

Formulation and Evaluation of Polyherbal Antimicrobial and Scar Soothing Gel

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ABSTRACT

The present study was focused on the formulation and evaluation of a polyherbal antimicrobial and scar soothing gel using natural herbal ingredients such as Neem extract (*Azadirachta indica*), Aloe vera extract (*Aloe barbadensis Miller*), and Tea Tree Oil (*Melaleuca alternifolia*). The objective of the study was to develop a safe, effective, and stable topical herbal formulation possessing antimicrobial, soothing, moisturizing, and wound healing properties for the management of minor skin infections and scar-related conditions. The gel formulation was prepared using Carbopol 940 as a gelling agent along with suitable pharmaceutical excipients including propylene glycol, glycerin, methyl paraben, propyl paraben, disodium EDTA, and triethanolamine. The prepared formulation was evaluated for various physicochemical and microbiological parameters such as appearance, pH, viscosity, spreadability, homogeneity, antimicrobial activity, and stability. The prepared gel exhibited satisfactory physicochemical characteristics including smooth texture, homogeneous appearance, acceptable viscosity, good spreadability, and skin-compatible pH. The antimicrobial study demonstrated significant inhibitory activity against selected microorganisms, which may be attributed to the synergistic action of Neem extract and Tea Tree Oil. Aloe vera contributed to the soothing, moisturizing, anti-inflammatory, and wound healing effects of the formulation.

The stability study indicated that the prepared formulation remained stable during the storage period without significant changes in color, odor, pH, consistency, or homogeneity. The results of the present study suggested that the formulated polyherbal antimicrobial and scar soothing gel may serve as a safe, effective, and natural alternative to synthetic topical preparations used for the treatment of skin infections, wounds, irritation, and scar-related conditions.

Keywords- Polyherbal Gel, Antimicrobial Activity, Scar Soothing Gel, Neem Extract, Aloe vera, Tea Tree Oil, Herbal Formulation, Topical Drug Delivery, Wound Healing, Skin Infection, Carbopol 940, Herbal Therapeutics

I. INTRODUCTION

^[1,3,6] The skin is the largest and one of the most vital organs of the human body, serving as a primary protective barrier against external environmental factors such as microorganisms, pollutants, ultraviolet radiation, and physical injury. It plays a significant role in maintaining homeostasis, regulating temperature, and preventing the entry of harmful pathogens. Despite its protective nature, the skin is highly susceptible to various disorders including microbial infections, inflammation, wounds, acne, and scar formation, especially when its integrity is compromised. Microbial infections of the skin are commonly caused by bacteria

such as *Staphylococcus aureus* and *Escherichia coli*, which can invade damaged or sensitive skin surfaces. These infections often lead to delayed healing and may result in the formation of scars, which can affect both the physiological function and aesthetic appearance of the skin. Scar formation is a complex biological process involving collagen deposition and tissue remodeling, and improper healing can lead to permanent marks or pigmentation. Conventional treatment approaches for such skin conditions generally involve the use of synthetic antimicrobial agents, antibiotics, and topical creams. Although these treatments are effective to some extent, their prolonged use is often associated with several drawbacks, including skin irritation, allergic

reactions, dryness, and the development of microbial resistance. These limitations have created a need for safer, more effective, and naturally derived alternatives.

In recent years, there has been a growing interest in herbal and polyherbal formulations due to their wide therapeutic potential, better compatibility with skin, and minimal side effects. Medicinal plants have been used traditionally for centuries in the treatment of various skin ailments. Among them, Neem is widely known for its potent antimicrobial, antifungal, and anti-inflammatory properties, making it highly effective in controlling skin infections. Similarly, Aloe vera is recognized for its soothing, moisturizing, and wound healing properties, and it helps in accelerating tissue regeneration and reducing inflammation. In addition to these herbal extracts, essential oils such as tea tree oil have gained importance due to their strong antimicrobial and antiseptic activities. Tea tree oil is effective against a broad spectrum of microorganisms and also contributes to reducing inflammation and promoting faster healing of damaged skin. The combination of multiple herbal ingredients in a single formulation, known as a polyherbal approach, often produces a synergistic effect, enhancing the overall therapeutic efficacy of the product. Among various topical dosage forms, gels are considered highly suitable for skin applications due to their non-greasy nature, ease of application, better spreadability, and improved patient compliance. Gels also provide effective drug delivery by allowing better penetration of active ingredients into the skin layers. Carbopol based gels, in particular, are widely used in pharmaceutical formulations because of their excellent gelling properties, stability, and compatibility with a wide range of active ingredients.

Therefore, the present study is focused on the formulation and evaluation of a polyherbal antimicrobial and scar soothing gel using natural ingredients. The objective is to develop a stable, effective, and skin-friendly formulation that can combat microbial infections while promoting healing and reducing scar formation. This approach not only aligns with the current trend of herbal therapeutics but also offers a safer and cost-effective alternative to conventional synthetic formulations.

II. [1,5,11,15] BENEFITS OF APPLYING ANTIMICROBIAL AND SCAR SOOTHING GEL

- Provides effective protection against microbial infections by inhibiting the growth of bacteria and fungi due to the presence of Neem and tea tree oil.
- Helps in faster wound healing by promoting cell regeneration and tissue repair with the help of Aloe vera.
- Assists in reducing scars and marks by regulating collagen formation and improving skin healing.

- Exhibits anti-inflammatory properties, which reduce redness, swelling, and irritation of the skin.
- Provides a cooling and soothing effect, giving relief from burning sensation, itching, and discomfort.
- Maintains skin hydration and moisture balance, preventing dryness and improving skin texture.
- Enhances penetration of active ingredients into deeper skin layers, leading to better therapeutic action.
- Has a non-greasy and non-sticky nature, making it easy to apply and comfortable for daily use.
- Shows better spreadability, ensuring uniform application over the affected area.
- Reduces the risk of side effects and skin irritation due to the use of natural and herbal components.
- Suitable for multiple skin conditions such as acne, minor wounds, infections, and scars.

The application of a polyherbal antimicrobial and scar soothing gel offers multiple therapeutic and cosmetic benefits for skin health. The combination of natural ingredients with a gel-based delivery system enhances both effectiveness and patient acceptability.

III. [1,2,14,17] PRECAUTIONS TO BE TAKEN WHILE APPLYING GEL

1. Always clean and dry the affected area before applying the gel to ensure better absorption and effectiveness.
2. Apply a thin and uniform layer of gel; excessive application may not increase effectiveness and can cause discomfort.
3. Perform a patch test on a small area of skin before first use to check for any allergic reaction or sensitivity.
4. Avoid contact with eyes, mouth, and mucous membranes; in case of accidental contact, rinse immediately with water.
5. Do not apply the gel on deep wounds, severe burns, or broken skin without medical supervision.
6. Use clean hands or sterile applicator while applying to prevent contamination.
7. Do not cover the applied area with tight bandages unless advised, as it may affect proper air circulation.
8. Store the gel in a cool and dry place, away from direct sunlight and heat.

IV. MATERIALS AND METHODS

All the materials used in the formulation were chosen based on their proven therapeutic efficacy, compatibility, and suitability for topical application. They were selected to ensure proper gel formation, stability, and enhanced skin penetration.

^[1,2,7,9,13] **NEEM (*Azadirachta indica*)**

(*Azadirachta indica*) is a well-known medicinal plant widely used in dermatological formulations due to its strong antimicrobial and healing properties. In polyherbal gel formulations, neem plays a crucial role as a natural therapeutic agent that targets skin infections and supports tissue repair



Fig 1. NEEM (*Azadirachta indica*)

Chemical constituents:

1. Azadirachtin → It is the main active compound in neem that helps in preventing the growth of harmful microorganisms and protects the skin from infections.
2. Nimbidin → This compound shows strong antibacterial and antifungal activity, helping to eliminate germs present on the skin.
3. Nimbin → It mainly works as an anti-inflammatory agent, reducing redness, irritation, and swelling of the skin.
4. Quercetin → A natural antioxidant that protects skin cells from damage and supports the healing process.
5. Tannins → These help in tightening the skin and promote faster healing of wounds, reducing scar formation.
6. Saponins → They act as natural cleansing agents and also support antimicrobial activity.
7. Salannin → This compound helps in protecting the skin from external microbial infections and enhances overall protection.

^[4,5,6,9,12] **ALOE VERA (*Aloe barbadensis miller*)**

Aloe barbadensis miller is a widely used medicinal plant known for its soothing, moisturizing, and healing properties. It is commonly used in skin care formulations because of its ability to hydrate the skin and promote faster repair of damaged tissues.



Fig 2. ALOE VERA (*Aloe barbadensis miller*)

Chemical constituents:

1. Acemannan → A polysaccharide that promotes cell regeneration and enhances wound healing.
2. Aloin → Provides mild antimicrobial activity and helps in protecting the skin from infection.
3. Aloe-emodin → Shows antibacterial and anti-inflammatory properties, supporting skin repair.
4. Vitamins (A, C, E) → Act as antioxidants and protect skin from damage caused by free radicals.
5. Enzymes (like amylase, lipase) → Help in reducing inflammation and improving skin metabolism.
6. Saponins → Provide cleansing and antiseptic properties, helping to keep the skin clean.
7. Amino acids → Support skin repair and help in maintaining healthy skin structure.

^[3,6,11,16] **Tea Tree Oil (*Melaleuca alternifolia*)**

Melaleuca alternifolia, commonly known as Tea Tree, is a medicinal plant whose essential oil is widely used in dermatological formulations due to its strong antimicrobial and anti-inflammatory properties. It is especially effective in treating skin infections, acne, and minor wounds.



Fig 3. Tea Tree Oil (*Melaleuca alternifolia*)

Chemical Constituents:

1. Terpinen-4-ol → The main active component responsible for strong antimicrobial activity.
2. γ -Terpinene → Acts as an antioxidant and supports overall skin protection.
3. α -Terpinene → Helps in reducing inflammation and contributes to antimicrobial effect.
4. 1,8-Cineole (Eucalyptol) → Provides mild antiseptic properties and soothing effect.
5. α -Pinene → Shows antibacterial activity and supports skin healing.
6. Limonene → Acts as an antioxidant and helps in improving skin condition.
7. Terpinolene → Contributes to antimicrobial and antifungal properties.

^[6,4,7,15] **Menthol (*Mentha-derived compound*)**

Menthol is a naturally occurring compound obtained from mint oils, especially from plants of the genus *Mentha*. It is widely used in topical formulations due to its cooling, soothing, and mild analgesic properties. It provides a refreshing sensation when applied to the skin, making it a popular ingredient in dermatological and cosmetic preparations.



Fig 4. Menthol (Mentha-derived compound)

Chemical Constituents:

1. Menthol ($C_{10}H_{20}O$) → The primary active compound responsible for cooling and soothing effect.
2. Menthone → Contributes to mild analgesic and refreshing properties.
3. Isomenthol → Supports cooling effect and enhances sensory feel.
4. Menthol esters → Help in maintaining fragrance and stability.
5. Limonene (trace) → Provides mild antioxidant activity.
6. Pulegone (trace) → Contributes to mint aroma and slight antimicrobial effect.
7. Pinene (trace) → Supports mild antimicrobial and anti-inflammatory activity.

[2,4,6,7]Carbopol 940 (Polyacrylic Acid Polymer)

Carbopol 940 is a synthetic high molecular weight polymer widely used in pharmaceutical and cosmetic formulations as a gelling agent. It is known for its excellent thickening ability and its capacity to form clear, stable gels when dispersed in water and neutralized. Due to its smooth texture and good compatibility with active ingredients, it is commonly used in topical gel preparations.



Fig 5. Carbopol 940 (Polyacrylic Acid Polymer)

Chemical Constituents:

1. Polyacrylic acid → Main backbone polymer responsible for gel formation and viscosity.
2. Cross-linked acrylic polymer → Provides stability and prevents breakdown of gel structure.
3. Carboxyl ($-COOH$) groups → Ionize on neutralization, causing swelling and gel formation.

4. High molecular weight chains → Responsible for thickening and consistency.
5. Hydrophilic nature → Allows absorption of water and swelling.
6. Cross-linking agents (trace) → Maintain 3D network structure of gel.
7. Anionic polymer nature → Helps in compatibility with various ingredients and pH adjustment.

[4,7,8,14]Propylene Glycol (Propane-1,2-diol)

Propylene glycol is a widely used pharmaceutical excipient that appears as a clear, colorless, and viscous liquid. It is commonly used in topical formulations due to its excellent solvent, moisturizing, and penetration-enhancing properties. It is highly compatible with both water and organic substances, making it suitable for gel preparations.

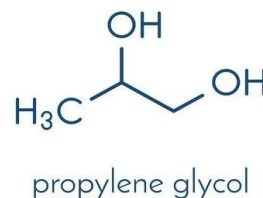


Fig 6. Propylene Glycol (Propane-1,2-diol)

Chemical Constituents:

1. Propane-1,2-diol ($C_3H_8O_2$) → Main compound responsible for its solvent and moisturizing properties.
2. Hydroxyl ($-OH$) groups → Provide hydrophilic nature and help in water retention.
3. Low molecular weight diol → Enhances skin penetration of active ingredients.
4. Hygroscopic nature → Attracts and retains moisture from the environment.
5. Miscibility with water and alcohol → Ensures uniform mixing of all components.
6. Stable organic compound → Maintains formulation stability over time.
7. Non-volatile nature → Helps in maintaining consistency of the gel.

[3,5,12,14]Glycerin (Glycerol)

Glycerin, also known as glycerol, is a clear, colorless, and viscous liquid widely used in pharmaceutical and cosmetic formulations. It is a natural compound obtained from plant oils and is well known for its excellent moisturizing and skin-softening properties. Due to its safety and compatibility, it is commonly used in topical gel preparations.

Chemical Formula : $C_3H_8O_3$

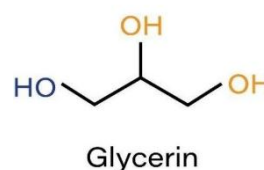


Fig 7. Glycerin (Glycerol)

Chemical Constituents:

1. Glycerol ($C_3H_8O_3$) → Main compound responsible for moisturizing and hydrating properties.
2. Three hydroxyl (-OH) groups → Provide strong water-binding capacity.
3. Hydrophilic nature → Attracts and retains moisture from surroundings.
4. Trihydric alcohol → Enhances skin softness and flexibility.
5. Viscous liquid structure → Contributes to smooth texture of gel.
6. Non-toxic and stable compound → Safe for topical application.
7. Water-miscible nature → Ensures uniform mixing in formulation.

[4,5,15,17] Methyl Paraben (Methyl Parahydroxybenzoate)

Methyl paraben is a widely used preservative in pharmaceutical and cosmetic formulations. It appears as a white crystalline powder and is known for its effective antimicrobial activity, especially against bacteria. It is commonly used in low concentrations to maintain product safety and stability.

Methylparaben

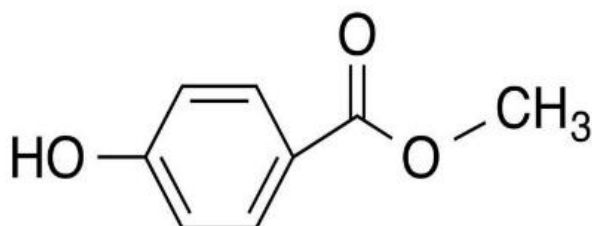


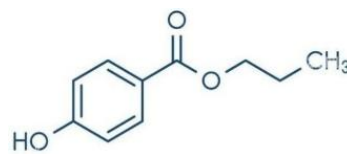
Fig 8. Methyl Paraben (Methyl Parahydroxybenzoate)

Chemical Constituents:

1. Methyl parahydroxybenzoate ($C_8H_8O_3$) → Main compound responsible for antimicrobial activity.
2. Ester of p-hydroxybenzoic acid → Provides preservative action.
3. Phenolic group (-OH) → Contributes to antimicrobial effect.
4. Low molecular weight compound → Easily soluble and effective in low concentration.
5. Stable organic compound → Maintains stability over time.
6. Slightly water-soluble nature → Suitable for aqueous formulations.
7. Compatible with other excipients → Works well in combined formulations.

[7,9,13,15] Propyl Paraben (Propyl Parahydroxybenzoate)

Propyl paraben is another commonly used preservative similar to methyl paraben but with stronger antifungal properties. It is also a white crystalline powder and is often used in combination with methyl paraben for better preservation.



propylparaben

Fig 9. Propyl Paraben (Propyl Parahydroxybenzoate)

Chemical Constituents:

1. Propyl parahydroxybenzoate ($C_{10}H_{12}O_3$) → Main compound with strong antifungal activity.
2. Ester of p-hydroxybenzoic acid → Responsible for preservative action.
3. Phenolic group (-OH) → Helps in inhibiting microbial growth.
4. Higher molecular weight than methyl paraben → Provides longer-lasting effect.
5. Less water-soluble nature → Works better in combination with other preservatives.
6. Stable compound → Maintains effectiveness over storage time.
7. Synergistic action with methyl paraben → Gives broad-spectrum preservation.

[5,7,11,17] Disodium EDTA (Disodium Ethylenediaminetetraacetate)

Disodium EDTA is a commonly used pharmaceutical excipient known for its chelating properties. It appears as a white crystalline powder and is widely used in formulations to improve stability by binding metal ions present in the system.

Disodium EDTA



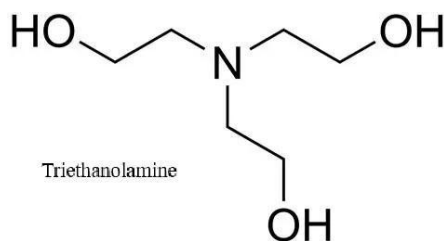
Fig 10. Disodium EDTA

Chemical Constituents:

1. Disodium EDTA ($C_{10}H_{14}N_2Na_2O_8$) → Main chelating compound that binds metal ions.
2. Carboxyl (-COO⁻) groups → Responsible for binding with metal ions like Ca^{2+} and Mg^{2+} .
3. Amine (-NH) groups → Assist in strong coordination with metal ions.
4. Chelating structure → Forms stable complexes with trace metals.
5. Water-soluble nature → Easily incorporated in aqueous formulations.
6. Stable compound → Maintains effectiveness over time.
7. Synergistic effect → Improves performance of preservatives like parabens.

[11,14,16,17]Triethanolamine

Triethanolamine is an organic compound widely used in gel formulations as a pH adjusting agent. It is a clear, viscous liquid and plays an essential role in converting polymer dispersions into gel form.

**Fig 11. Triethanolamine (TEA)****Chemical Constituents:**

1. Triethanolamine ($C_6H_{15}NO_3$) → Main compound responsible for pH adjustment and gel formation.
2. Amine group (-N) → Provides basic nature for neutralization.
3. Hydroxyl (-OH) groups → Improve solubility and compatibility.
4. Weak base property → Helps in controlling formulation pH.
5. Viscous liquid form → Contributes to smooth texture.
6. Water-miscible nature → Ensures uniform mixing.
7. Stable organic compound → Maintains consistency of gel.

V. [3,7,16,17] FORMULATION AND EVALUATION

S. No	Ingredient Name	Scientific / Chemical Name	Sample Quantity
1	Neem Extract	Azadirachta indica	3.3ml
2	Aloe vera Gel	Aloe barbadensis miller	11g
3	Tea Tree Oil	Melaleuca alternifolia oil	0.17ml
4	Carbopol 940	Polyacrylic acid polymer	0.83g
5	Propylene Glycol	Propane-1,2-dio	7.7ml
6	Glycerin	Glycerol	4.4g
7	Methyl Paraben	Methyl parahydroxybenzoate	0.20g
8	Propyl Paraben	Propyl parahydroxybenzoate	0.022g
9	Disodium EDTA	Disodium edetate	0.055g
10	Triethanolamine	Triethanolamine	0.6ml
11	Distilled Water	Purified water	q.s
12	Menthol	Mentha-derived compound	0.11ml

VI. [3,4,7,16] METHOD OF PREPARATION

The polyherbal antimicrobial and scar soothing gel was formulated using a standard gel preparation technique with slight modifications as reported in previous studies. Initially, the gelling agent, Carbopol 940, was dispersed in a measured quantity of distilled water under continuous stirring to avoid lump formation and was allowed to hydrate completely. In a separate phase, the required quantities of propylene glycol and glycerin were taken and used as a solvent system for dissolving the preservatives, followed by the incorporation of the essential oil component to ensure uniform distribution. Subsequently, the herbal extracts, including Azadirachta indica and Aloe barbadensis miller, were gradually incorporated into the mixture with continuous stirring to obtain a homogeneous dispersion. The prepared mixture was then slowly added to the hydrated Carbopol base under controlled conditions.

Further, disodium EDTA was incorporated to enhance formulation stability, and the pH of the system was adjusted using triethanolamine to achieve a suitable skin-compatible range, which also resulted in the conversion of the dispersion into a gel form. The final formulation was subjected to continuous stirring to ensure uniform consistency and was allowed to stand for complete stabilization and removal of entrapped air.

The prepared gel was then transferred into suitable containers for further evaluation studies. The overall method followed was based on established pharmaceutical gel formulation techniques with necessary modifications to accommodate the polyherbal components.

VII. [7,10,12,17] EVALUATION OF GEL pH**Determination:**

The pH of the prepared polyherbal gel was determined using a calibrated digital pH meter. For measurement, a small quantity of gel was dispersed in distilled water and the electrode was immersed into the sample. The pH plays a crucial role in maintaining skin compatibility, as formulations with highly acidic or alkaline nature may lead to irritation, redness, or discomfort. Therefore, maintaining the pH within the physiological skin range (approximately 5.5–6.5) is essential. Additionally, appropriate pH also contributes to the stability of both herbal extracts and synthetic excipients present in the formulation.

Viscosity:

Viscosity of the gel was evaluated to understand its rheological behavior and flow characteristics. It determines the resistance of the gel to flow and directly affects its application properties. An ideal gel should possess optimum viscosity so that it

remains adhered to the skin surface for a sufficient period while still being easy to apply. If the viscosity is too low, the gel may spread excessively and fail to remain at the site of application, whereas excessively high viscosity can make application difficult. Thus, maintaining balanced viscosity is important for both stability and patient compliance.

Spreadability:

Spreadability was determined by placing a fixed amount of gel between two clean glass slides and applying a certain amount of pressure. The ease with which the gel spreads over the surface indicates its spreadability. Good spreadability ensures that the gel can be easily applied with minimal effort and forms a uniform thin layer over the skin. This property is particularly important for ensuring even distribution of active herbal components, thereby enhancing the therapeutic effectiveness of the formulation.

Homogeneity:

Homogeneity of the gel was evaluated by visual inspection and by gently rubbing a small quantity of gel between fingers. The formulation should appear smooth, uniform, and free from lumps or coarse particles. The absence of phase separation or aggregation indicates proper mixing of all ingredients. A homogeneous gel ensures that the active constituents are uniformly distributed throughout the formulation, which is essential for consistent antimicrobial and scar soothing activity.

Antimicrobial Activity:

The antimicrobial activity of the polyherbal gel was assessed using standard microbiological techniques such as the agar well diffusion method. In this method, the gel sample is applied to a culture medium inoculated with selected microorganisms, and the zone of inhibition is observed after incubation. A larger zone of inhibition indicates stronger antimicrobial activity. This evaluation is particularly important for confirming the effectiveness of herbal ingredients like neem and tea tree oil in inhibiting the growth of pathogenic bacteria and fungi associated with skin infections.

Stability Study:

Stability studies were performed by storing the prepared gel under different environmental conditions such as room temperature and elevated temperature for a specified period. During the study, parameters such as color, odor, pH, and viscosity were periodically observed. The purpose of this evaluation is to determine whether the formulation maintains its physical and chemical stability over time. A stable formulation shows no significant changes in its properties, ensuring its safety, efficacy, and acceptable shelf life.

Observation and Result's

The prepared polyherbal antimicrobial and scar soothing gel was evaluated for various physicochemical and functional parameters. The results obtained indicated that the formulation possessed acceptable characteristics suitable for topical application.

S. No	Evaluation Parameters	Result Obtained	Inference
1	pH	5.5 ± 0.1	Ideal skin-compatible
2	Viscosity	3200–3600 cps	Suitable consistency
3	Spreadability	6.5 g·cm/sec	Good spreading ability
4	Homogeneity	Smooth, no lumps	Uniform formulation
5	Antimicrobial Activity	Zone of inhibition: 12–16 mm	Effective against microbes
6	Stability Study	No significant change	Stable formulation

VIII. SUMMARY

The present review focuses on the formulation and evaluation of a polyherbal antimicrobial and scar soothing gel using natural ingredients such as neem extract, aloe vera extract, and tea tree oil. The selection of these herbal components was based on their well-documented antimicrobial, anti-inflammatory, and wound healing properties, making them suitable for topical therapeutic applications. The gel-based delivery system was preferred over other dosage forms due to its non-greasy nature, ease of application, better patient compliance, and enhanced penetration of active constituents into the skin. The formulation was developed using suitable excipients to achieve optimal consistency, stability, and effectiveness. Various evaluation parameters such as pH, viscosity, spreadability, homogeneity, antimicrobial activity, and stability were carried out to assess the quality of the prepared formulation. The obtained results indicated that the gel possesses desirable physicochemical properties, effective antimicrobial action, and good stability under normal conditions.

Overall, the developed polyherbal gel demonstrates significant potential as a safe, effective, and economical topical formulation for managing minor skin infections and promoting scar soothing. This study highlights the importance of herbal-based formulations as promising alternatives to synthetic products in dermatological applications.

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