Formulation and Evaluation of Polyherbal Topical Gel Containing Aloe Vera and Centella Asiatica Extracts for Anti-Inflammatory and Wound-Healing Activity

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***Abstract*—Wound healing is a complex biological process involving hemostasis, inflammation, proliferation, re-epithelialization, angiogenesis, extracellular matrix deposition and tissue remodeling. Excessive inflammation, oxidative stress, microbial contamination and impaired tissue regeneration may delay normal wound repair. Therefore, the development of topical formulations containing medicinal plant extracts has attracted considerable pharmaceutical and biomedical interest.**

Aloe vera and Centella asiatica are traditionally used medicinal plants with reported properties relevant to skin repair. Aloe vera contains polysaccharides and other bioactive constituents associated with moisturizing, antioxidant and anti-inflammatory effects. Centella asiatica contains important triterpenoid constituents, particularly asiaticoside, madecassoside, asiatic acid and madecassic acid, which have been investigated for their roles in collagen synthesis, fibroblast activity, angiogenesis and tissue regeneration.

The present paper discusses the formulation and evaluation of a polyherbal topical gel containing Aloe vera and Centella asiatica extracts for potential anti-inflammatory and wound-healing applications. Carbopol 940 is considered as the gelling agent, while propylene glycol functions as a humectant and co-solvent. A 30 mL formulation framework containing different concentrations of Centella asiatica extract is proposed for formulation screening. Evaluation includes appearance, homogeneity, pH, viscosity, spreadability, extrudability, extract/marker content, in-vitro release, antimicrobial activity and stability.

***Index Terms*—Aloe vera; Centella asiatica; Polyherbal gel; Topical formulation; Wound healing; Anti-inflammatory activity; Asiaticoside; Madecassoside; Carbopol 940; Herbal drug delivery.**

I. INTRODUCTION

Wound healing is an essential physiological mechanism through which injured tissue undergoes repair and restoration. The process consists of several overlapping phases, including hemostasis, inflammation, proliferation and remodeling. Successful healing requires precise coordination between inflammatory cells, fibroblasts, keratinocytes, endothelial cells, extracellular matrix components and numerous signaling molecules.

Immediately after injury, hemostasis prevents excessive blood loss and produces a provisional matrix. The inflammatory phase subsequently removes damaged tissue and microorganisms. This phase must eventually resolve so that fibroblast proliferation, collagen deposition, angiogenesis and epithelialization can proceed. During remodeling, the newly formed extracellular matrix undergoes reorganization and maturation.

Prolonged inflammation, oxidative stress and microbial contamination may interfere with these processes and result in delayed or chronic wound healing. Consequently, topical formulations capable of maintaining a favorable wound environment and delivering bioactive substances have become an important area of pharmaceutical research.

Medicinal plants contain numerous phytoconstituents that may act through multiple biological pathways. Aloe vera and Centella asiatica are particularly interesting because both have a long history of topical use and have been investigated for wound-related biological effects.

Aloe vera is widely used in dermatological and cosmetic preparations. Its leaf gel contains a high proportion of water together with polysaccharides and

other constituents. It has been investigated for moisturizing, antioxidant and anti-inflammatory properties and for potential effects on tissue repair.

Centella asiatica, commonly known as Gotu kola, contains several characteristic triterpenoid compounds, including asiaticoside, madecassoside, asiatic acid and madecassic acid. These constituents have been investigated in relation to collagen synthesis, fibroblast proliferation, angiogenesis, epithelialization and inflammatory modulation.

The supplied 2024 study provides a direct precedent for combining Centella asiatica and Aloe vera in a topical gel. It developed a bioactive gel containing triterpene-rich Centella asiatica extract and Aloe vera and evaluated physicochemical characteristics, release, stability, skin irritation and antimicrobial activity.

The formulation described in that study contained Centella asiatica extract, Aloe vera, Carbopol 940, propylene glycol, benzyl alcohol and sorbitan solution. Thus, a polyherbal gel containing Aloe vera and Centella asiatica provides a rational platform for investigating topical anti-inflammatory and wound-healing activity.

II. BIOLOGICAL BASIS AND PHARMACOLOGICAL POTENTIAL

2.1 Wound-Healing Process

Hemostasis is the initial response following tissue injury. Platelet activation and fibrin formation produce a clot that limits blood loss and creates a temporary matrix for subsequent repair.

Neutrophils and macrophages remove damaged material and microorganisms and release cytokines and growth factors. Controlled inflammation is essential, but persistent inflammation may delay tissue repair.

The proliferative stage includes fibroblast proliferation, collagen synthesis, angiogenesis, granulation tissue formation and re-epithelialization.

During remodeling, collagen and extracellular matrix components are reorganized and matured, gradually increasing tissue strength.

2.2 Aloe vera

Aloe vera is a succulent medicinal plant widely used in topical preparations. The inner leaf gel contains polysaccharides and other constituents. The plant has been investigated for moisturizing, antioxidant and anti-inflammatory effects. These properties may be useful in topical wound-care formulations. The biological activity of Aloe vera preparations can vary according to cultivar, cultivation, harvesting, processing and storage; therefore, pharmaceutical development requires botanical authentication and standardization.

2.3 Centella asiatica

Centella asiatica is a medicinal herb traditionally associated with skin health and wound management. Major triterpenoid constituents include asiaticoside, madecassoside, asiatic acid and madecassic acid. These constituents have been investigated in relation to collagen production, fibroblast proliferation, angiogenesis and tissue regeneration.

2.4 Anti-inflammatory and Wound-Healing Potential

Inflammation is essential during the initial stages of wound healing but prolonged inflammatory signaling can interfere with tissue regeneration. Centella asiatica triterpenes have been investigated for potential effects on inflammatory mediators and oxidative stress, while Aloe vera has been investigated for modulation of inflammatory responses. Potential wound-healing endpoints include wound contraction, epithelialization, collagen deposition, fibroblast proliferation, angiogenesis and inflammatory-marker changes.

III. RATIONALE FOR POLYHERBAL TOPICAL GEL

A combination of Aloe vera and Centella asiatica is scientifically interesting because the two botanical materials contain different but potentially complementary classes of constituents. Aloe vera contributes a hydrated botanical component, while Centella asiatica contributes triterpenoid constituents associated with connective-tissue repair.

A topical gel can provide easy application, good spreadability, prolonged contact with skin, convenient incorporation of botanical extracts and potentially controlled release. Carbopol 940 can provide a suitable gel matrix, propylene glycol can function as a humectant and co-solvent, and a suitable preservative system may support microbiological quality.

IV. MATERIALS AND METHODS

4.1 Materials

Centella asiatica extract, Aloe vera gel/extract, Carbopol 940, propylene glycol, benzyl alcohol or another validated preservative system, purified water and an appropriate neutralizing agent.

4.2 Extraction of Centella asiatica

The supplied 2024 study used hot maceration. According to the source, dried Centella asiatica was treated with 95% ethanol at a 1:5 plant-to-solvent ratio and heated at 60°C for 120 minutes.

4.3 Phytochemical Screening

The supplied study reported Salkowski, Horizon, Liebermann–Burchard and Noller's tests for qualitative indication of triterpenes.

V. 30 ML FORMULATION

The following is a proposed 30 mL laboratory-development formulation. The source paper gives formulation quantities but does not specify a final 30 mL batch volume; therefore, these values are a starting formulation and require experimental optimization.

Ingredient	F1	F2	F3	F4	Function
Centella asiatica extract	0.15 g	0.30 g	0.45 g	0.60 g	Active herbal extract
Aloe vera gel/extract	0.30 g	0.30 g	0.30 g	0.30 g	Botanical/moisturizing component
Carbopol 940	0.30 g	0.30 g	0.30 g	0.30 g	Gelling agent
Propylene glycol	1.0 mL	1.0 mL	1.0 mL	1.0 mL	Humectant/co-solvent
Benzyl alcohol*	0.30 mL	0.30 mL	0.30 mL	0.30 mL	Preservative
Purified water	q.s.	q.s.	q.s.	q.s.	Vehicle
Neutralizing agent	q.s.	q.s.	q.s.	q.s.	Gel formation/pH adjustment
Final volume	30 mL	30 mL	30 mL	30 mL	--

*Proposed working value for formulation planning; preservative concentration and safety must be confirmed by an appropriate validated procedure.

VI. METHOD OF PREPARATION

1. Accurately weigh Carbopol 940 and slowly disperse it into a portion of purified water with gentle stirring. Allow complete hydration.
2. Accurately weigh the required Centella asiatica extract and, if necessary, disperse it in a small quantity of propylene glycol.
3. Add Aloe vera gel/extract gradually to the hydrated Carbopol dispersion.
4. Incorporate the Centella asiatica extract phase slowly with continuous gentle mixing.
5. Add the selected preservative according to the validated formulation procedure.
6. Add the appropriate neutralizing agent gradually until the required gel consistency develops.
7. Measure pH using a calibrated pH meter and adjust gradually using the approved laboratory procedure.
8. Transfer the formulation to a calibrated vessel and add purified water q.s. to 30 mL.
9. Mix gently until a uniform homogeneous gel is obtained and allow entrapped air to dissipate.
10. Fill into a suitable clean container and label with formulation code, batch number, date and storage condition.

Process flow: Centella extract → Carbopol hydration → Propylene glycol incorporation → Aloe vera incorporation → Centella incorporation → Preservative → Neutralization → pH adjustment → Volume make-up → Homogenization → Filling → Evaluation.

VII. EVALUATION PARAMETERS

Parameter	Method/Purpose
Appearance and homogeneity	Visual examination for color, odor, texture, consistency, phase separation and visible particles.

pH	Measurement using a calibrated digital pH meter.
Viscosity	Measurement using a suitable Brookfield viscometer under controlled conditions.
Spreadability	Determination using a validated glass-slide or equivalent method.
Extrudability	Assessment of ease of extrusion from the selected container.
Extract/marker content	Validated assay where possible; asiaticoside or asiatic acid may be considered as Centella markers.
In-vitro release	Diffusion-cell study using an appropriate membrane and controlled conditions.
Antimicrobial activity	Standardized microbiological method with suitable controls.
Skin tolerability	Appropriate validated and ethically approved irritation/tolerability protocol.
Stability	Monitoring appearance, pH, viscosity, marker content and microbiological quality.

VIII. RESULTS AND DISCUSSION

The following numerical values are reported from the supplied 2024 reference paper and are not newly generated experimental results for the proposed 30 mL formulation.

Parameter	F1	F2	F3	F4
pH	6.25	6.13	6.45	6.27
Extract content (%)	98.02	97.78	96.45	97.32
24-h in-vitro release (%)	96.41	94.33	92.05	90.27

The reported pH values indicate mildly acidic-to-near-neutral formulations. Extract-content values were above 96% for all four formulations. The source reported decreasing cumulative release across the formulation series, with the highest 24-hour release for F1 and the lowest for F4. These results should be interpreted only within the experimental conditions used by the source study.

For the present project, actual laboratory results should be entered only after experimentation. Results should preferably be expressed as mean ± standard deviation from appropriate replicate measurements, with statistical analysis selected according to the study design.

IX. STABILITY STUDY

Stability testing should monitor physical, chemical and microbiological characteristics during predefined storage. The following table can be used for recording experimental observations.

Parameter	Initial	1 Month	2 Months	3 Months
Appearance	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally
Homogeneity	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally
pH	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally
Viscosity	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally
Marker/extract content	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally
Microbial quality	To be determined experimentally	To be determined experimentally	To be determined experimentally	To be determined experimentally

X. CONCLUSION

The development of a polyherbal topical gel containing Aloe vera and Centella asiatica represents a rational formulation approach for investigating anti-inflammatory and wound-healing applications. Centella asiatica contributes triterpenoid constituents such as asiaticoside, madecassoside, asiatic acid and madecassic acid, while Aloe vera provides a complementary botanical component with moisturizing and reported anti-inflammatory properties.

Carbopol 940 can provide a suitable gel matrix, while propylene glycol can support humectancy and incorporation of botanical constituents. The supplied 2024 study provides a useful precedent for combining these two plants and evaluating physicochemical properties, release, stability, antimicrobial activity and skin tolerability.

The proposed 30 mL formulation is a laboratory-development starting point and is not an experimentally validated final formulation. Actual optimization requires laboratory testing of pH, viscosity, spreadability, extrudability, marker content, release, stability and biological activity. Further studies using standardized extracts, validated analytical methods, appropriate controls and ethically approved biological models are required to establish safety and efficacy.

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