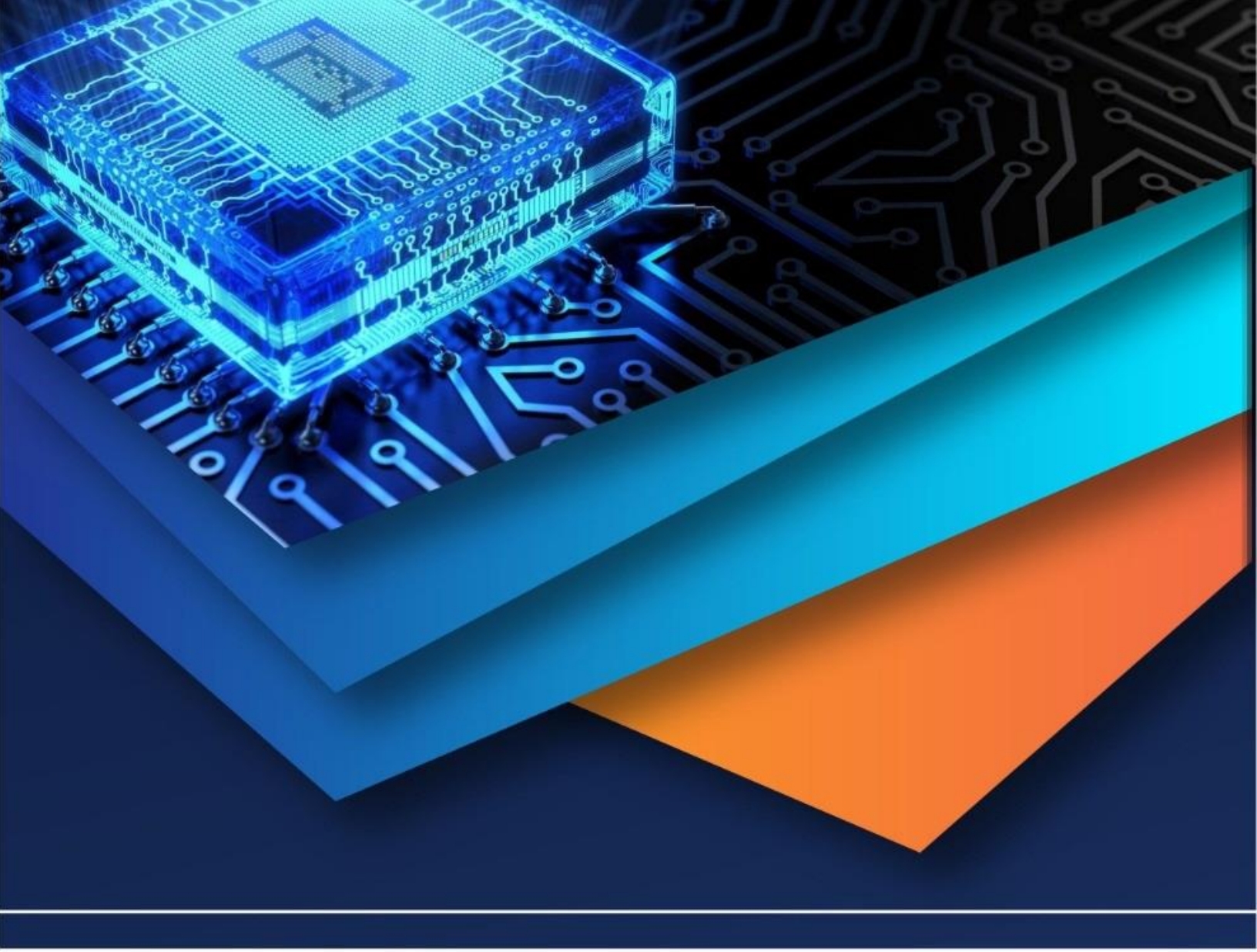
©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

A. Declarations

1) Acknowledgement: The author acknowledges the guidance, laboratory facilities and institutional support of Dr. Vedprakash Patil Pharmacy College, Chh. Sambhajinagar. This manuscript was prepared from the submitted thesis data.
2) Funding: No external funding was reported.
3) Conflict of interest: The author declares no conflict of interest.
4) Ethics statement: No human participants or clinical trial subjects were involved. Ocular irritation was assessed using the HET-CAM model as described in the thesis.
5) Data availability: All relevant formulation and evaluation data used to prepare this manuscript are included in the article and were derived from the submitted thesis.

REFERENCES

[1] Bhattarai N, Gunn J, Zhang M. Chitosan-based hydrogels for controlled, localized drug delivery. Adv Drug Deliv Rev. 2010;62:83-99.
[2] Deligkaris K, Tadele ST, Olthuis W, van den Berg A. Hydrogel-based devices for biomedical applications. Sens Actuators B Chem. 2010;147:765-774.
[3] Nie J, Pei B, Wang Z, Hu Q. Construction of ordered structure in polysaccharide hydrogel: A review. Carbohydr Polym. 2019;205:225-235.
[4] Ashique S, Aqil M, Imam SS, Ahad A. Processed excipients in ocular drug delivery systems: applications in hydrogels and ocular inserts. Drug Deliv Transl Res. 2024;14:1-18.
[5] Gupta H, Aqil M, Khar RK, Ali A. Cellulosic polymers in ocular drug delivery: current status and future perspectives. Int J Biol Macromol. 2021;183:1201-1215.
[6] Irimia T, Dinu-Pirvu CE, Ghica MV, Lupuleasa D. Chitosan-based in situ gels and nanoparticles for ocular drug delivery applications. Mar Drugs. 2018;16:380-395.
[7] Shaik MR, Vaka SRK, Dudhipala N. Optimization of thermosensitive in situ gel of bromofenac sodium using factorial design. Saudi Pharm J. 2017;25:1132-1141.
[8] Haddad NM, Farooq AV, Patel S, Singh K. NSAIDs versus corticosteroids for postoperative inflammation after cataract surgery: a systematic review and meta-analysis. J Cataract Refract Surg. 2024;50:1-10.
[9] Patel D, Shah P, Patel J. Formulation and evaluation of bromofenac sodium-loaded Pluronic F127 nanomicelles for ocular delivery. J Drug Deliv Sci Technol. 2022;72:103402.
[10] Lee RM, Blair J. Dexamethasone intracanalicular insert for postoperative ocular pain and inflammation management. Clin Ophthalmol. 2020;14:1235-1244.
[11] Alshammari A, Ahmed M, Khan R, El-Sayed H. Development of dual-phase ocular inserts containing bromofenac-loaded PLGA microspheres for sustained anti-inflammatory delivery. Int J Pharm. 2025;650:123456.
[12] Li Q, Li Z, Zeng W, et al. Proniosome-derived niosomes for tacrolimus topical ocular delivery: in vitro cornea permeation, ocular irritation, and in vivo anti-allograft rejection. Eur J Pharm Sci. 2014;62:115-123.
[13] Jiao J. Polyoxyethylated nonionic surfactants and their applications in topical ocular drug delivery. Adv Drug Deliv Rev. 2008;60:1663-1673.
[14] Mahale NB, Thakkar PD, Mali RG, Walunj DR, Chaudhari SR. Niosomes: novel sustained release nonionic stable vesicular systems - an overview. Adv Colloid Interface Sci. 2012;183:46-54.
[15] Yin H, Gong C, Shi S, Liu X, Wei Y, Qian Z. Toxicity evaluation of biodegradable and thermosensitive PEG-PCL-PEG hydrogel as a potential in situ sustained ophthalmic drug delivery system. J Biomed Mater Res B Appl Biomater. 2009;92:129-137.
[16] Marianecci C, Rinaldi F, Mastriota M, et al. Anti-inflammatory activity of novel ammonium glycyrrhizinate/niosomes delivery system: human and murine models. J Control Release. 2012;164:17-25.
[17] Mehta SK, Jindal N. Tyloxapol niosomes as prospective drug delivery module for antiretroviral drug nevirapine. AAPS PharmSciTech. 2014;16:67-75.
[18] Bayindir ZS, Besikci A, Yuksel N. Paclitaxel-loaded niosomes for intravenous administration: pharmacokinetics and tissue distribution in rats. Turk J Med Sci. 2015;45:1403-1412.
[19] Pooprommin T, Srikhao N, Chaiyana W. Alginate-pectin hydrogel films incorporated with mangosteen extract-loaded niosomes for wound dressing applications. Int J Biol Macromol. 2022;200:100-112.
[20] Sharma UK, Verma A, Kaur I. Formulation and evaluation of positively charged amikacin-loaded polymeric nanoparticles for ocular drug delivery. Colloids Surf B Biointerfaces. 2015;135:137-145.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)