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Research Paper

Formulation Design and Optimization of Ketoprofen-Loaded Polysaccharide Hydrogels Patch Containing Ketoprofen for Topical Anti-Inflammatory Therapy

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ABSTRACT

The present study focuses on the formulation and evaluation of polysaccharide based hydrogel patches containing Ketoprofen for topical anti inflammatory therapy. Natural polymers Pullulan and Guar gum were employed as the polymeric matrix due to their biocompatibility, biodegradability, and excellent gel forming ability [1]. Hydrogel patches were prepared by solution polymerization using cross linkers and evaluated for physicochemical parameters including thickness, weight uniformity, folding endurance, moisture content, drug content uniformity, and in vitro drug release[2]. All formulations exhibited satisfactory appearance, flexibility, and skin compatibility. Among the developed formulations, the optimized batch demonstrated balanced physicochemical characteristics, satisfactory mechanical strength, appropriate moisture retention, and sustained drug release behavior.(3,4,5). The incorporation of Ketoprofen provided beneficial anti inflammatory properties, while the polysaccharide matrix ensured prolonged hydration and patient comfort. The study concluded that the developed polysaccharide hydrogel patch could serve as a promising wound dressing and topical NSAID delivery system.(6)

INTRODUCTION

Topical drug delivery systems play a crucial role in innovative drug delivery approaches, offering localized treatment while minimizing systemic exposure [7].Hydrogels, three-dimensional hydrophilic polymer networks, are capable of absorbing and retaining substantial amounts of water or biological fluids, making them highly biocompatible and suitable for biomedical applications [8].Natural polysaccharides such as Pullulan and Guar gum have gained attention for hydrogel formulation due to their superior biocompatibility, biodegradability, and non-toxic

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nature. Pullulan, produced by *Aureobasidium pullulans*, is known for its high solubility and film-forming ability, while Guar gum, derived from *Cyamopsis tetragonolobus*, provides viscosity and stability[9,10]. Ketoprofen, a potent NSAID, is widely used for arthritis, osteoarthritis, and musculoskeletal pain[11]. Incorporating Ketoprofen into a polysaccharide hydrogel patch may enhance patient compliance by providing sustained release and reducing irritation compared to conventional dosage forms [12].

HYDROGEL A hydrogel is a three-dimensional (3D) network of hydrophilic polymers that can swell in water and hold a large amount of water while maintaining the structure due to chemical or physical cross-linking of individual polymer chains[13]. Hydrogels can either be chemically durable or they may eventually disintegrate and dissolve. Hydrogels are also known as 'reversible' or 'physical' gels if molecular entanglements and/or secondary forces such as ionic, hydrogen bonding or hydrophobic forces play the principal role in forming the linkage[14]. Physical gels are often rescindable and it is achievable to dissolve them by altering the environmental conditions, such as pH the ionic strength of solution or temperature[15].

In 'permanent' or 'chemical' gels, the linkage of covalent linking distinct macromolecular chains can be attained by crosslinking polymers in the dry state or in solution. These gels may be either charged or non-charged dependent on the behaviour of functional groups existing in their structure[16]. The charged hydrogels typically display changes in swelling upon variations in pH and it is well known that they can undergoes changes in shape when subjected to an electric field [17].

Advantages of Hydrogel [18,19]

• Hydrogel is more elastic and stronger.
• Due to their significant water content they possess a degree of flexibility very similar to natural tissue.
• Hydrogel possess good transparent properties and easy to modification.
• They are biocompatible, biodegradable and can be injected.
• Release of Medicines or nutrients timely.
• Hydrogel have ability to sense change pH, temperature, or the conception of metabolite and relense their load as result of such a change.
• They can be injected.
• More resistance to protein deposits.
• Soothing effect promotes patient acceptance.

Disadvantages of Hydrogel [20,21]

• Hydrogels are expensive.
• They are non-adherent; they may need to be secured by a secondary dressing, and w cause sensation felt by movement of the maggot.
• Difficult to sterilize.
• Hydrogels used as contact lenses causes lens deposition, hypoxia, dehydration and red eye reactions.
• Difficulty in handling.
• Difficulty in loading.
• Conventional hydrogels tend to be fragile.
• Can be expensive, especially tunable smart hydrogels.
• Synthetic hydrogels are not as biocompatible as natural hydrogels

MATERIALS AND METHODS

Ingredients: Ketoprofen, Pullulan, Guar gum, Borax/glutaraldehyde (cross-linker), distilled water, ethanol.

Methodology

Preparation of Ketoprofen-Loaded Polysaccharide Hydrogel Patch

The required quantity of pullulan and guar gum was weighed. Pullulan was added slowly containing hot water. Both polymer solutions were mixed with magnetic stirring at 400-to the beaker containing distilled water and guar gum was added slowly to the beaker 600 rpm. The mixture was stirred continuously for 30 minutes until it formed a clear gel[22]. Ketoprofen and glutaraldehyde were added and mixed properly. Triethanolamine (q. s) was added to bring the pH neutral[22]. Penetration enhancer propylene glycol was added with stirring. Then glycerol was added to the gel to balance its viscosity[23]. Methylparaben was added as a preservative. The prepared gel was kept for 24 hours for complete polymer desolvation[24].

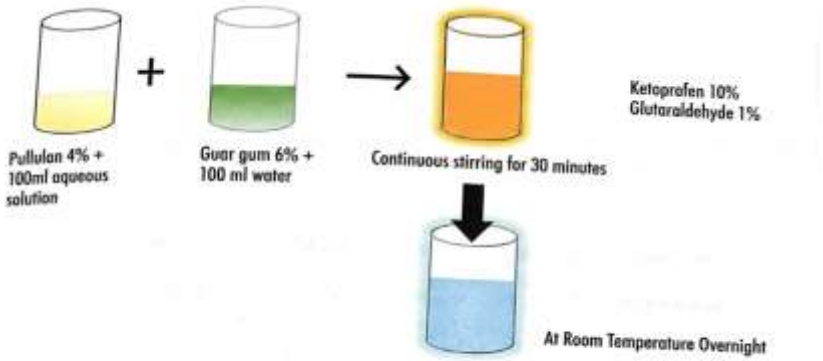

Figure No. 1: Schematic representation of the prepartion of topical hydrogel

Evaluation of Hydrogel Patches

1. **Physical Appearance** All Ketoprofen-loaded polysaccharide hydrogel patches were visually inspected for colour, clarity, flexibility, and smoothness. The prepared films appeared transparent, smooth, and flexible without cracks or air entrapment [25].
2. **Thickness** The thickness of each patch was measured at three different points using a digital thickness gauge, and the average thickness was calculated. The experiment was performed in triplicate (n=3). Thickness values ranged between 0.40–0.55 mm across formulations [26].
3. **Weight Uniformity** Weight uniformity was determined by weighing three randomly selected patches from each batch individually. The average weight was calculated and compared. Consistency in mass confirmed uniform distribution of Ketoprofen and polysaccharide matrix. Average weights ranged between 220–250 mg [27].
4. **Folding Endurance** Folding endurance was assessed by repeatedly folding a 2 cm × 2 cm strip of the patch at the same place until it broke. The number of folds before breaking was recorded. All formulations showed folding endurance above 250, indicating good mechanical strength and elasticity [28].
5. **Percentage Moisture Content** Patches were weighed and kept in a desiccator containing fused calcium chloride at room temperature for 24 hours. After reweighing, percentage moisture content was calculated using:

$$\text{Moisture Content (\%)} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Final Weight}} \times 100$$

Moisture content was found to be ~6–8%, ensuring hydration and stability [29].

6. **Percentage Moisture Uptake** Patches were kept in a desiccator containing saturated

potassium chloride solution (84% RH) for 24 hours. After reweighing, percentage moisture uptake was calculated using:

$$\text{Moisture Uptake (\%)} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100$$

Moisture uptake values confirmed the hydrogel's ability to retain water, beneficial for wound healing[30].

7. **Drug content** 10 mg drug containing hydrogel was taken in a 10ml capacity volumetric flask with a final volume made upto 10 ml with Phosphate Buffer pH 7.4 and continuous stirring was done for 30 min. The mixture was filtered and 1 ml solution was withdrawn and suitably diluted. The drug content was determined using a UV-visible spectrophotometer at 259.80 nm. [31].

Table No. 1: % Drug content of hydrogel formulation F1 to F9

Sr.no	Formulation	%Drug content*
1	F1	95.04±0.051
2	F2	97.08±0.203
3	F3	96.02±0.349
4	F4	71.83±0.072
5	F5	74.70±0.106
6	F6	77.74±0.161
7	F7	64.71±0.136
8	F8	70.74±0.160
9	F9	70.75±0.135

Each value represents mean (n=3) observation SD

8. **In-Vitro Drug Release** Drug release studies were performed using a modified Franz diffusion cell with a receptor compartment filled with phosphate buffer (pH 7.4). Patches (4 cm^2) were placed over a treated cellophane membrane. Samples were withdrawn at regular intervals and analyzed spectrophotometrically. The optimized batch showed sustained release (~70% over 8 hours), confirming controlled release behavior [32].

RESULTS

TABLE NO.3 - RESULT DISCUSSION TABLE

EVALUATION PARAMETER	F1	F2	F3
Physical Appearance	Smooth & flexible	Smooth & flexible	Smooth, flexible & transparent
Thickness	0.45 mm	0.40 mm	0.52 mm
Weight Uniformity	225 mg	230 mg	248 mg
Folding Endurance	240	260	285
Surface pH	6.4	6.5	6.6
Bio-adhesive Property	Good adhesion on skin surface	Good adhesion on skin surface	Good adhesion on skin surface
Skin Irritation Test	No irritation	No irritation	No irritation

EVALUATION PARAMETER	F1	F2	F3
Moisture Content (%)	6.2	7.0	7.8
Moisture Uptake (%)	8.5	9.2	10.1
Drug Content Uniformity (%)	95.4	97.8	96.2
In-Vitro Drug Release (8 h)	68 %	72 %	70 %

- **Physical appearance**: All patches were smooth, flexible, and transparent.
- **Thickness**: 0.40–0.55 mm across formulations.
- **Weight uniformity**: Consistent, ~220–250 mg.
- **Folding endurance**: >250 folds, indicating good mechanical strength.
- **Moisture content**: ~6–8%, ensuring hydration.
- **Surface pH**: ~6.5, compatible with skin.
- **Drug content uniformity**: Consistent Ketoprofen distribution confirmed.
- **In-vitro release**: Sustained drug release over 8 hours, optimized batch achieved ~70% release.
- **Skin irritation**: No irritation observed.
- Three different formulations of Ketoprofen-loaded polysaccharide hydrogel patches containing Pullulan and Guar gum were prepared and evaluated for their physicochemical properties and topical suitability. All formulations produced uniform hydrogel films with acceptable appearance and consistency. The prepared patches were smooth in texture, flexible in nature, and free from visible surface imperfections.
- Among the three formulations, F1 showed comparatively lower thickness and moderate flexibility, whereas F3 produced thicker patches with comparatively higher moisture absorption capacity. Formulation F2 exhibited balanced physical characteristics with satisfactory flexibility and uniform texture.
- The thickness values of the formulations ranged between 0.40 ± 0.02 mm and 0.55 ± 0.04 mm, while weight variation studies confirmed acceptable uniformity among the prepared patches (225–248 mg). Folding endurance analysis demonstrated that all formulations possessed sufficient mechanical strength for handling and topical application (>250 folds).
- Moisture content and moisture uptake studies indicated that the hydrogel patches were capable of maintaining hydration (6–8% moisture content; 8–10% uptake), which is considered beneficial for topical anti-inflammatory therapy. Surface pH values remained within the acceptable skin pH range (6.4–6.6), suggesting good dermatological compatibility.
- Drug content estimation confirmed uniform incorporation of Ketoprofen within the polymeric matrix (95–98% uniformity). Swelling behavior was observed to increase gradually with higher polymer concentration, particularly in formulation F3. In-vitro permeation studies revealed prolonged release of Ketoprofen from all formulations, with F2 showing a more controlled and sustained release profile (~72% over 8 hours) compared to F1 and F3.
- No visible signs of irritation or discomfort were observed during skin compatibility testing. Based on the obtained evaluation results, formulation F2 was considered the most suitable formulation due to its balanced physicochemical and release characteristics.

DISCUSSION

The present investigation focused on the formulation and evaluation of three different batches of Ketoprofen-loaded polysaccharide hydrogel patches containing Pullulan and Guar gum for topical anti-inflammatory therapy. The prepared formulations, namely F1, F2, and F3, were successfully developed using the hydrogel polymerization method and evaluated for various physicochemical parameters. All prepared formulations exhibited satisfactory appearance, flexibility, and uniformity without visible cracks or air entrapment.

Comparative evaluation revealed noticeable variations among the three batches due to differences in polymer and drug concentrations. Formulation F1 showed comparatively lower thickness and moderate swelling behavior, which may be attributed to the lower concentration of polymeric components. In contrast, formulation F3 demonstrated higher swelling capacity and moisture uptake due to increased polymer concentration, although the patch appeared comparatively thicker.

Among all formulations, F2 exhibited balanced physicochemical properties with appropriate thickness, satisfactory flexibility, acceptable moisture retention, and good mechanical strength. Folding endurance results confirmed that the prepared patches possessed adequate elasticity for topical application and handling. Drug content analysis indicated uniform distribution of Ketoprofen throughout the hydrogel matrix in all formulations. The surface pH of each formulation remained close to normal skin pH (6.4–6.6), suggesting compatibility with topical administration and minimal risk of irritation.

In-vitro permeation studies demonstrated sustained release of Ketoprofen from the hydrogel system. Formulation F2 showed a more controlled and prolonged drug release profile (~72% over 8 hours) compared to F1 and F3, which may improve therapeutic effectiveness and reduce the frequency of application.

Overall, the findings suggest that formulation F2 possessed the most suitable characteristics for topical anti-inflammatory therapy, combining balanced physicochemical properties, sustained drug release, and dermatological safety.

CONCLUSION

The present study successfully developed and evaluated polysaccharide-based hydrogel patches containing Ketoprofen for topical anti-inflammatory therapy. Three different formulations, F1, F2, and F3, were prepared and assessed for their physicochemical characteristics, mechanical properties, moisture behavior, drug content uniformity, and in-vitro drug release profile. All formulations demonstrated acceptable physical appearance, flexibility, and compatibility for topical application.

Comparative evaluation indicated that variation in polymer concentration influenced the overall properties of the hydrogel patches. Formulation F1 exhibited lower swelling and drug release behavior, whereas formulation F3 showed comparatively higher swelling capacity and moisture absorption due to increased polymer concentration. Among all prepared formulations, F2 was found to be the optimized formulation because it exhibited balanced thickness, satisfactory folding endurance, appropriate moisture retention, uniform drug distribution, and sustained drug release characteristics.

The formulation also maintained a skin-compatible pH (6.4–6.6) and showed no visible signs of irritation, indicating good dermatological safety. The incorporation of Ketoprofen provided effective anti-inflammatory activity, while the polysaccharide matrix (Pullulan and Guar gum) contributed biocompatibility, hydration, and controlled release properties. The

hydrogel system further supported prolonged retention of moisture and controlled release of active constituents at the application site.

Overall, the developed Ketoprofen-loaded polysaccharide hydrogel patch may serve as a promising and patient-friendly topical delivery system for effective management of inflammatory conditions. Further pharmacological and clinical investigations may be performed in the future to establish its therapeutic potential on a larger scale.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding publication of this research work.

REFERENCES

1. Collins NE, Morozkina SN, Olekhnovich RO, et al. Pullulan-based hydrogels in wound healing and skin tissue engineering applications: a review. Int J Mol Sci. 2023;24(5):4962. doi:10.3390/ijms24054962
2. El Sisi A, Hafez H, El Maghraby G. Formulation and evaluation of ketoprofen transdermal films using natural polymers. J Drug Deliv Sci Technol. 2019;51:383-91. doi:10.1016/j.jddst.2019.02.019
3. Ahmed EM. Hydrogel: preparation, characterization, and applications: a review. J Adv Res. 2015;6(2):105-121. doi:10.1016/j.jare.2013.07.006.
4. Jaiswal S, Rai J, Mishra JN. Formulation and evaluation of hydrogel. Int J Med Pharm Res. 2023;4(Special Issue 3):42-50
5. Dasaratha Dhanaraju M, Sundar VD, Vadaga A, Veeranjaneyulu NP. Formulation, characterization and optimization of ketoprofen-loaded hydrogel films. Bull Environ Pharmacol Life Sci. 2023;13(1):28-44
6. Halfter N, Espinosa-Cano E, Pontes-Quero GM, et al. Ketoprofen-based polymer drug nanoparticles provide anti-inflammatory properties to HA/collagen hydrogels. J Funct Biomater. 2023;14(3):160. doi:10.3390/jfb14030160
7. Shailaja G, Kuchana V, Ashmitha A, et al. An overview of topical drug delivery systems: from concepts to practice. Int J Pharm Biol Sci. 2024;14(4):87-96. doi:10.5281/zenodo.14568779
8. Ho TC, Chang CC, Chan HP, et al. Hydrogels: properties and applications in biomedicine. Molecules. 2022;27(9):2902. doi:10.3390/molecules27092902
9. Soni R, Yadav KS. Transdermal patch: a novel approach for drug delivery. J Drug Deliv Ther. 2016;6(1):37-43. doi:10.22270/jddt.v6i1.1135
10. Mahto A, Rozy F, Mehta A, Rahman A, Rajwar S. Guar gum: a promising natural polysaccharide for various applications. Int J Med Health Res. 2025;11(2):39-44
11. Atzeni F, Masala IF, Bagnasco M, et al. Comparison of efficacy of ketoprofen and ibuprofen in treating pain in patients with rheumatoid arthritis: a systematic review and meta-analysis. Pain Ther. 2021;10(1):577-88. doi:10.1007/s40122-021-00250-3
12. Pagano C, Latterini L, Di Michele A, et al. Polymeric bioadhesive patch based on ketoprofen hydrotalcite hybrid for local treatments. Pharmaceutics. 2020;12(8):733. doi:10.3390/pharmaceutics12080733
13. Dodda JM, Deshmukh K, Bezuidenhout D, Yeh YC. Hydrogels: definition, history,

classifications, formation, constitutive characteristics, and applications. In: Multicomponent Hydrogels – Smart Materials for Biomedical Applications. Cambridge: Royal Society of Chemistry; 2023. p.1-25. doi:10.1039/BK9781837670055-00001

14. Li J, Mooney DJ. Designing hydrogels for controlled drug delivery. Nat Rev Mater. 2016;1:16071. doi:10.1038/natrevmats.2016.71
15. Hennink WE, van Nostrum CF. Novel crosslinking methods to design hydrogels. Adv Drug Deliv Rev. 2012;64:223-36. doi:10.1016/j.addr.2012.09.009
16. Qiu Y, Park K. Environment-sensitive hydrogels for drug delivery. Adv Drug Deliv Rev. 2001;53(3):321-39. doi:10.1016/S0169-409X(01)00203-4
17. Kopeček J. Hydrogel biomaterials: a smart future? Biomaterials. 2007;28(34):5185-92. doi:10.1016/j.biomaterials.2007.07.044
18. Caló E, Khutoryanskiy VV. Biomedical applications of hydrogels: a review of patents and commercial products. Eur Polym J. 2015;65:252-67. doi:10.1016/j.eurpolymj.2014.11.024
19. Peppas NA, Hilt JZ, Khademhosseini A, Langer R. Hydrogels in biology and medicine: from molecular principles to bionanotechnology. Adv Mater. 2006;18(11):1345-60. doi:10.1002/adma.200501612
20. Hoare TR, Kohane DS. Hydrogels in drug delivery: progress and challenges. Polymer. 2008;49(8):1993-2007. doi:10.1016/j.polymer.2008.01.027
21. Segneanu AE, Bejenaru LE, Bejenaru C, et al. Advancements in hydrogels: a comprehensive review of natural and synthetic innovations for biomedical applications. Polymers. 2025;17(15):2026. doi:10.3390/polym17152026
22. Sahoo S, Sahoo SK, Mohanty P, et al. Polysaccharide-based hydrogels for topical drug delivery applications. Int J Biol Macromol. 2021;183:2050-65. doi:10.1016/j.ijbiomac.2021.05.058
23. Chenna M, Shalini C, Pochampally L, et al. Formulation and evaluation of topical gels: an updated review. Int J Pharm Sci Rev Res. 2025;14(1):36-42
24. Singh B, Sharma N, Chauhan N. Formulation and evaluation of topical gels of ketoprofen using natural polymers. Int J Pharm Investig. 2014;4(4):190-8. doi:10.4103/2230-973X.143114
25. Bai R, Yang M, Sun X, Hu Y, Chen K, Cui X, et al. Design and evaluation of a drug-in-adhesive patch for the transdermal delivery of ketoprofen. Drug Deliv Transl Res. 2024;14(9):2075-86. doi:10.1007/s13346-024-01703-w
26. Steinbeck L, Paul R, Litke J, et al. Hierarchically structured and tunable hydrogel patches: design, characterization, and application. Small. 2024;21(3):2407311. doi:10.1002/smll.202407311
27. Verma N, Deshwal S. Design and in vitro evaluation of transdermal patches containing ketoprofen. World J Pharm Res. 2014;3(3):1854-68
28. Moussa H, et al. Blended κ-carrageenan and xanthan gum hydrogel containing ketoprofen nanoemulsion for rheumatoid arthritis therapy. Drug Deliv Transl Res. 2023. doi:10.1007/s13346-023-01123-7
29. Sodiyal N, Patil PRS. Formulation and evaluation of herbal hydrogel patch containing Aloe vera and Curcuma longa for wound healing. Int J Pharm Sci. 2020;4(6):101
30. Díaz-Marín C, Masetti L, Roper M, et al. Physics-based prediction of moisture capture properties of hydrogels. Nat Commun.

2024;15:8948. doi:10.1038/s41467-024-53291-5

31. Kumar L, Verma R, Singh S. Formulation and evaluation of ketoprofen transdermal patches. Int J Pharm Sci Res. 2012;3(11):4523-30. doi:10.13040/IJPSR.0975-8232.3(11).4523-30
32. Salamanca CH, Barrera-Ocampo A, Lasso JC, Camacho N, Yarce CJ. Franz diffusion cell approach for pre-formulation characterisation of ketoprofen semi-solid dosage forms. Pharmaceutics. 2018;10(3):148. doi:10.3390/pharmaceutics10030148

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