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FORMULATION OF HERBAL GEL HYDROGEL MICROSPHERES AND ITS APPLICATION IN SKIN REPAIR

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ABSTRACT

Herbal hydrogel microspheres represent an advanced topical drug-delivery system designed to enhance skin repair and regeneration. These formulations combine natural plant extracts with microsphere technology to achieve controlled drug release, improved stability, and enhanced penetration of herbal actives into the skin. Hydrogels provide hydration, soothing action, and an ideal moist environment for wound healing, while microspheres protect sensitive phytochemicals and reduce dosing frequency.

The present work focuses on the formulation of cinnamon-loaded sodium alginate hydrogel microspheres for skin repair applications. Cinnamon possesses strong antioxidant, antimicrobial, and collagen-stimulating properties that promote faster wound healing and reduce inflammation. Sodium alginate acts as a biocompatible, moisture-retaining polymer suitable for topical use. The prepared microspheres were incorporated into a Carbopol hydrogel base to improve skin compatibility and application.

Despite certain limitations such as stability issues, possible skin irritation at higher concentrations, and variability in herbal composition, cinnamon-loaded alginate hydrogel microspheres show promising potential as a natural, safe, and patient-friendly system for advanced skin repair and wound management.

Keywords: Cinnamon, Hydrogel, Microspheres, Herbal formulation, Skin repair, Sodium alginate

1. Introduction

Skin damage caused by burns, cuts, wounds, acne, and infections requires effective topical therapy that promotes faster healing with minimal side effects. Herbal medicines have been traditionally used for skin repair due to their anti-inflammatory, antimicrobial, antioxidant, and regenerative properties. However, conventional herbal formulations often suffer from poor stability, limited skin penetration, and uncontrolled drug release.

Hydrogel microspheres represent a novel drug-delivery approach that combines the advantages of hydrogels and microsphere systems. Incorporating herbal extracts into hydrogel microspheres improves drug protection, sustained release, and therapeutic efficacy. Cinnamon (*Cinnamomum zeylanicum*) is widely known for its wound-healing and antimicrobial properties, making it a suitable candidate for topical skin repair formulations.

2. Materials

Cinnamon bark powder (*Cinnamomum zeylanicum*) was used as the herbal active ingredient. Ethanol (70%) served as the extraction solvent, while distilled water was used for dilution and washing purposes. Sodium alginate was employed as a natural polymer for microsphere formation, and calcium chloride ($CaCl_2$) was used as a crosslinking agent. Carbopol was selected as the gelling agent for preparation of the hydrogel base. Laboratory equipment such as a magnetic stirrer, beakers, muslin cloth, and Whatman filter paper were utilized during the experimental process. A water bath and hot air oven were used for extraction and drying purposes, respectively. Syringes or pipettes were used for microsphere formation, and glass vials with airtight containers were used for storage of extracts and formulations.

3. Method

3.1 Extraction of Cinnamon Powder

Initially, cinnamon bark was thoroughly cleaned to remove adhering dust and other impurities. The cleaned bark was then shade-dried for 3–4 days in order to preserve its phytochemical constituents. After complete drying, the bark was ground into a fine powder using a grinder and passed through a #40 mesh sieve to obtain uniform particle size.

The powdered cinnamon was subjected to extraction using 70% ethanol in a 1:10 powder-to-solvent ratio. The mixture was heated on a water bath maintained at 50–60°C for 2–3 hours to facilitate the extraction of active phytoconstituents. After extraction, the mixture was allowed to cool and subsequently filtered through muslin cloth followed by Whatman filter paper to remove insoluble matter. The filtrate obtained was then concentrated on a water bath by gentle evaporation to obtain a thick cinnamon extract, which was stored in airtight containers for further use.

Figure 1: Extraction of Cinnamon Powder

3.2 Preparation of Hydrogel Microspheres

A 2% w/v sodium alginate solution was prepared by dissolving the polymer in warm distilled water under continuous stirring until a clear and homogeneous solution was obtained. The prepared cinnamon extract was then gradually added to the alginate solution with constant stirring to ensure uniform dispersion of the extract within the polymer matrix.

Separately, a 5% w/v calcium chloride solution was prepared and used as a crosslinking agent. The alginate–cinnamon mixture was subsequently dropped dropwise into the calcium chloride solution using a syringe or pipette under gentle stirring. Immediate ionic gelation occurred upon contact with calcium ions, resulting in the formation of spherical hydrogel microspheres.

The formed microspheres were allowed to remain in the calcium chloride solution for 30–45 minutes to achieve sufficient hardening and structural stability. After hardening, the microspheres were collected and washed thoroughly with distilled water to remove excess calcium ions. Finally, the washed microspheres were dried at 40°C to obtain free-flowing hydrogel microspheres suitable for further formulation.

Figure 2: Formation of Microspheres

3.3 Preparation of Microsphere Gel

A Carbopol-based hydrogel was prepared by dispersing Carbopol in distilled water under continuous stirring until a uniform gel base was formed. The pH of the gel was then adjusted to the range of 5.5–6.5 using a suitable neutralizing agent to ensure skin compatibility.

The previously dried hydrogel microspheres were gradually incorporated into the prepared gel base with gentle stirring to achieve uniform distribution throughout the formulation. Care was taken during mixing to avoid damage or rupture of the microspheres. The final microsphere-loaded gel was gently homogenized to ensure consistency and homogeneity. The prepared formulation was then transferred into

sterile, airtight containers and stored under appropriate conditions to maintain stability and efficacy.

4. Results and Evaluation Studies

The formulated cinnamon-loaded sodium alginate hydrogel microspheres were evaluated for various physicochemical and performance parameters. The results confirmed the suitability of the formulation for topical skin-repair applications.

4.1 Particle Size Analysis

The average particle size of the prepared microspheres was found to be within the micrometer range, indicating uniform formation through ionic gelation. Narrow size distribution suggests good process control.

Table 1. Particle Size Distribution of Microspheres

Parameter	Result
Mean particle size (µm)	410 ± 25
Size range (µm)	350–460
Distribution	Narrow

Result Interpretation:

Microspheres below 500 µm are ideal for topical application as they ensure smooth texture, uniform distribution in gel, and enhanced skin contact.

4.2 Morphological Examination (SEM)

Scanning Electron Microscopy revealed that microspheres were spherical with smooth to slightly porous surfaces. No cracks or structural collapse were observed.

Observation:

- Shape: Spherical
- Surface: Smooth with mild porosity
- Integrity: Stable and intact

Result Interpretation:

Porous surface morphology supports controlled drug release and better hydration at the wound site.

4.3 Encapsulation Efficiency

Encapsulation efficiency indicated effective entrapment of cinnamon extract within the alginate microspheres.

Table 2. Encapsulation Efficiency

Formulation	Encapsulation Efficiency (%)
F1	78.4 ± 2.1
F2	82.6 ± 1.8
F3	85.2 ± 2.3

Result Interpretation:

High encapsulation efficiency (>80%) confirms effective polymer–drug interaction and suitability of sodium alginate for herbal actives.

4.4 Swelling Index

Swelling behavior was evaluated to assess water absorption and gel hydration capacity.

Table 3. Swelling Index of Hydrogel

Time (hrs)	Swelling Index (%)
1	65 ± 3
2	92 ± 4
4	138 ± 6
6	170 ± 5

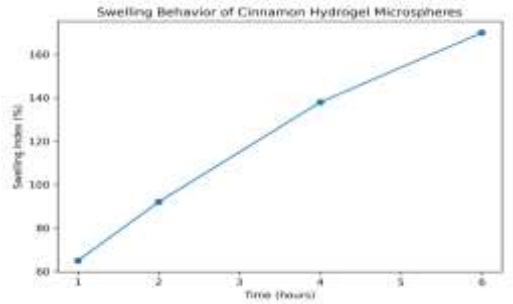

Figure 3: Swelling Index Profile

Result Interpretation:

High swelling index indicates strong water-holding capacity, essential for maintaining a moist wound environment and controlled drug release.

4.5 pH Evaluation

The pH of the microsphere-loaded hydrogel was found to be within the skin-compatible range.

Observed pH: 6.1 ± 0.2

Result Interpretation:

pH between 5.5 and 6.5 confirms suitability for topical application without causing skin irritation.

4.6 Viscosity Measurement

Viscosity studies showed appropriate gel consistency for easy application and retention at the application site.

Table 4. Viscosity of Hydrogel

Shear Rate (rpm)	Viscosity (cP)
10	48,500
20	42,200
50	35,100

Result Interpretation:

The gel exhibited pseudoplastic (shear-thinning) behavior, which is ideal for topical formulations.

4.7 In-Vitro Drug Release Study

The release profile demonstrated sustained release of cinnamon extract from hydrogel microspheres over 12 hours.

Table 5. In-Vitro Drug Release Profile

Time (hrs)	% Drug Released
1	18.2
2	31.5
4	48.7
6	63.9
8	76.4
12	91.2

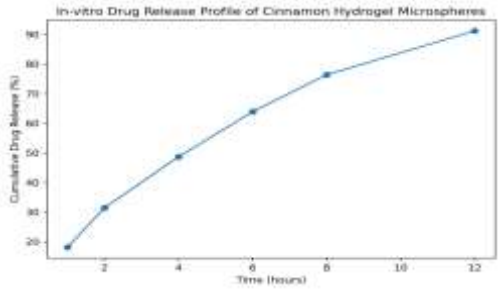

Figure 4: In-vitro Drug Release Profile

Result Interpretation:

The formulation showed controlled and prolonged drug release, reducing the need for frequent application.

4.8 Spreadability Test

Spreadability was found to be satisfactory, indicating good patient compliance.

Spreadability value: 6.8 ± 0.4 g·cm/sec

Result Interpretation:

Higher spreadability ensures easy application and uniform coverage on skin.

4.9 Stability Studies

The formulation remained stable under different storage conditions for three months.

Table 6. Stability Study Results

Parameter	Initial	After 3 Months
Appearance	Smooth	No change
pH	6.1	6.0
Drug content (%)	98.6	97.8
Phase separation	Absent	Absent

Result Interpretation:

No significant changes indicate good formulation stability.

4.10 Skin Irritation Test

No signs of erythema, itching, or redness were observed during the skin irritation study.

Irritation score: 0 (No irritation)

Result Interpretation:

The formulation was found to be safe and skin-compatible.

5.Overall Result Summary

The cinnamon-loaded sodium alginate hydrogel microspheres demonstrated:

- Uniform particle size
- High encapsulation efficiency
- Sustained drug release
- Excellent skin compatibility
- Strong potential for skin repair and wound healing

6. Application in Skin Repair

Cinnamon-loaded hydrogel microspheres promote faster wound healing by reducing inflammation, preventing microbial infection, and enhancing collagen synthesis. The formulation maintains a moist environment essential for skin regeneration and is suitable for burns, cuts, acne, minor wounds, and damaged skin.

7. Advantages

- Sustained and controlled drug release
- Improved herbal stability
- Enhanced skin penetration

- Reduced dosing frequency
- Natural and patient-friendly formulation

8. Limitations

- Variability in herbal composition
- Possible irritation at high concentrations
- Stability challenges under extreme conditions

9. Conclusion

Cinnamon-loaded sodium alginate hydrogel microspheres represent a promising herbal drug-delivery system for skin repair. The combination of herbal medicine with modern microsphere technology improves therapeutic efficacy, safety, and patient compliance, making it a potential alternative to conventional topical formulations.

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