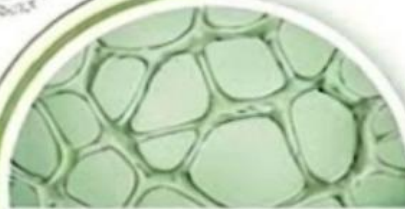


EXPLORING NATURE'S GENTLE POWER KEY FINDINGS OF THE POLYHERBAL ANTIOXIDANT

pH Balance



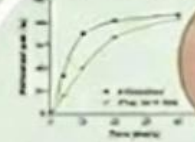
OPTIMIZED PH (5.5)
FOR SENSITIVE SKIN
compatibility



SUPERIOR TEXTURE AND STABILITY. Synergistic structure from Aloe, Watermelon, and Pomegranate extracts.



Antioxidant potency



POTENT ANTIOXIDANT ACTIVITY. Significant scavenging of free radicals, validated for effectiveness.



GEL STUDY KEY FINDINGS OF THE POLYHERBAL ANTIOXIDANT GEL STUDY



Formulation and Characterization of a Polyherbal Antioxidant Gel for Sensitive Skin Using Aloe vera, Watermelon, and Pomegranate Extracts

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Abstract

Sensitive skin is a multifactorial dermatological condition characterised by impaired barrier function, oxidative stress, inflammation, and heightened neurosensory reactivity. The present study aimed to develop and evaluate a polyphenol-rich herbal gel incorporating extracts of *Aloe barbadensis* Miller, *Citrullus lanatus*, and *Punica granatum* for sensitive skin application. The selected botanicals were chosen for their complementary pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, moisturising, and regenerative effects. Plant extracts were phytochemically characterised and evaluated for in vitro antioxidant potential using DPPH and ABTS assays. Polyherbal gels were formulated using Carbopol 940 and assessed for physicochemical properties, stability, spreadability, pH, viscosity, and homogeneity. Biological evaluation included antimicrobial and anti-inflammatory studies along with preliminary skin irritation assessment. The formulation demonstrated favourable stability, significant antioxidant activity, and good dermatological compatibility, suggesting its potential as a safe and effective herbal topical preparation for sensitive skin management.

Keywords: Sensitive skin, Polyherbal gel, Polyphenols, Antioxidant activity, Herbal dermatological formulation.

INTRODUCTION

Overview of Human Skin

The skin is the largest organ of the human body, covering approximately 1.5 to 2 square metres in an adult, and its architecture reflects the extraordinary range of functions it is expected to perform. Organised into three principal strata—the epidermis, dermis, and hypodermis—it achieves both structural resilience and physiological versatility. The outermost epidermal layer terminates in the stratum corneum, a lamellar arrangement of corneocytes embedded within a lipid matrix of ceramides, free fatty acids, and cholesterol that constitutes the skin's primary permeability barrier. The dermis, rich in collagen, elastin, and fibroblasts, provides mechanical support and houses

blood vessels, lymphatics, and sensory nerve endings. Together, these layers regulate transepidermal water loss, exclude external irritants and pathogens, facilitate vitamin D synthesis, and mediate immune and thermoregulatory responses—functions that are collectively contingent on the preservation of the skin's structural integrity [1].

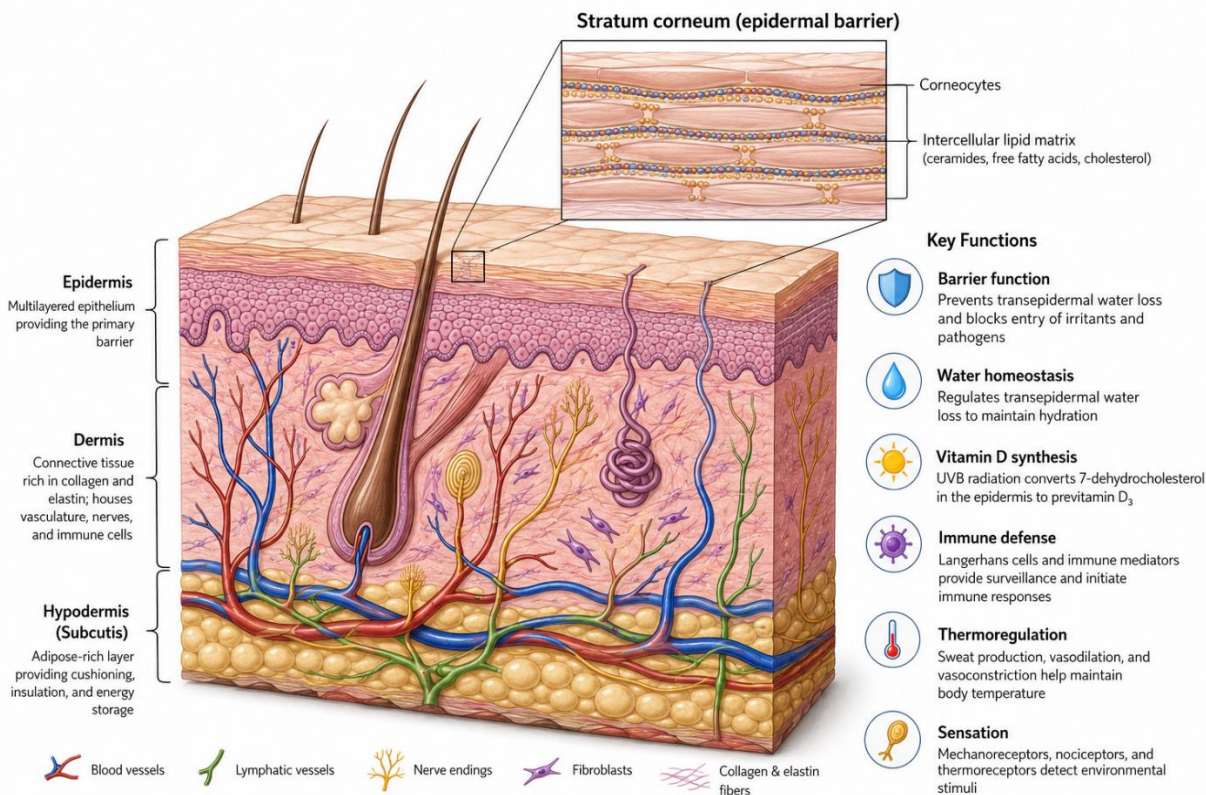


Figure 1: Overview of human skin.

Sensitive Skin: Definition and Clinical Significance

Sensitive skin is broadly defined as a condition in which unpleasant cutaneous sensations—stinging, burning, pruritus, and tightness—arise in response to stimuli that most individuals tolerate without discomfort. These symptoms often occur without visible inflammatory signs, making objective clinical classification difficult and placing the condition at the interface of dermatological pathology and subjective patient experience. Epidemiological surveys indicate a self-reported prevalence of 40-60% across global populations. Its pathophysiological basis includes a structurally deficient stratum corneum with elevated transepidermal water loss, diminished ceramide content, and heightened C-fibre nociceptor reactivity. Environmental triggers such as UV radiation, cold temperatures, and low humidity, alongside chemical provocateurs including synthetic surfactants, preservatives, and artificial fragrances, frequently initiate or aggravate episodes. Existing synthetic treatments—corticosteroids, retinoids, and petrochemical emollients—carry well-recognised limitations including side effects, irritancy, and failure to address the underlying barrier deficiency, leaving a clear therapeutic gap [2].

Need for Herbal-Based Dermatological Formulations

Growing awareness of the adverse effects associated with synthetic cosmetic ingredients has renewed scientific and clinical interest in plant-derived dermatological preparations. Herbal

extracts offer a form of pharmacological versatility—simultaneously expressing antioxidant, anti-inflammatory, antimicrobial, and barrier-supportive activities through structurally diverse phytochemical constituents—that is difficult to replicate with a single synthetic molecule. This multimodal action is particularly suited to sensitive skin, whose pathology is itself multifactorial. Phytochemicals also tend to exhibit greater biocompatibility with cutaneous tissues, reducing the likelihood of immunogenic or irritant responses upon repeated application. Well-formulated herbal preparations can, moreover, be designed without synthetic preservatives, petrochemical emollients, or artificial dyes, thereby reducing the aggregate chemical burden imposed on already-compromised skin. The challenge lies in converting this phytochemical potential into stable, reproducible, and clinically validated topical formulations [3].

Polyphenols and Their Role in Skin Health

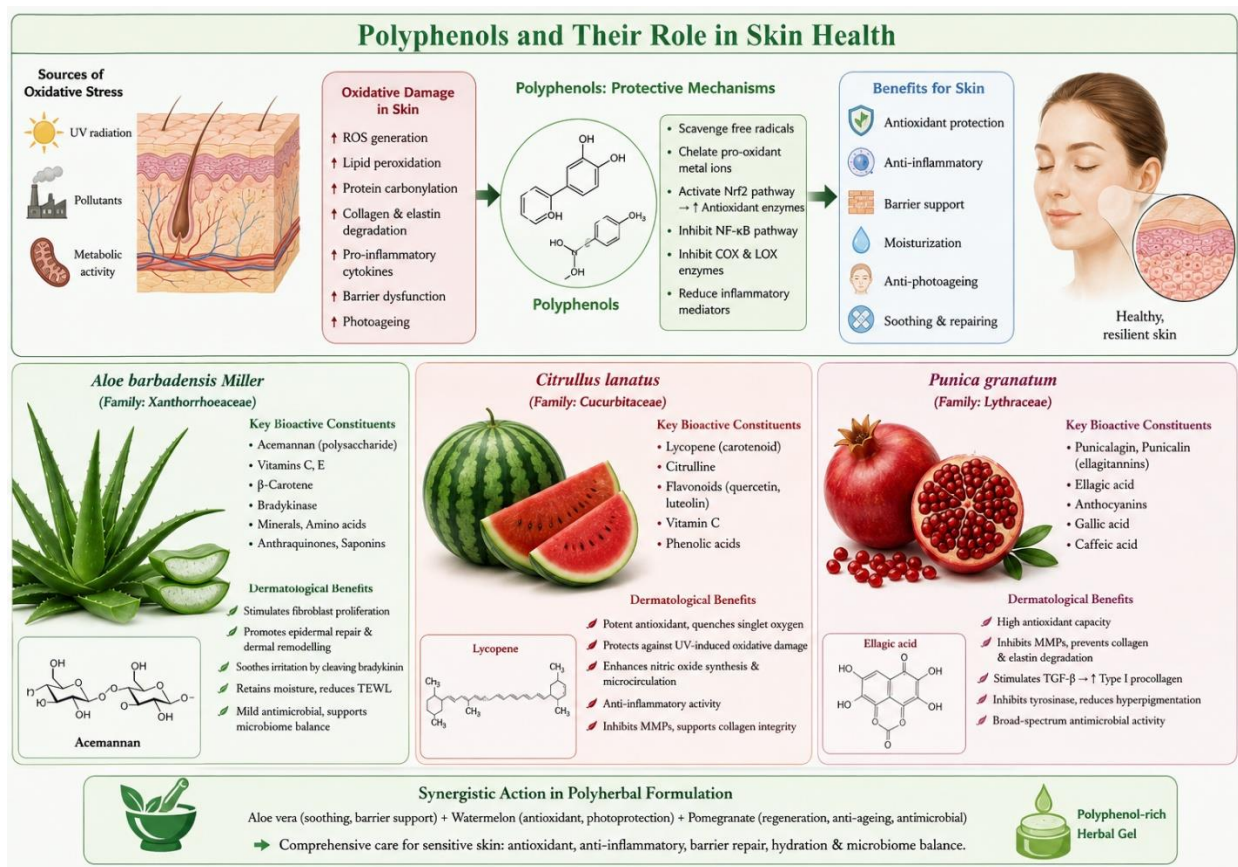


Figure 2: Polyphenols and their role in human skin.

Polyphenols are a structurally heterogeneous class of plant secondary metabolites defined by phenolic hydroxyl groups on aromatic rings, and their subclasses—flavonoids, phenolic acids, tannins, stilbenes, and lignans—collectively display a broad range of biological activities relevant to cutaneous health. The skin is a primary target of oxidative injury: reactive oxygen species generated by UV radiation, atmospheric pollutants, and metabolic activity initiate lipid peroxidation, protein carbonylation, and fragmentation of collagen and elastin fibres, while simultaneously activating pro-inflammatory signalling cascades that impair barrier function and accelerate photoaging. Polyphenols counteract these processes by scavenging free radicals,

chelating metal ions that catalyse ROS generation, and activating the Nrf2 pathway to upregulate endogenous antioxidant enzymes. Their anti-inflammatory effects—mediated through NF-κB suppression and inhibition of cyclooxygenase and lipoxygenase enzymes—reduce cytokine-driven inflammation and eicosanoid-mediated cutaneous pain, making them pharmacologically appropriate actives for sensitive skin formulations [4].

***Aloe barbadensis* Miller**

Aloe barbadensis Miller (family Xanthorrhoeaceae) is among the most extensively characterised medicinal plants in dermatological science. Its inner leaf gel contains more than seventy-five bioactive constituents, including the polysaccharide acemannan, antioxidant vitamins C and E, beta-carotene, and the enzyme bradykinase. Acemannan stimulates fibroblast proliferation and upregulates growth factors, including VEGF and FGF, collectively supporting epidermal repair and dermal remodelling. Bradykinase cleaves bradykinin—a key mediator of cutaneous pain and neurogenic irritation—providing a direct mechanistic basis for the soothing effect clinically attributed to aloe vera. Its hygroscopic polysaccharides retain moisture within the stratum corneum, reducing transepidermal water loss in barrier-compromised skin. Mild antimicrobial properties further support microbiome balance on sensitive skin surfaces, establishing aloe vera as a well-evidenced foundational ingredient in herbal dermatological formulations [5].

Medicinal Benefits of *Aloe barbadensis* Miller

Aloe barbadensis Miller possesses a broad spectrum of dermatological and therapeutic activities owing to its rich composition of polysaccharides, vitamins, enzymes, amino acids, minerals, and phenolic compounds. The medicinal benefits most relevant to skin care and topical pharmaceutical formulations are summarised below:

1. Wound Healing and Tissue Regeneration

Aloe vera promotes rapid wound contraction and accelerates epithelialisation through stimulation of fibroblast proliferation, collagen synthesis, and angiogenesis. The polysaccharide acemannan enhances the production of growth factors such as vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF), thereby supporting dermal repair and extracellular matrix remodelling.

2. Anti-Inflammatory Activity

The gel exhibits significant anti-inflammatory effects by inhibiting cyclooxygenase pathways and reducing the synthesis of inflammatory mediators such as prostaglandins and bradykinin. The enzyme bradykinase contributes to the reduction of pain, erythema, and neurogenic irritation commonly associated with sensitive or inflamed skin conditions.

3. Moisturising and Barrier-Protective Effects

Aloe vera polysaccharides possess strong hygroscopic properties that improve hydration of the stratum corneum and reduce transepidermal water loss (TEWL). This enhances skin elasticity and restores barrier integrity in dry, sensitive, or damaged skin.

4. Antioxidant and Photoprotective Properties

Antioxidant constituents including vitamins C and E, beta-carotene, flavonoids, and phenolic compounds neutralise reactive oxygen species generated by ultraviolet radiation

and environmental pollutants. These actions help minimise oxidative stress, lipid peroxidation, and premature skin ageing.

5. **Antimicrobial Activity**

Aloe vera demonstrates mild antibacterial, antifungal, and antiviral properties attributed to anthraquinones, saponins, and phenolic compounds. These effects may assist in maintaining microbial balance on the skin surface and reducing the risk of secondary infections in compromised skin.

6. **Immunomodulatory Effects**

Acemannan and related polysaccharides can modulate macrophage activation and cytokine production, thereby supporting innate immune responses and enhancing tissue repair processes without inducing excessive irritation.

7. **Anti-Ageing Potential**

By stimulating collagen and elastin synthesis while simultaneously reducing oxidative damage, aloe vera contributes to improved skin firmness, elasticity, and wrinkle reduction. Its bioactive compounds also support dermal matrix preservation.

8. **Soothing Effect in Sensitive Skin Disorders**

Due to its cooling, hydrating, and anti-irritant properties, aloe vera is widely used in the management of sensitive skin conditions such as mild dermatitis, sunburn, eczema-associated dryness, and cosmetic irritation [6].

Citrullus lanatus

Citrullus lanatus (family Cucurbitaceae) has attracted growing dermatological interest on account of a phytochemical profile that extends well beyond its nutritional reputation. The fruit is an exceptionally rich source of lycopene, a carotenoid whose singlet oxygen quenching capacity surpasses that of both beta-carotene and alpha-tocopherol, making it one of the most potent lipophilic antioxidants identified in any botanical source. Topically applied, lycopene mitigates UV-induced oxidative damage to epidermal cells by neutralising reactive oxygen species before they can initiate lipid peroxidation or DNA strand breaks. The fruit additionally provides citrulline, which supports nitric oxide synthesis and dermal microcirculation; flavonoids including quercetin and luteolin, which exert anti-inflammatory effects; and vitamin C, which is an obligatory cofactor in collagen biosynthesis. Watermelon rind extract has further demonstrated inhibitory activity against collagen-degrading matrix metalloproteinases [7].

Medicinal Benefits of *Citrullus lanatus*

Citrullus lanatus possesses considerable medicinal and dermatological significance due to its abundance of carotenoids, amino acids, vitamins, flavonoids, and phenolic antioxidants. Beyond its nutritional value, the plant exhibits multiple pharmacological activities relevant to skin protection, tissue repair, and cosmetic formulations [8].

1. **Potent Antioxidant Activity**

Watermelon is a rich natural source of lycopene, a highly efficient singlet oxygen quencher

and free-radical scavenger. Lycopene protects epidermal and dermal cells from oxidative stress induced by ultraviolet radiation, pollution, and metabolic processes. Additional antioxidants such as vitamin C, beta-carotene, flavonoids, and phenolic compounds further contribute to the reduction of lipid peroxidation and cellular oxidative damage.

2. **Photoprotective Effects**

Lycopene-rich extracts demonstrate protective activity against UV-induced erythema, photoageing, and oxidative injury. By neutralising reactive oxygen species before they initiate DNA damage or membrane degradation, watermelon phytochemicals help preserve skin integrity and minimise premature ageing associated with chronic sun exposure.

3. **Anti-Inflammatory Properties**

Flavonoids including quercetin and luteolin exhibit anti-inflammatory activity through modulation of inflammatory signalling pathways and reduction of pro-inflammatory cytokines. These effects may help alleviate irritation, redness, and inflammatory responses in sensitive or stressed skin.

4. **Collagen Preservation and Anti-Ageing Activity**

Watermelon extract contributes to dermal matrix preservation through inhibition of matrix metalloproteinases (MMPs), enzymes responsible for collagen degradation. Vitamin C present in the fruit additionally acts as an essential cofactor for collagen biosynthesis, supporting skin firmness, elasticity, and structural integrity.

5. **Improvement of Dermal Microcirculation**

The amino acid citrulline serves as a precursor for nitric oxide synthesis, promoting vasodilation and enhanced dermal blood circulation. Improved microcirculation may facilitate nutrient delivery, oxygen transport, and tissue repair processes within the skin.

6. **Hydrating and Skin-Conditioning Effects**

Due to its high water content and naturally occurring sugars, watermelon provides moisturising and soothing effects that support hydration of the stratum corneum and improve skin softness and texture.

7. **Wound-Healing Support**

Antioxidants, amino acids, and vitamins collectively contribute to tissue repair by reducing oxidative injury, supporting collagen deposition, and promoting cellular regeneration during the healing process.

8. **Potential Antimicrobial Activity**

Certain phenolic and flavonoid constituents of watermelon rind and seed extracts have demonstrated mild antimicrobial activity against selected bacterial and fungal strains, which may assist in maintaining skin hygiene and reducing microbial colonisation [9].

Punica granatum

Punica granatum (family Lythraceae) is widely regarded as one of the most polyphenol-dense fruits in the botanical kingdom, with the peel fraction carrying total antioxidant capacity that may exceed that of the juice by a substantial margin. Its predominant constituents—the ellagitannins punicalagin and punicalin—are hydrolysed to ellagic acid, which inhibits matrix metalloproteinases responsible for collagen and elastin degradation in photoaged skin while simultaneously stimulating TGF-beta-mediated fibroblast synthesis of type I procollagen. Ellagic acid also inhibits tyrosinase activity, offering benefits in managing post-inflammatory hyperpigmentation. Anthocyanins, gallic acid, and caffeic acid extend the antioxidant and anti-inflammatory capacity of the extract, while broad-spectrum antimicrobial activity against dermatologically relevant pathogens—including *Staphylococcus aureus*, *Propionibacterium acnes*, and *Candida albicans*—makes *Punica granatum* a uniquely comprehensive ingredient for sensitive skin formulations [10].

Medicinal Benefits of *Punica granatum*

Punica granatum is recognised as a highly valuable medicinal plant due to its exceptionally rich concentration of polyphenols, flavonoids, anthocyanins, tannins, and organic acids. Different parts of the plant, particularly the peel, seeds, and juice, exhibit significant pharmacological and dermatological activities that support its application in therapeutic and cosmeceutical formulations[11].

1. Powerful Antioxidant Activity

Pomegranate contains high levels of ellagitannins such as punicalagin and punicalin, along with ellagic acid, anthocyanins, gallic acid, and caffeic acid. These compounds effectively neutralise reactive oxygen species and reduce oxidative stress, thereby protecting skin cells from lipid peroxidation, protein oxidation, and DNA damage induced by ultraviolet radiation and environmental pollutants.

2. Anti-Ageing and Collagen-Protective Effects

Ellagic acid inhibits matrix metalloproteinases (MMPs), enzymes responsible for the degradation of collagen and elastin fibres during skin ageing and photoageing. Simultaneously, pomegranate polyphenols stimulate fibroblast activity and promote transforming growth factor-beta (TGF- β)-mediated synthesis of type I procollagen, contributing to improved skin elasticity, firmness, and dermal regeneration.

3. Anti-Inflammatory Properties

Pomegranate extracts suppress inflammatory mediators and cytokines involved in cutaneous inflammation. The presence of flavonoids and phenolic acids helps reduce erythema, irritation, and oxidative inflammatory responses associated with sensitive or damaged skin.

4. Skin Brightening and Anti-Hyperpigmentation Activity

Ellagic acid demonstrates tyrosinase inhibitory activity, reducing melanin synthesis and helping manage post-inflammatory hyperpigmentation, uneven skin tone, and UV-induced pigmentation disorders.

5. Antimicrobial Activity

Broad-spectrum antimicrobial properties have been reported against several dermatologically significant microorganisms, including *Staphylococcus aureus*, *Cutibacterium acnes* (formerly *Propionibacterium acnes*), and *Candida albicans*. These activities support skin hygiene, reduce microbial colonisation, and may aid in preventing secondary skin infections.

6. Wound-Healing and Tissue-Regenerative Effects

Pomegranate phytochemicals enhance wound healing through stimulation of fibroblast proliferation, collagen deposition, angiogenesis, and reduction of oxidative injury at the wound site. These effects collectively accelerate tissue repair and improve skin regeneration.

7. Photoprotective Effects

The antioxidant-rich composition of pomegranate provides protection against UV-induced oxidative stress and photoageing. Polyphenols help minimise inflammation, collagen degradation, and cellular damage caused by chronic sun exposure.

8. Moisturising and Barrier-Supportive Properties

Seed oil from pomegranate contains punicic acid and essential fatty acids that help strengthen the epidermal barrier, improve skin hydration, and maintain elasticity, making the plant particularly beneficial for dry and sensitive skin formulations [12].

Rationale for the Polyherbal Gel Formulation

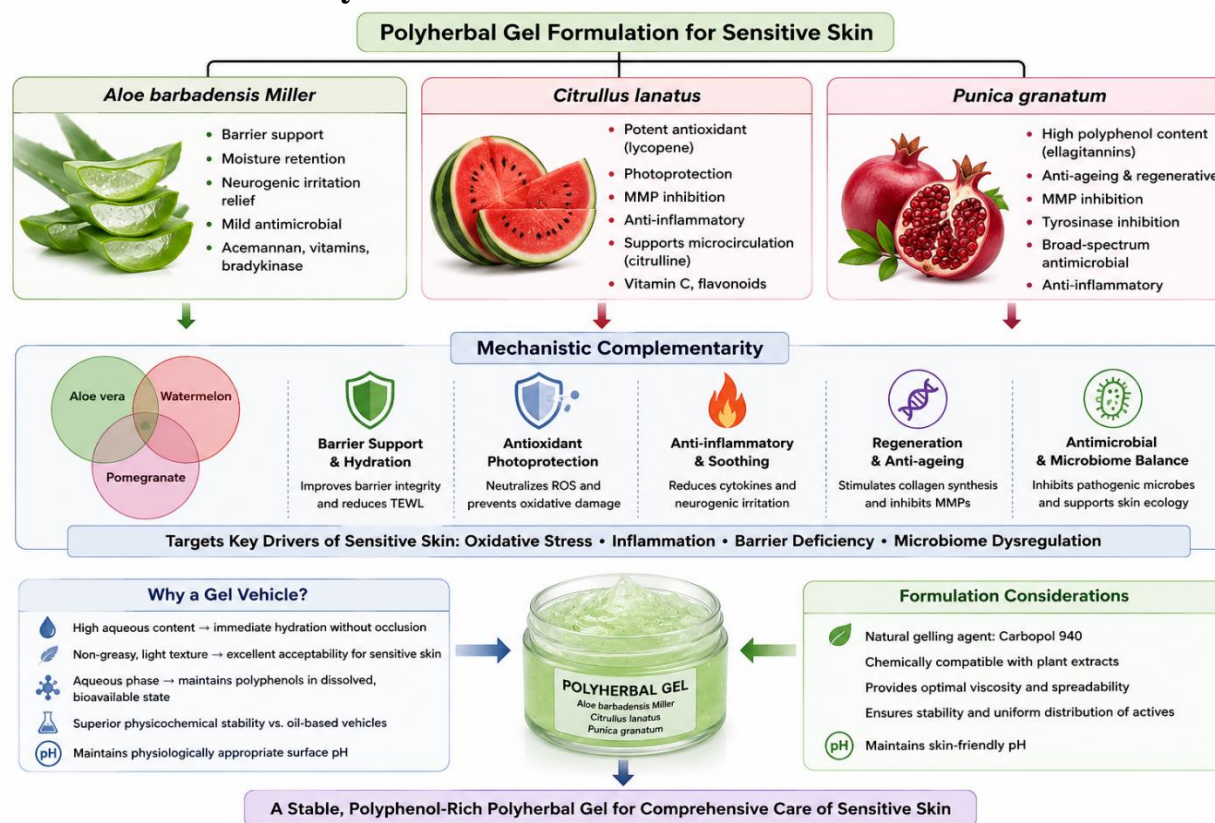


Figure 3: Rationale for the Polyherbal Gel Formulation.

The combination of *Aloe barbadensis* Miller, *Citrullus lanatus*, and *Punica granatum* in a single gel formulation is underpinned by their mechanistic complementarity rather than mere additive co-formulation. Aloe vera addresses barrier support, moisture retention, and neurogenic irritation; watermelon contributes antioxidant photoprotection and MMP-inhibitory activity; and pomegranate delivers regenerative, anti-ageing, and antimicrobial effects through its ellagitannin-rich fraction. Together, they target oxidative stress, inflammatory signalling, barrier deficiency, and microbiome dysregulation—the principal pathological drivers of sensitive skin—in ways that no single extract achieves independently. A gel vehicle was selected because its high aqueous content provides immediate hydration without occlusion, its non-greasy texture is well tolerated by sensitive individuals, and the aqueous phase maintains polyphenolic compounds in a dissolved, bioavailable state while offering superior physicochemical stability relative to oil-based vehicles. Natural gelling agents such as Carbopol 940 are chemically compatible with the constituent extracts and maintain physiologically appropriate surface pH [13].

Research Gap, Aim, and Objectives

Despite robust published evidence for the individual dermatological activities of each selected plant, no study to date has systematically combined all three within a single characterised polyphenol-rich gel and evaluated the resulting formulation using standardised physicochemical, biological, and stability methodologies. This represents a meaningful gap in the evidence base for polyherbal sensitive skin products. The present study, therefore, aims to develop and evaluate a stable, polyphenol-rich herbal gel incorporating standardised extracts of *Aloe barbadensis* Miller, *Citrullus lanatus*, and *Punica granatum* for sensitive skin application. The specific objectives are: (i) to prepare and phytochemically characterise the plant extracts; (ii) to assess in vitro antioxidant activity using DPPH and ABTS assays; (iii) to formulate and optimise herbal gels and evaluate their physicochemical properties; (iv) to evaluate in vitro anti-inflammatory and antimicrobial activities; (v) to conduct ICH-guided accelerated stability studies; and (vi) to assess primary skin irritation potential to establish a preliminary safety profile [14].

Conclusion

The present study successfully demonstrated the formulation and evaluation of a polyphenol-rich herbal gel containing extracts of *Aloe barbadensis* Miller, *Citrullus lanatus*, and *Punica granatum* for sensitive skin application. The developed formulation exhibited favourable physicochemical characteristics, including appropriate pH, viscosity, homogeneity, spreadability, and stability, indicating its suitability for topical use. In vitro antioxidant studies confirmed significant free radical scavenging activity, while anti-inflammatory and antimicrobial evaluations supported the therapeutic potential of the polyherbal combination. The synergistic action of the selected botanicals contributed to barrier protection, reduction of oxidative stress, and soothing of irritated skin without evident irritation. Overall, the study highlights the potential of plant-based polyphenolic formulations as safe, effective, and biocompatible alternatives to conventional synthetic dermatological products for the management of sensitive skin conditions.

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FORMULATION AND CHARACTERIZATION OF A POLYHERBAL ANTIOXIDANT GEL FOR SENSITIVE SKIN



**USING ALOE VERA, WATERMELON,
AND POMEGRANATE EXTRACTS**

