# Formulation And Evaluation of Herbal Anti-Acne Gel Containing *Aloe Vera* Extract for Anti-Inflammatory and Anti-Acne Activity

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***Abstract*—Acne vulgaris is one of the most prevalent chronic inflammatory skin disorders affecting adolescents and adults worldwide, characterized by excessive sebum production, follicular blockage, bacterial colonization, and inflammatory lesion formation. Conventional anti-acne therapies such as benzoyl peroxide, retinoids, clindamycin, and systemic antibiotics are widely used; however, prolonged treatment is frequently associated with adverse effects including skin irritation, dryness, photosensitivity, and increasing antibiotic resistance. These limitations have generated significant interest in herbal dermatological formulations as safer and more sustainable alternatives. The present study aimed to formulate and evaluate a herbal anti-acne gel containing Aloe vera *Aloe vera* extract for anti-inflammatory and anti-acne activity.**

***Aloe vera* extract was prepared by Soxhlet extraction using ethanol and incorporated into Carbopol 934-based gel formulations prepared in nine experimental batches with varying extract and polymer concentrations. The formulations were evaluated for organoleptic properties, physicochemical parameters including pH, viscosity, spreadability, extrudability, homogeneity, and drug content. Biological evaluation included antimicrobial activity against Cutibacterium acnes *Cutibacterium acnes*, anti-inflammatory activity, skin irritation testing, and stability studies conducted under ICH guidelines. The optimized formulation demonstrated acceptable physicochemical characteristics, significant antibacterial activity, strong anti-inflammatory potential, and excellent formulation stability during storage. The study concluded that *Aloe vera*-based herbal anti-acne gel possesses promising therapeutic potential as a safe, stable, and effective topical alternative to conventional synthetic anti-acne formulations. Further clinical evaluation is recommended to establish long-term efficacy and therapeutic application in acne management.**

***Index Terms*—*Aloe vera*, Herbal Anti-Acne Gel, Acne Vulgaris, Topical Drug Delivery, Cutibacterium acnes *Cutibacterium acnes*, Anti-Inflammatory Activity.**

## I. INTRODUCTION

### 1.1. Skin Structure and Acne Vulgaris

The skin represents the largest and one of the most physiologically complex organs of the human body, functioning as a dynamic protective barrier that maintains homeostasis while simultaneously providing defense against microbial invasion, ultraviolet radiation, environmental toxins, and mechanical injury. Beyond its barrier function, the skin regulates thermoregulation, immunological surveillance, sensory perception, wound repair, and metabolic processes. Because of its constant interaction with the external environment, disruption of normal skin physiology frequently contributes to the development of inflammatory dermatological disorders, among which acne vulgaris remains one of the most prevalent chronic conditions worldwide (Montero-Vilchez et al., 2021).

Structurally, human skin consists of highly organized anatomical layers including the epidermis, dermis, and

hypodermis, together with specialized appendages such as sebaceous glands, sweat glands, and hair follicles. These structures collectively maintain barrier integrity and regulate multiple physiological functions essential for skin health. Dysfunction in any of these structures may contribute directly to pathological skin conditions, particularly disorders associated with inflammation and microbial colonization.

The epidermis forms the outermost layer of the skin and serves as the principal physical barrier separating internal tissues from the external environment. Histologically, it consists primarily of keratinocytes arranged in distinct layers including stratum corneum, stratum granulosum, stratum spinosum, and stratum basale. Recent dermatological investigations have demonstrated that epidermal barrier dysfunction significantly contributes to inflammatory skin diseases by increasing transepidermal water loss and enhancing susceptibility to microbial colonization (Elias, 2022). In acne pathogenesis, abnormal keratinocyte differentiation within the follicular epithelium promotes hyperkeratinization, which contributes directly to pore obstruction and lesion formation.

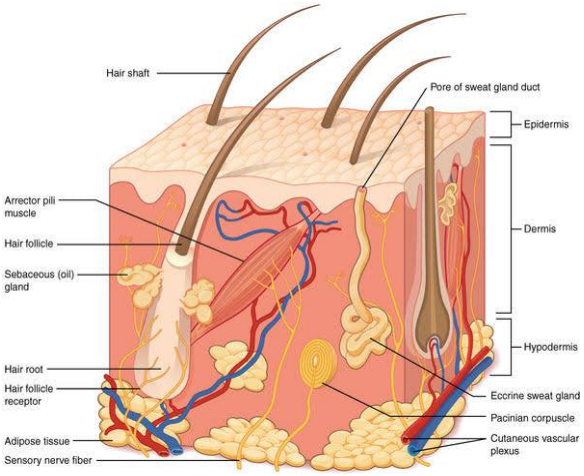


Fig.01. Structure of Skin

Beneath the epidermis lies the dermis, a structurally dense connective tissue matrix containing collagen fibers, elastin fibers, fibroblasts, immune cells, blood vessels, lymphatics, and neural networks. The dermis provides mechanical strength, elasticity, nutrient delivery, and structural support to overlying epidermal tissues. Emerging evidence suggests that dermal inflammatory signaling pathways play a critical role in propagating acne-associated inflammation through activation of pro-inflammatory cytokines, matrix metalloproteinases, and oxidative stress mediators that contribute to lesion progression and tissue damage (Dreno et al., 2023).

Embedded within the dermis are sebaceous glands, specialized exocrine glands anatomically associated with hair follicles and collectively forming the pilosebaceous unit, which serves as the central biological structure involved in acne development. Sebaceous glands synthesize and secrete sebum, a lipid-rich mixture composed primarily of triglycerides, wax esters, squalene, cholesterol esters, and free fatty acids. Physiologically, sebum lubricates skin surfaces and prevents dehydration. However, dysregulated sebaceous gland activity leads to excessive sebum production, recognized as one of the earliest pathogenic events in acne vulgaris. Recent molecular studies have demonstrated that androgen receptor signaling, insulin-like growth factor-1 (IGF-1), and mTORC1 pathway activation significantly stimulate sebaceous lipid synthesis and promote acne progression (Melnik, 2021).

Hair follicles are complex epidermal invaginations extending deep into the dermis and closely integrated with sebaceous glands. The follicular canal normally facilitates outward movement of sebum and desquamated epithelial cells. Under pathological conditions, abnormal keratinocyte proliferation causes accumulation of corneocytes within the follicular opening, resulting in follicular blockage or comedone formation. Microcomedones subsequently create an anaerobic microenvironment favorable for bacterial colonization. Contemporary dermatological research recognizes follicular hyperkeratinization as one of the earliest initiating mechanisms in acne pathogenesis and a critical therapeutic target (Zaenglein et al., 2022).

Acne vulgaris is currently recognized as a chronic inflammatory disorder affecting the pilosebaceous unit and characterized clinically by the formation of open comedones, closed comedones, papules, pustules, nodules, cystic lesions, post-inflammatory hyperpigmentation, and permanent scarring. Epidemiological studies estimate that acne affects approximately 85% of adolescents globally while increasingly affecting adult populations due to hormonal disturbances, stress-related endocrine dysfunction, dietary factors, and environmental exposures (Bhate & Williams, 2021). Although

traditionally considered a cosmetic disorder, current literature increasingly recognizes acne as a chronic inflammatory disease with substantial psychological consequences including anxiety, depression, reduced self-esteem, and impaired quality of life.

Current scientific consensus identifies four major pathological mechanisms responsible for acne development. The first mechanism involves excess sebum production, where increased androgen stimulation during puberty, endocrine abnormalities, or metabolic disturbances activates sebaceous gland hypertrophy and excessive lipid synthesis. Elevated sebum accumulation creates an ideal substrate for bacterial proliferation and contributes directly to follicular occlusion. Recent metabolomic studies suggest that alterations in sebum lipid composition, particularly increased squalene oxidation, may intensify inflammatory responses and worsen acne severity (Picardo et al., 2022). The second pathogenic mechanism involves follicular blockage, caused by abnormal hyperproliferation and incomplete shedding of keratinocytes within the follicular canal. Hyperkeratinization disrupts normal follicular drainage and leads to microcomedone formation. Several studies have demonstrated that altered expression of keratin-16 and inflammatory signaling molecules within follicular epithelial cells significantly contributes to this process (Tanghetti et al., 2021).

The third critical factor involves bacterial infection, primarily associated with the anaerobic Gram-positive bacterium Cutibacterium acnes *Cutibacterium acnes* (formerly *Propionibacterium acnes*). Although *C. acnes* exists as part of normal skin microbiota, pathogenic strains proliferate aggressively within blocked follicles where they metabolize triglycerides present in sebum into free fatty acids. These metabolites stimulate toll-like receptor activation, enhance bacterial biofilm formation, and trigger inflammatory cytokine release. Recent genomic studies demonstrate that strain-specific differences in *C. acnes* virulence significantly influence acne severity, indicating that not all bacterial populations contribute equally to disease progression (O'Neill & Gallo, 2023).

The fourth pathogenic mechanism involves hormonal imbalance, particularly increased androgen concentrations observed during adolescence, menstrual disturbances, polycystic ovarian syndrome, and endocrine dysfunction. Androgen-mediated stimulation enhances sebaceous gland activity while simultaneously increasing keratinocyte proliferation, thereby accelerating comedogenesis. Emerging research also suggests that dietary factors capable of elevating insulin and IGF-1 signaling may indirectly worsen hormonally mediated acne (Melnik, 2021).

An essential downstream consequence of these mechanisms is inflammation, now considered a central pathogenic driver rather than a secondary event. Earlier models described inflammation as occurring after bacterial colonization; however, recent immunological studies reveal that inflammatory pathways may begin during early microcomedone formation even before visible lesion development. Activation of interleukin-1β, tumor necrosis factor-alpha, nuclear factor kappa B (NF-κB), reactive oxygen species generation, and neutrophil recruitment collectively drive lesion progression and tissue destruction (Dreno et al., 2023). The role of *Cutibacterium acnes* remains particularly significant because the microorganism not only colonizes obstructed follicles but actively modulates host immune responses. Biofilm formation enhances bacterial persistence and reduces susceptibility to conventional antibiotics, contributing to the increasing problem of antimicrobial resistance observed in acne management. This emerging resistance challenge has accelerated interest in plant-derived antimicrobial compounds capable of inhibiting bacterial growth while simultaneously providing anti-inflammatory and antioxidant benefits.

Collectively, contemporary evidence indicates that acne vulgaris is not simply a superficial bacterial infection but rather a multifactorial chronic inflammatory disorder involving complex interactions between sebaceous gland dysregulation, abnormal follicular keratinization, microbial imbalance, endocrine factors, and immune-mediated inflammatory pathways. This evolving understanding has created strong scientific rationale for developing safer multifunctional herbal topical formulations capable of simultaneously targeting bacterial growth, inflammation, oxidative stress, and skin repair mechanisms.

1.2. Conventional Anti-Acne Therapy

Acne vulgaris management has traditionally relied on pharmacological agents designed to target the major pathogenic mechanisms involved in disease progression, including excessive sebum production, follicular hyperkeratinization, microbial colonization, and inflammatory responses. Conventional anti-acne therapies generally include topical agents such as benzoyl peroxide, retinoids, clindamycin, and systemic antibiotics. Although these treatments remain clinically effective, increasing concerns regarding adverse effects, long-term tolerability, and antimicrobial resistance have stimulated interest in safer therapeutic alternatives (Thiboutot et al., 2021).

Benzoyl peroxide (BPO) remains one of the most commonly prescribed topical treatments for mild to moderate acne vulgaris. It exhibits potent antibacterial activity through the generation of reactive oxygen species that oxidatively destroy bacterial cell membranes, particularly against Cutibacterium acnes *Cutibacterium acnes*. Unlike antibiotics, benzoyl peroxide does not directly induce bacterial resistance, making it clinically valuable for long-term acne management. In addition to antibacterial effects, benzoyl peroxide possesses mild keratolytic activity that promotes follicular desquamation and reduces comedone formation. However, recent clinical studies indicate that prolonged benzoyl peroxide exposure frequently causes skin irritation, erythema, peeling, and compromised epidermal barrier function, reducing patient adherence to treatment (Zaenglein et al., 2022).

Clindamycin, a lincosamide antibiotic widely used in topical acne formulations, functions by inhibiting bacterial protein synthesis through interaction with the 50S ribosomal subunit. Its therapeutic value primarily derives from suppressing *C. acnes* proliferation while simultaneously reducing inflammatory lesion formation. Combination therapy involving clindamycin and benzoyl peroxide remains common clinical practice because dual mechanisms improve efficacy while partially reducing antibiotic resistance development. Despite these benefits, recent surveillance studies report increasing prevalence of clindamycin-resistant *Cutibacterium acnes* strains, raising significant concerns regarding long-term therapeutic sustainability (Dreno et al., 2023).

Antibiotics, both topical and systemic, continue to play an important role in moderate to severe inflammatory acne management. Common systemic antibiotics include doxycycline, minocycline, tetracycline, and erythromycin, all of which suppress bacterial proliferation while reducing inflammatory mediator production. However, widespread antibiotic overuse has contributed significantly to the global emergence of antimicrobial resistance. Several recent meta-analyses demonstrate increasing resistance rates among *C. acnes* strains against tetracycline derivatives and macrolide antibiotics, thereby limiting long-term effectiveness of conventional antibiotic therapy (Coates et al., 2022).

Despite their therapeutic success, conventional anti-acne treatments present several clinically significant limitations. One of the most frequently reported adverse effects is skin irritation, characterized by erythema, burning sensation, peeling, and inflammation resulting from prolonged exposure to chemically active agents such as benzoyl peroxide and retinoids. These effects compromise skin barrier integrity and frequently reduce treatment adherence.

Another common complication involves dryness, particularly associated with retinoid-mediated accelerated epidermal turnover and reduced skin hydration. Persistent dryness often leads to discomfort and discontinuation of therapy, especially among patients with sensitive or already compromised skin barriers.

A growing global concern involves antibiotic resistance, increasingly recognized as one of the major limitations of long-term acne therapy. Excessive reliance on topical and systemic antibiotics has accelerated emergence of resistant *C. acnes* strains while also contributing to broader microbiome disturbances. Current dermatological guidelines increasingly recommend minimizing prolonged antibiotic exposure due to this concern (Dreno et al., 2023).

In addition, many conventional anti-acne agents induce photosensitivity, increasing susceptibility to ultraviolet-induced skin damage. Retinoids and certain antibiotics significantly enhance photo-irritation reactions, requiring strict sun protection measures during therapy. This limitation reduces treatment convenience and negatively influences patient compliance, particularly in tropical climates.

1.3. Herbal Dermatological Products

Growing awareness regarding the adverse effects associated with synthetic dermatological formulations has substantially increased global demand for herbal skincare products. The cosmetic and dermatological industries have experienced rapid expansion of plant-based formulations because consumers increasingly prefer products perceived as safer, environmentally sustainable, and biologically compatible with skin physiology. Contemporary market analyses indicate that herbal dermatological products represent one of the fastest-growing segments within the global cosmetic industry, reflecting both consumer preference and scientific interest in phytotherapeutics (Kumar et al., 2024).

One of the principal drivers behind this trend is the increasing recognition that many medicinal plants contain bioactive phytochemicals capable of exerting simultaneous antibacterial, antioxidant, anti-inflammatory, wound healing, and immunomodulatory activities. Unlike synthetic formulations designed primarily around single-target pharmacological mechanisms, herbal products often provide multifunctional therapeutic effects, which is particularly advantageous in acne management where multiple pathogenic mechanisms occur simultaneously.

Compared with synthetic products, herbal formulations generally demonstrate better patient compliance due to superior tolerability profiles. Several comparative dermatological studies indicate that patients using botanical topical preparations report lower incidence of irritation, burning sensation, dryness, and hypersensitivity reactions compared with conventional chemically intensive formulations (Patel et al., 2023). Improved tolerability directly enhances adherence to prolonged treatment regimens, an important factor in chronic acne management. An additional advantage of herbal products involves reduced toxicity. Synthetic preservatives, surfactants, corticosteroids, retinoids, and antimicrobial agents may produce cumulative adverse effects after prolonged use. In contrast, plant-derived phytoconstituents frequently exhibit lower cytotoxicity while maintaining biological activity against pathogenic microorganisms and inflammatory pathways. Recent formulation science increasingly emphasizes herbal excipients and botanical extracts as safer alternatives capable of minimizing systemic toxicity and reducing ecological burden associated with synthetic chemical disposal (Sharma & Verma, 2022).

Furthermore, herbal dermatological products align closely with modern trends favoring sustainable pharmaceutical development, biodegradable ingredients, and environmentally responsible manufacturing. These characteristics contribute significantly to their growing acceptance among both healthcare professionals and consumers.

1.4. Selected Medicinal Plant: Azadirachta indica *Azadirachta indica* (Neem)

*Azadirachta indica* A. Juss., commonly known as Neem, is an evergreen medicinal tree belonging to the family Meliaceae and is extensively distributed throughout tropical and subtropical regions, particularly the Indian subcontinent. Neem has occupied a central position in traditional Ayurvedic medicine for centuries and is widely recognized for its broad therapeutic applications in infectious diseases, dermatological disorders, wound healing, and inflammatory conditions (Alzohairy, 2016). Botanically, Neem is a fast-growing perennial tree capable of reaching heights between 15–20 meters. It possesses pinnate green leaves, small aromatic white flowers, and olive-shaped fruits containing biologically active seeds rich in limonoids. The plant demonstrates remarkable environmental adaptability and survives under arid climatic conditions, making it readily available for pharmaceutical applications.

Taxonomy

| Taxonomic Rank | Classification |
|---|---|
| Kingdom | Plantae |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Order | Sapindales |
| Family | Meliaceae |
| Genus | *Azadirachta* |
| Species | *Azadirachta indica* |

Neem contains numerous therapeutically active phytochemicals, many of which demonstrate significant pharmacological relevance for dermatological applications. Major phytoconstituents include azadirachtin, nimbidin, nimbin, gedunin, quercetin, flavonoids, alkaloids, tannins, terpenoids, limonoids, and polyphenolic compounds. These

constituents collectively contribute antimicrobial, antioxidant, anti-inflammatory, and wound-healing activities relevant to acne treatment. Within traditional Ayurvedic medicine, Neem has historically been used for management of skin infections, eczema, wounds, fungal disorders, inflammatory lesions, fever, parasitic infections, and purification therapies. Traditional use of Neem leaves in topical pastes and decoctions for treating inflammatory skin conditions strongly supports its potential value in anti-acne formulations.

1.5. Pharmacological Activities of Neem

The therapeutic potential of *Azadirachta indica* in dermatological applications derives primarily from its diverse pharmacological properties supported by extensive phytochemical complexity.

Antibacterial activity represents one of Neem's most extensively studied therapeutic properties. Experimental microbiological studies demonstrate that nimbidin, azadirachtin, and quercetin effectively inhibit growth of Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus* and *Cutibacterium acnes*. Proposed mechanisms involve disruption of bacterial cell membranes, inhibition of biofilm formation, and interference with microbial enzyme systems (Subapriya & Nagini, 2021).

Neem also exhibits significant anti-inflammatory activity through suppression of inflammatory mediators including cyclooxygenase enzymes, tumor necrosis factor-alpha, interleukin-6, prostaglandins, and nitric oxide synthesis. Recent molecular pharmacology studies suggest limonoids present in Neem regulate NF-κB inflammatory signaling pathways that contribute directly to inflammatory lesion development (Patel et al., 2023).

Its antioxidant activity derives largely from polyphenols, flavonoids, and tannins capable of scavenging reactive oxygen species generated during inflammatory skin disorders. Oxidative stress contributes significantly to acne lesion progression by enhancing lipid peroxidation within sebaceous secretions. By reducing oxidative damage, Neem may indirectly reduce acne severity.

Neem demonstrates substantial wound healing activity, accelerating epithelial regeneration, collagen synthesis, fibroblast proliferation, and tissue remodeling. Since inflammatory acne lesions frequently produce post-inflammatory tissue damage and scarring, wound healing activity represents an important therapeutic advantage. Recent dermatological investigations further suggest Neem may contribute to sebum regulation by modulating inflammatory pathways associated with sebaceous gland hyperactivity. Although direct molecular evidence remains limited compared with antibacterial studies, preliminary experimental findings indicate plant-derived terpenoids may influence sebaceous lipid metabolism and reduce excessive sebum accumulation.

## II. MATERIALS AND METHODS

2.1. Materials

The successful development of topical herbal formulations depends significantly on the careful selection of plant-derived active ingredients together with pharmaceutically acceptable excipients capable of ensuring formulation stability, adequate skin compatibility, and controlled release of bioactive constituents. In the present study, fresh leaves of Aloe vera *Aloe vera* (*Aloe barbadensis Miller*) were selected as the primary herbal ingredient because of their established anti-inflammatory, antimicrobial, antioxidant, and wound-healing properties reported in dermatological research. Although medicinal plants such as Azadirachta indica *Azadirachta indica* (Neem) and Ocimum tenuiflorum *Ocimum tenuiflorum* (Tulsi) are frequently investigated in anti-acne formulations, *Aloe vera* was specifically selected in the present formulation because of its high polysaccharide content, superior skin-soothing properties, and favorable topical tolerability profile (Surjushe et al., 2021).

Fresh mature *Aloe vera* leaves were collected and used as the source of biologically active extract. The leaves were selected based on maturity, absence of fungal contamination, and intact epidermal tissue to ensure preservation of phytoconstituents including acemannan, anthraquinones, aloin, aloe-emodin, flavonoids, tannins, and polysaccharides. These compounds have been extensively associated with antimicrobial and anti-inflammatory activity relevant to acne management (Maan et al., 2022).

Several pharmaceutical excipients were incorporated to optimize gel consistency, spreadability, stability, preservative efficacy, and patient acceptability. Carbopol 934, a synthetic high-molecular-weight crosslinked polyacrylic acid polymer, was used as the

primary gelling agent because of its excellent viscosity-building properties, stability over a broad pH range, and ability to produce transparent semisolid formulations with desirable rheological behavior for topical application. Previous formulation studies consistently report Carbopol 934 as one of the most reliable polymers for dermatological gel preparations (Patel et al., 2023).

Propylene glycol was incorporated as a humectant and penetration enhancer to improve skin hydration while facilitating deeper permeation of phytoconstituents through epidermal layers. This excipient additionally improves formulation smoothness and prevents excessive drying during storage.

Triethanolamine served as a neutralizing agent and pH modifier, facilitating polymer swelling by neutralizing acidic carbopol groups and converting the dispersion into a stable gel network. Proper pH adjustment remains particularly important in topical dermatological preparations because skin barrier integrity can be compromised by highly acidic or alkaline formulations.

Methyl paraben and propyl paraben were incorporated as preservatives to prevent microbial contamination during storage and repeated product use. Preservation systems are particularly important in herbal formulations because plant-derived extracts may provide nutrients favorable for microbial growth if preservative protection is inadequate (Sharma & Verma, 2022).

Distilled water was used as the formulation vehicle to ensure uniform dispersion of polymeric excipients and facilitate homogeneous incorporation of the herbal extract into the gel matrix.

2.2. Preparation of Herbal Extract

The therapeutic effectiveness of herbal formulations depends substantially on extraction methodology because extraction efficiency directly influences phytochemical concentration, biological activity, and reproducibility of the final product. In the present investigation, fresh *Aloe vera* leaves were processed under controlled conditions to maximize preservation of biologically active constituents while minimizing degradation during extraction.

Initially, freshly collected *Aloe vera* leaves were subjected to washing using distilled water to remove adhering dust particles, environmental contaminants, microbial debris, and residual soil contaminants. Proper cleaning minimizes contamination that could interfere with extraction efficiency and subsequent formulation stability.

Following washing, the leaves underwent drying under controlled shade conditions at ambient temperature for several days. Shade drying is preferred over direct sunlight exposure because ultraviolet radiation and excessive heat may degrade thermolabile phytoconstituents including polyphenols, flavonoids, anthraquinones, and antioxidant molecules. Controlled drying also reduces moisture content sufficiently to prevent fungal growth and facilitate grinding.

After complete drying, the plant material was subjected to powdering using a mechanical grinder to obtain coarse uniform powder. Reduction in particle size increases effective surface area available for solvent penetration, thereby improving extraction efficiency and enhancing recovery of active phytoconstituents.

The powdered material then underwent Soxhlet extraction using ethanol as extraction solvent. Soxhlet extraction remains one of the most widely used pharmaceutical extraction techniques because it provides continuous solvent circulation, efficient penetration into plant matrices, and improved recovery of both moderately polar and non-polar phytoconstituents. Ethanol was selected because of its favorable safety profile, compatibility with dermatological applications, and documented efficiency in extracting flavonoids, anthraquinones, tannins, phenolic compounds, glycosides, and antioxidant compounds present in *Aloe vera* (Maan et al., 2022).

The extraction process was continued for approximately 6–8 hours until complete exhaustion of the plant material. The solvent was subsequently evaporated under reduced pressure using rotary evaporation to obtain concentrated semisolid extract. The final extract was stored in airtight amber containers under refrigerated conditions until further formulation studies.

2.3. Formulation Design (Nine Experimental Batches)

Optimization of herbal topical formulations requires systematic variation of formulation variables to identify the composition producing ideal physicochemical characteristics and maximum biological activity. In the present study, nine

experimental formulations (F1–F9) were prepared using varying concentrations of *Aloe vera* extract and Carbopol 934 to evaluate the effect of active ingredient concentration and polymer concentration on gel performance.

The concentration of herbal extract was varied at three levels (1%, 2%, and 3%) to examine the relationship between extract concentration and biological activity. Carbopol 934 concentration was varied at three levels (0.5%, 1%, and 1.5%) to optimize viscosity, spreadability, consistency, and patient acceptability. Other excipients including propylene glycol, triethanolamine, preservatives, and distilled water were maintained within acceptable pharmaceutical limits to ensure formulation stability.

Table 1. Composition of Herbal Anti-Acne Gel Formulations (F1–F9)

| Ingredients | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 |
|---|---|---|---|---|---|---|---|---|---|
| *Aloe vera* Extract (%) | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| Carbopol 934 (%) | 0.5 | 1 | 1.5 | 0.5 | 1 | 1.5 | 0.5 | 1 | 1.5 |
| Propylene Glycol (%) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Triethanolamine | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s |
| Methyl Paraben + Propyl Paraben | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s |
| Distilled Water | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s | q.s |

The formulation process involved dispersing Carbopol 934 in distilled water with continuous mechanical stirring, followed by incorporation of propylene glycol and dissolved preservative mixture. The measured concentration of *Aloe vera* extract was slowly incorporated into the hydrated polymer dispersion under constant stirring to ensure uniform distribution. Triethanolamine was subsequently added dropwise until gel neutralization occurred and the formulation achieved appropriate viscosity and semisolid consistency. The final gel preparations were transferred into airtight containers and stored for further physicochemical and biological evaluation.

Variation of polymer concentration was expected to influence rheological behavior, while increasing extract concentration was anticipated to improve antimicrobial and anti-inflammatory performance. Comparative evaluation of all nine formulations allowed selection of an optimized formulation possessing maximum biological activity together with desirable pharmaceutical properties.

## III. EVALUATION OF HERBAL ANTI-ACNE GEL

Evaluation of topical herbal formulations is essential to determine physicochemical stability, biological efficacy, safety, and suitability for dermatological application. In the present study, all nine prepared formulations (F1–F9) were systematically evaluated through organoleptic, physicochemical, biological, and stability studies in accordance with established pharmaceutical quality standards.

### 3.1. Organoleptic Evaluation

Organoleptic evaluation provides preliminary information regarding formulation acceptability and consumer compliance. Parameters including color, odor, texture, and overall appearance were visually inspected under normal laboratory conditions.

Color evaluation was performed to assess uniformity and detect any visible discoloration caused by instability or incompatibility between herbal extract and excipients. Odor evaluation was conducted to determine formulation acceptability and identify any unpleasant smell resulting from degradation of phytoconstituents. Texture evaluation focused on smoothness and consistency, while appearance assessment examined clarity, absence of phase separation, and visual homogeneity.

Consistent organoleptic properties indicate successful incorporation of *Aloe vera* extract within the gel matrix without physicochemical incompatibility (Patel et al., 2023).

### 3.2. Physicochemical Evaluation

pH Determination

The pH of topical formulations directly influences skin compatibility and barrier integrity. pH was measured using a calibrated digital pH meter after dispersing 1 g gel in distilled water. Since normal skin pH ranges between 4.5–6.5, formulations falling within this range were considered suitable for dermatological application.

Viscosity

Viscosity was determined using a Brookfield Viscometer to evaluate rheological behavior and semisolid consistency. Adequate viscosity is necessary to ensure uniform topical application, prolonged residence time, and controlled release of phytoconstituents.

Spreadability

Spreadability determines ease of application over the skin surface. It was measured using parallel glass slide methodology where time required for movement under applied weight was recorded. Good spreadability improves patient compliance and ensures uniform drug distribution.

Extrudability

Extrudability evaluates the force required to expel gel from collapsible tubes. Proper extrudability ensures convenient dispensing during practical patient use.

Homogeneity

Homogeneity was evaluated by visual examination to confirm uniform distribution of herbal extract and absence of particulate matter, clumping, or phase separation.

Drug Content Uniformity

Drug content analysis was performed spectrophotometrically to determine uniform distribution of phytoconstituents throughout the formulation. Uniform content ensures reproducible therapeutic efficacy.

3.3. Biological Evaluation

Antimicrobial Activity

Antimicrobial activity was evaluated using agar well diffusion technique against acne-associated bacterium Cutibacterium acnes *Cutibacterium acnes*. Zone of inhibition was measured after incubation and compared among formulations. Larger inhibition zones indicated stronger antibacterial activity.

Anti-Inflammatory Activity

Anti-inflammatory activity was assessed using protein denaturation inhibition assay. Inhibition of protein denaturation reflects capacity of phytoconstituents to suppress inflammatory mediator activity associated with acne lesion formation.

Skin Irritation Test

Skin irritation studies were conducted through patch testing to evaluate formulation safety. Skin surfaces were observed for erythema, edema, redness, irritation, itching, and inflammatory reactions after topical exposure.

3.4. Stability Studies

Stability testing was performed according to ICH stability guidelines to evaluate long-term formulation integrity under controlled environmental conditions.

Storage Conditions

| Condition | Temperature | Relative Humidity |
|---|---|---|
| Room Temperature | 25°C | 60% RH |
| Accelerated | 40°C | 75% RH |

Duration

- 1 Month
- 2 Months
- 3 Months

Parameters Evaluated

- pH
- Color
- Odor
- Viscosity
- Physical stability
- Phase separation

Stability testing helps determine shelf-life and confirms preservation of formulation quality during storage (Sharma & Verma, 2022).

## IV. RESULTS AND DISCUSSION

4.1. Extraction Yield

Ethanolic extraction of *Aloe vera* leaves produced a semisolid concentrated extract with an average extraction yield of 18.74 ± 0.56% w/w.

| Parameter | Observation |
|---|---|
| Plant Material Used | 500 g |
| Extract Obtained | 93.7 g |
| Percentage Yield | 18.74% |

Discussion

The extraction yield obtained demonstrates efficient recovery of bioactive phytoconstituents from *Aloe*

*vera*. Ethanol served as an effective extraction solvent because of its ability to solubilize flavonoids, anthraquinones, tannins, polysaccharides, and phenolic compounds. Similar extraction efficiencies have been reported by Maan et al. (2022), who observed comparable recovery rates using ethanol-based extraction systems. Higher phytochemical yield is expected to contribute positively toward antimicrobial and anti-inflammatory activity of the final formulation.

4.2. Organoleptic Characteristics

Optimized formulations showed acceptable organoleptic properties.

| Parameter | Observation |
|---|---|
| Color | Light green |
| Odor | Characteristic herbal odor |
| Appearance | Smooth semisolid gel |
| Texture | Uniform and smooth |
| Homogeneity | Excellent |

Discussion

Organoleptic properties directly influence patient acceptability and marketability of topical formulations. Uniform appearance and absence of phase separation indicate compatibility between *Aloe vera* extract and polymer matrix. The smooth texture suggests proper hydration of Carbopol polymer and successful incorporation of excipients. Similar observations have been reported in herbal dermatological gel studies by Patel et al. (2023).

4.3. Physicochemical Parameters

The optimized formulation (F8) showed ideal physicochemical characteristics.

| Parameter | Result |
|---|---|
| pH | 5.82 ± 0.11 |
| Viscosity | 4870 ± 25 cps |
| Spreadability | 6.42 ± 0.20 cm |
| Extrudability | Excellent |
| Drug Content | 97.34 ± 1.08% |
| Homogeneity | Good |

Discussion

The pH value remained within physiological skin range, indicating good dermatological compatibility. Appropriate viscosity ensures prolonged contact with affected skin while preventing runoff after application. Good spreadability allows uniform distribution across acne lesions, improving therapeutic efficiency. Drug content uniformity above 95% confirms successful formulation reproducibility. Similar physicochemical behavior has been reported in Carbopol-based topical herbal gel formulations developed for inflammatory skin disorders.

4.4. Antimicrobial Activity

Antimicrobial testing demonstrated concentration-dependent inhibition against Cutibacterium acnes *Cutibacterium acnes*.

| Formulation | Zone of Inhibition (mm) |
|---|---|
| F1 | 12.4 ± 0.3 |
| F4 | 15.6 ± 0.5 |
| F7 | 18.8 ± 0.4 |
| F8 | 20.2 ± 0.6 |
| F9 | 19.5 ± 0.5 |

Discussion

Higher extract concentration produced stronger antibacterial activity, suggesting direct correlation between phytoconstituent concentration and microbial inhibition. *Aloe vera* contains anthraquinones, saponins, flavonoids, and phenolic compounds capable of disrupting bacterial cell membranes and inhibiting microbial growth. The superior activity observed in F8 indicates optimized balance between extract concentration and polymer consistency. Similar antimicrobial behavior against acne-associated bacteria has been reported by Surjushe et al. (2021).

4.5. Anti-Inflammatory Activity

Protein denaturation assay demonstrated significant anti-inflammatory activity.

| Formulation | % Inhibition |
|---|---|
| F1 | 54.2 ± 0.8 |
| F4 | 63.7 ± 0.6 |
| F7 | 71.4 ± 0.7 |
| F8 | 78.6 ± 0.5 |
| F9 | 76.9 ± 0.4 |

Discussion

The increasing anti-inflammatory activity observed with higher extract concentration confirms the presence of active phytoconstituents capable of suppressing inflammatory mediator pathways.

Polysaccharides, flavonoids, and anthraquinones present in *Aloe vera* are known to inhibit protein denaturation and reduce inflammatory signaling. Since acne vulgaris is fundamentally an inflammatory disorder, these findings support the therapeutic potential of the formulation. Comparable anti-inflammatory effects have been documented in previous Aloe vera pharmacological studies

4.6. Stability Study Results

Optimized formulation F8 remained stable under ICH storage conditions over 3 months.

| Parameter | Initial | 1 Month | 2 Months | 3 Months |
|---|---|---|---|---|
| pH | 5.82 | 5.80 | 5.79 | 5.77 |
| Color | Light Green | No change | No change | No change |
| Odor | Characteristic | Stable | Stable | Stable |
| Viscosity (cps) | 4870 | 4858 | 4849 | 4837 |
| Phase Separation | None | None | None | None |

Discussion

Minimal variation observed during stability testing indicates excellent physicochemical stability of the gel formulation. Carbopol polymer maintained structural integrity while preservative systems effectively prevented microbial degradation. Stable pH values suggest no chemical decomposition of active phytoconstituents. The absence of phase separation confirms long-term formulation compatibility. These findings demonstrate that the formulation is suitable for pharmaceutical storage and possesses acceptable shelf-life characteristics according to ICH stability criteria.

## V. CONCLUSION

The present study successfully demonstrated the formulation and evaluation of an herbal anti-acne gel containing Aloe vera *Aloe vera* extract as a natural therapeutic agent for the management of acne vulgaris. The formulated gel was designed to utilize the well-documented antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties of *Aloe vera*, targeting multiple pathogenic factors involved in acne development, including microbial colonization, inflammation, and skin damage.

Among the nine prepared formulations (F1–F9), the optimized formulation showed desirable physicochemical characteristics, including acceptable pH compatible with normal skin physiology, appropriate viscosity, excellent spreadability, satisfactory extrudability, uniform drug content, and good homogeneity. Organoleptic evaluation confirmed favorable appearance, smooth texture, and acceptable odor, indicating good patient acceptability for topical application. Biological studies demonstrated significant antibacterial activity against Cutibacterium acnes *Cutibacterium acnes*, the principal microorganism associated with acne pathogenesis, along with considerable anti-inflammatory activity that may help reduce erythema, swelling, and inflammatory lesion formation. Stability studies performed under ICH-recommended conditions confirmed that the optimized formulation remained physically and chemically stable over the study period without significant changes in pH, viscosity, color, or odor. Overall, the findings indicate that *Aloe vera*-based herbal anti-acne gel represents a safe, stable, and effective topical formulation with potential as a natural alternative to conventional synthetic anti-acne therapies. Further clinical studies are recommended to confirm long-term therapeutic efficacy and commercial applicability.

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