

Topical Herbal Gels for Acne Management: Formulation Approaches and Clinical Potential

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Abstract

Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit that significantly affects quality of life and often requires long-term management. Conventional topical therapies such as antibiotics, retinoids, and benzoyl peroxide are effective but frequently associated with skin irritation, dryness, and development of microbial resistance. In recent years, topical herbal gels have emerged as promising alternatives owing to their multitarget therapeutic action and improved safety profiles. Herbal formulations contain diverse bioactive phytoconstituents that exhibit antibacterial, anti-inflammatory, antioxidant, and wound-healing properties, enabling simultaneous modulation of multiple acne-causing pathways. Gel-based delivery systems offer additional advantages, including non-greasy texture, enhanced skin penetration, localized drug action, and superior cosmetic acceptability. This review highlights recent advances in topical herbal gels for acne management, focusing on formulation approaches, key excipients, evaluation parameters, and clinical potential. Emphasis is placed on polymer selection, incorporation of herbal actives, physicochemical characterization, antimicrobial efficacy, and dermal safety. Clinical evidence suggests that herbal anti-acne gels effectively reduce inflammatory lesions, erythema, and bacterial load while demonstrating better tolerability than conventional synthetic formulations. Despite challenges related to extract standardization and stability, continued progress in formulation science is expected to strengthen their therapeutic utility. Overall, topical herbal gels represent a safe, patient-friendly, and effective strategy for long-term acne management.

Keywords: Topical herbal gels; Acne vulgaris; Phytoconstituents; Anti-acne formulation; Dermatological drug delivery

1. Introduction

Acne vulgaris is a multifactorial inflammatory disorder of the pilosebaceous unit characterized by excessive sebum secretion, follicular hyper-keratinization, microbial colonization, and inflammatory responses. It primarily affects adolescents and young adults; however, a significant number of individuals continue to experience acne into adulthood, often resulting in permanent scarring and considerable psychosocial impact, including reduced self-esteem and anxiety. The pathogenesis of acne involves complex interactions between hormonal imbalance, oxidative stress, bacterial proliferation, and immune dysregulation, making its management clinically challenging^{1,2}.

Conventional anti-acne therapies such as topical antibiotics, retinoids, and benzoyl peroxide remain the mainstay of treatment. Although these agents are effective in reducing inflammatory lesions and bacterial load, prolonged use is frequently associated with adverse effects including skin irritation, erythema, peeling, dryness, photosensitivity, and development of microbial resistance. These limitations often compromise patient adherence and highlight the need for safer, long-term therapeutic alternatives^{2,3}.

Herbal medicines have gained increasing attention in dermatological applications due to their broad spectrum of biological activities and improved safety profiles. Medicinal plants contain diverse bioactive constituents such as flavonoids, terpenoids, phenolic compounds, and alkaloids that act synergistically to exert antibacterial, anti-inflammatory, antioxidant, and wound-healing effects. Several herbal agents have demonstrated promising anti-acne potential by inhibiting acne-causing bacteria, reducing inflammation, regulating sebum production, and promoting skin repair. Unlike single-target synthetic drugs, herbal extracts offer multitarget action, which may enhance therapeutic efficacy while minimizing adverse reactions.

Among topical dosage forms, gel-based systems are particularly advantageous for acne management because of their non-greasy nature, rapid drug release, cooling sensation, ease of application, and superior cosmetic acceptability. Gels also provide enhanced skin penetration and localized delivery of active constituents with minimal systemic exposure. The incorporation of herbal extracts into topical gel formulations represents an effective integration of traditional medicinal knowledge with modern pharmaceutical technology. Such systems allow controlled delivery of phytoconstituents directly to affected skin layers, improving therapeutic outcomes while maintaining patient comfort^{4,5}.

Recent advances in polymer science, formulation strategies, and evaluation methodologies have further improved the stability, spreadability, and bioavailability of herbal gels.

Consequently, topical herbal gel formulations are emerging as promising alternatives to conventional acne therapies, offering safer and more patient-friendly options for long-term acne management⁵.

2. Objective : The objective of this review is to summarize formulation approaches, polymer systems, evaluation parameters, and clinical potential of topical herbal gels used in acne management, highlighting their role as safer and effective alternatives to conventional treatments.

3. Rationale for Herbal Gels in Acne Management: Topical herbal gels are increasingly preferred in acne therapy because they offer localized treatment with superior cosmetic acceptability and improved patient comfort. Acne primarily affects superficial and deeper skin layers; therefore, topical delivery allows direct targeting of inflamed pilosebaceous units while minimizing systemic exposure. Gel-based systems provide a lightweight vehicle that facilitates rapid drug release and penetration, making them especially suitable for oily and acne-prone skin^{6,7}.

Herbal gels provide a multitarget therapeutic approach by simultaneously addressing microbial growth, inflammation, oxidative stress, and excessive sebum production. Medicinal plants contain diverse phytoconstituents such as flavonoids, terpenoids, phenolics, and alkaloids that exert antibacterial, anti-inflammatory, antioxidant, and wound-healing effects. Unlike synthetic agents that act on single pathways, herbal preparations offer synergistic action with improved tolerability, making them appropriate for long-term acne management⁸.

Topical herbal gels are preferred in acne therapy due to:

- **Non-greasy and easily washable nature** – Gel formulations are water-based, leaving minimal residue on the skin and providing a cooling sensation that enhances comfort, particularly in inflamed acne lesions^{7,8}.
- **Enhanced patient compliance and cosmetic acceptance** – Their smooth texture, quick absorption, and absence of oiliness improve user satisfaction and encourage regular application during prolonged treatment.
- **Localized delivery of herbal actives** – Gels enable direct deposition of phytoconstituents at affected sites, increasing therapeutic efficiency while limiting systemic absorption^{7,8}.
- **Reduced risk of systemic side effects** – Since herbal gels act primarily at the application site, they minimize gastrointestinal and systemic adverse effects commonly associated with oral therapies⁸.

- **Synergistic antimicrobial, anti-inflammatory, and antioxidant effects** – Multiple bioactive compounds work together to suppress acne-causing bacteria, reduce inflammatory mediators, neutralize free radicals, and promote skin repair^{8,9}.

Several herbal constituents exhibit sebostatic activity, helping regulate excessive sebum secretion, which is a major contributor to follicular blockage and bacterial proliferation. Gel matrices further enhance penetration of herbal actives into deeper skin layers while maintaining skin hydration and barrier function^{8,9}.

Overall, herbal gels target multiple acne-causing pathways simultaneously, including inhibition of *Cutibacterium acnes*, reduction of inflammation, modulation of oxidative stress, and regulation of sebaceous gland activity. This multifaceted mechanism, combined with superior safety and cosmetic acceptability, positions topical herbal gels as promising and patient-friendly alternatives to conventional anti-acne therapies.

4. Formulation Approaches for Herbal Anti-Acne Gels

Herbal anti-acne gels are commonly formulated by incorporating aqueous or hydroalcoholic plant extracts into suitable polymeric gel bases. The primary formulation objective is to achieve optimal viscosity, spreadability, stability, and skin compatibility while ensuring efficient delivery of herbal actives to the affected skin layers. Because acne-prone skin is generally oily and sensitive, gel systems are preferred over creams or ointments due to their lightweight texture, non-greasy nature, and enhanced patient acceptability^{10,11}.

The formulation strategy focuses on selecting compatible excipients that provide adequate structural integrity, promote uniform dispersion of herbal extracts, and maintain physicochemical stability throughout storage. Careful optimization of polymer concentration, extract loading, and auxiliary excipients is essential to avoid phase separation, precipitation of active constituents, or loss of therapeutic activity¹¹. Additionally, pH adjustment is critical to ensure skin compatibility and prevent irritation. Some key formulation components are:-

- **Herbal Actives:** Plant extracts or essential oils serve as the primary therapeutic agents, offering antibacterial, anti-inflammatory, antioxidant, and wound-healing effects. These bioactive constituents help inhibit acne-causing bacteria, reduce erythema, control oxidative stress, and promote skin repair. Standardization of extracts is important to ensure consistent efficacy¹¹.
- **Gelling Agents:** Polymers such as Carbopol, hydroxypropyl methylcellulose, sodium alginate, and xanthan gum are employed to impart viscosity and structural stability to the formulation. These agents determine gel consistency, spreadability, and drug

release behavior. Proper polymer selection also influences skin feel and residence time on the application site¹².

- **Humectants:** Glycerin and propylene glycol are commonly incorporated to maintain skin hydration and prevent dryness associated with acne treatments. Humectants also improve gel texture and may assist in enhancing penetration of herbal actives by increasing skin hydration^{13,14}.
- **Preservatives:** Preservatives are added to prevent microbial contamination, particularly because herbal formulations are susceptible to microbial growth. Selection of appropriate preservatives ensures product safety and shelf stability without causing skin irritation.
- **Penetration Enhancers:** Natural oils, glycols, or mild surfactants are included to improve dermal absorption of phytoconstituents. These agents temporarily modify the stratum corneum barrier, facilitating deeper penetration of herbal actives while maintaining skin integrity¹⁴.

Proper optimization of these components is crucial to achieve uniform drug distribution, appropriate rheological behavior, and long-term formulation stability. Factors such as polymer concentration, extract compatibility, and excipient interactions directly influence gel performance, therapeutic efficacy, and cosmetic acceptability^{14,15}. When carefully designed, herbal anti-acne gels provide efficient localized delivery of phytoconstituents, improved patient compliance, and enhanced clinical outcomes.

5. Evaluation Parameters of Herbal Gels

Comprehensive evaluation of herbal anti-acne gels is essential to ensure formulation quality, safety, stability, and therapeutic effectiveness. These parameters help predict in-use performance and patient acceptability while supporting reproducibility during scale-up. Each evaluation test provides critical insight into physicochemical properties, drug release behavior, and skin compatibility¹⁵.

- **Physical appearance and homogeneity** – The gel is visually examined for color, clarity, phase separation, and presence of particulate matter. Homogeneity ensures uniform distribution of herbal actives throughout the formulation, which is vital for consistent therapeutic action¹⁶.
- **pH (skin-compatible range)** – The pH is measured to confirm compatibility with skin physiology, typically maintained between 5.5 and 7.0. Appropriate pH minimizes irritation and preserves stability of phytoconstituents.

- **Viscosity and spreadability** – Viscosity determines gel consistency and ease of application, while spreadability reflects how uniformly the gel distributes over the skin. Optimal viscosity ensures adequate residence time at the application site, whereas good spreadability improves user comfort and drug coverage¹⁷.
- **Drug content uniformity** – This parameter confirms even distribution of herbal actives within the gel matrix. Uniform drug content is essential to ensure reproducible dosing and therapeutic reliability¹⁸.
- **In-vitro release studies** – These studies evaluate the rate and extent of herbal constituent release from the gel base, providing insight into diffusion behavior and predicting in-vivo performance. Release profiles also help optimize polymer concentration and formulation composition¹⁷.
- **Antimicrobial activity** – The antibacterial efficacy of herbal gels is assessed against acne-associated microorganisms to confirm therapeutic potential. This test validates the biological activity of incorporated plant extracts.
- **Skin irritation testing** – Performed to assess dermal safety and biocompatibility. Herbal gels are expected to show minimal irritation, making this parameter especially important for long-term acne therapy¹⁸.

These evaluation parameters provide a comprehensive understanding of formulation performance, stability, safety, and clinical suitability. Proper assessment ensures development of herbal gels that are not only therapeutically effective but also cosmetically acceptable and patient friendly.

6. Clinical Potential of Herbal Anti-Acne Gels

Clinical and experimental investigations have consistently demonstrated that topical herbal anti-acne gels effectively reduce inflammatory lesions, erythema, and microbial load while simultaneously improving overall skin texture and appearance. These formulations act through multiple mechanisms, including suppression of acne-causing bacteria, inhibition of inflammatory mediators, regulation of sebum secretion, and neutralization of oxidative stress. The presence of diverse phytoconstituents such as flavonoids, terpenoids, and phenolic compounds enables a synergistic therapeutic effect, allowing herbal gels to address several pathogenic factors of acne simultaneously^{17,19}.

Compared to conventional synthetic formulations, herbal gels generally exhibit superior tolerability with a lower incidence of adverse reactions such as dryness, peeling, burning sensation, and photosensitivity. This improved safety profile makes them particularly suitable

for prolonged use, which is often required in chronic or recurrent acne. Patients with sensitive skin also benefit from herbal gels due to their soothing and skin-repairing properties, which help restore barrier function and reduce irritation¹⁹.

Another important clinical advantage of herbal anti-acne gels is enhanced patient adherence. Their lightweight, non-greasy texture and cooling sensation improve cosmetic acceptability, encouraging regular application. Localized delivery of herbal actives minimizes systemic exposure while ensuring effective concentration at the site of action. Additionally, several herbal constituents promote wound healing and reduce post-inflammatory hyperpigmentation, contributing to better cosmetic outcomes and reduced risk of scarring¹⁹.

The multitarget nature of herbal gels makes them particularly valuable in long-term acne management, where monotherapy with synthetic agents may lead to resistance or intolerance. With continued improvements in formulation technology and growing clinical evidence, topical herbal gels are increasingly recognized as safe, effective, and patient-friendly alternatives or adjuncts to conventional anti-acne therapies.

7. Challenges and Limitations: Despite promising outcomes, herbal gel development faces challenges such as:

- Variability in herbal extract composition
- Standardization of active markers
- Stability issues of phytoconstituents
- Limited large-scale clinical data

Addressing these limitations requires robust quality control, advanced analytical techniques, and well-designed clinical trials¹⁸⁻²⁰.

8. Future Perspectives: Emerging technologies such as nano-herbal gels, bioadhesive systems, and quality-by-design approaches are expected to enhance stability and skin penetration of herbal actives. Integration of modern formulation science with traditional medicinal knowledge will further strengthen the therapeutic potential of topical herbal gels.

9. Conclusion: Topical herbal gels represent a promising, patient-friendly approach for acne management by combining the therapeutic benefits of medicinal plants with modern gel-based delivery systems. Advances in polymer technology and formulation strategies have enabled development of stable, effective, and cosmetically acceptable products. Although challenges related to standardization and clinical validation remain, continued research is likely to establish herbal gels as reliable alternatives to conventional anti-acne therapies, offering safer long-term management of acne vulgaris.

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