Development and evaluation of hydrogel loaded with herbal extracts for wound dressing

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Abstract- **Hydrogels are promising wound dressings due to their moist wound-healing environment and drug delivery capabilities. This study developed a turmeric (Curcuma longa)-loaded Carbopol-940 hydrogel for enhanced wound healing. Curcumin was extracted via Soxhlet extraction and incorporated into the hydrogel matrix. The formulation exhibited optimal physicochemical properties (pH 6.8-7.2, viscosity 8,040±120 cP, spreadability 7.58±0.06 cm²/g) and sustained drug release following Higuchi kinetics (R^2=0.98). Biological evaluations demonstrated significant antioxidant (IC50: 42 µg/mL) and antimicrobial activity (12 mm and 10 mm inhibition zones against S. aureus and E. coli, respectively). With suitable mechanical properties (firmness: 43.5 g, adhesiveness: 19.7 g), this turmeric hydrogel shows great potential as an advanced wound dressing, combining structural benefits with therapeutic effects of curcumin. Further in vivo studies are warranted to validate its clinical efficacy.**

Keywords: Hydrogel, Turmeric, Wound healing, Curcumin, Antimicrobial, Antioxidant, Drug delivery

I. INTRODUCTION

Wound management remains a critical clinical challenge, particularly for chronic and infected wounds. Hydrogels, with their three-dimensional polymer networks, offer ideal wound dressings by maintaining hydration, facilitating gas exchange, and delivering bioactive compounds [1][2].

Hydrogels are 3D, water-insoluble polymer networks that absorb body fluids and form via chemical (covalent bonds) or physical (non-covalent forces) crosslinking. Made from natural or synthetic polymers, their properties affect function and mimic the ECM, making them useful in tissue engineering, wound dressings, drug delivery, and contact lenses [3]. Natural polymers like cellulose, alginate, chitosan, gelatin, and dextran are used in hydrogels for their biocompatibility and biodegradability. Chitosan offers antibacterial properties, alginate gels with calcium ions aiding wound care, and gelatin supports cell growth and tissue regeneration. [4]. Synthetic polymers such as polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP), and polyethylene glycol (PEG) are also utilized in hydrogel production. These materials offer advantages like controlled mechanical strength and stability. PVA, for example, can form hydrogels through freeze-thaw cycles, resulting in physically crosslinked networks suitable for wound dressings [5]. Hydrogels can possess antimicrobial properties either inherently or through the incorporation of antimicrobial agents. Materials like chitosan, peptides, collagen, and alginate are notable for their natural antimicrobial activity and are utilized in hydrogel formulations for wound healing applications [6][7].

Hydrogel wound dressings are valued for their ability to maintain a moist environment, which is conducive to wound healing. They promote granulation and epithelialization, essential phases in tissue repair. Their cooling effect also provides pain relief, making them suitable for burn wound management [8].

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Turmeric (*Curcuma longa*), long recognized in traditional medicine, is rich in curcuminoids—bioactive compounds known for their anti-inflammatory, antimicrobial, and antioxidant properties [10]. Integrating turmeric into hydrogel systems offers the potential to combine curcumin's therapeutic benefits with the structural and moisture-retentive properties of hydrogels. Such combinations have shown promise in enhancing wound healing efficacy by promoting tissue regeneration and reducing infection risks [11]. While herbal-infused hydrogels are gaining attention for biomedical applications, particularly in wound care, further research is needed to refine their formulations and ensure stability, bioavailability, and clinical applicability [12].

In this study, a novel turmeric-loaded hydrogel formulation was developed using Carbopol as the polymeric base. The formulation was systematically characterized to evaluate its physicochemical properties, in vitro drug release kinetics, and biological activities, including antimicrobial efficacy and wound healing potential. These evaluations aimed to determine the hydrogel's suitability and effectiveness as a topical wound dressing, leveraging the therapeutic properties of curcumin and the biocompatible nature of the Carbopol matrix.

II. MATERIAL AND METHODOLOGY

A. Materials

Turmeric rhizomes (dried, powdered)
Carbopol-940 (gelling agent)
Acetone (extraction solvent)
Analytical reagents (Folin-Ciocalteu, DPPH)

B. Extraction of Curcumin

Turmeric powder was Soxhlet-extracted with acetone at 60°C for 8 hours. The extract was concentrated using a rotary evaporator, and curcumin content was confirmed via TLC (Rf: 0.8 for curcumin).

C. Hydrogel Preparation

Swelling: Carbopol-940 was hydrated in water for 4 hours.

Formulation: Curcumin extract (10 mg) was dissolved in water, mixed with carbopol, and stirred for 3–4 hours.

Gel Formation: The mixture was stored for 24 hours to ensure homogeneity.

D. Characterization

Physical Evaluation: Color, odor, consistency.
pH: Digital pH meter (6.8–7.2).
Viscosity: Brookfield viscometer (100 rpm).
Spreadability: Glass plate method (S = ML/T).
Drug Release: Franz diffusion cell with egg membrane (UV analysis at 410 nm).

E. Biological Activity - Total Polyphenolic Content (TPC): Folin-Ciocalteu method (75.2 mg GAE/g). Antioxidant Activity: DPPH assay (IC50: 12.5–100 μg/mL).
Antimicrobial Testing: Agar diffusion against S. aureus and E. coli.

III. RESULTS AND DISCUSSION

A. Physicochemical Properties

The hydrogel exhibited optimal pH (6.8–7.2), viscosity (8,040 cP), and spreadability (7.58 cm²/g), ensuring compatibility with skin and ease of application (Table 1).

Table 1. Physicochemical properties of the hydrogel.

Parameter	Value
pH	6.8-7.2
Viscosity (cP)	8,040 ± 120
Spreadability (cm²/g)	7.58 ± 0.06

B. Drug Release and Kinetics

The hydrogel showed sustained release over 24 hours, fitting the Higuchi model (R^2 = 0.98), indicating diffusion-controlled release.

C. Biological Activity

Antioxidant: IC50 of 42 μg/mL (vs. Trolox standard).
Antimicrobial: Inhibition zones of 12 mm (S. aureus) and 10 mm (E. coli).

D. Mechanical Properties

Texture analysis revealed reduced firmness (43.5 g) and adhesive force (19.7 g) compared to the blank hydrogel, but within acceptable limits for wound dressings (Table 2).

Table 2. Texture analysis of hydrogels.

Formulation	Firmness (g)	Adhesiveness (g)
Blank hydrogel	57.7	26.2
Turmeric-loaded hydrogel	43.5	19.7

IV. CONCLUSION

The developed turmeric-Carbopol hydrogel demonstrated optimal physicochemical properties, sustained drug release, and significant antimicrobial/antioxidant activity, making it a promising wound dressing candidate. Its bioactive properties combined with mechanical stability address key challenges in wound management. Future work should focus on *in vivo* validation and clinical translation to assess therapeutic efficacy. This study advances herbal-based hydrogel development for improved wound care solutions.

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