**Journal of Emerging Technologies and Industrial Applications**
*Vol. 5 No. 1 (2026) pp. 1-14*
*e-ISSN: 2948-507X*
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*Journal homepage: https://jetia.mbot.org.my/index.php/jetia/index*

# *Gardenia jasminoides* in Cosmetic Science: Whitening, Anti-Wrinkle, Soothing, and Skin Barrier Repair Activities

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**Abstract:** The growing demand for natural, safe, and multifunctional cosmetic ingredients has increased interest in plant-derived bioactives that can simultaneously address multiple skin concerns while minimizing potential adverse effects associated with synthetic compounds. This mini-review aims to critically evaluate the cosmetic potential of *Gardenia jasminoides*, with particular emphasis on its whitening, anti-wrinkle, soothing, anti-inflammatory, and skin barrier repair activities. Relevant peer-reviewed studies, including *in vitro, in vivo, in silico*, and human clinical investigations, were systematically reviewed and analyzed to assess the underlying mechanisms and cosmetic applications of Gardenia-derived bioactives. The findings indicate that iridoids (geniposide, genipin, and related glycosides) and carotenoid derivatives (crocin and crocetin) regulate multiple skin-related pathways. Whitening effects are primarily associated with tyrosinase inhibition and suppression of melanogenic regulators such as microphthalmia-associated transcription factor, while anti-wrinkle activity is linked to antioxidant effects and inhibition of matrix metalloproteinases involved in collagen degradation. Soothing and anti-inflammatory properties are supported by reductions in pro-inflammatory cytokines and suppression of NF-κB and MAPK signaling pathways. Furthermore, recent studies demonstrate significant skin barrier repair activity through aryl hydrocarbon receptor-mediated upregulation of filaggrin, loricrin, and involucrin, accompanied by reduced transepidermal water loss and improved skin hydration. Overall, current evidence supports *Gardenia jasminoides* as a promising multifunctional cosmeceutical ingredient for skin whitening, anti-aging, soothing, and barrier repair applications. Nevertheless, further studies are required to establish long-term safety, formulation stability, and standardized extract specifications to support broader cosmetic commercialization.

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Received 10 February 2026; Accepted 01 May 2026; Available online 26 June 2026

Keywords: *Gardenia jasminoides*, Cosmeceuticals, Skin barrier repair, Melanogenesis and tyrosinase inhibition, Anti-inflammatory and anti-aging

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## 1. Introduction

*Gardenia jasminoides* J. Ellis (Rubiaceae) is an evergreen flowering plant widely distributed in East and Southeast Asia. Its dried mature fruit, commonly referred to as *Gardeniae Fructus*, has a long history of use in traditional Asian medicine. Historically, *Gardeniae Fructus* has been used for its heat-clearing, anti-inflammatory, and detoxifying properties in traditional medicine and food systems. In modern phytochemical research, *Gardenia jasminoides* is recognized as a rich source of iridoid glycosides, including geniposide, genipin, geniposidic acid, and related derivatives, as well as carotenoid-type pigments such as crocin and crocetin. These compounds form the biochemical basis for many of the skin-related bioactivities reported in contemporary cosmetic and dermatological studies, including antioxidant, anti-inflammatory, pigmentation-modulating, and barrier-repair effects [1, 2, 3].

The global cosmetic industry has undergone a marked shift toward multifunctional products that simultaneously address whitening, anti-aging, soothing, and barrier repair, particularly for sensitive or environmentally stressed skin. This trend is driven by increased consumer awareness of ingredient safety, sustainability, and long-term skin health, as well as regulatory pressure on the use of certain synthetic cosmetic ingredients. Natural plant-derived actives with pleiotropic mechanisms are therefore increasingly favored over single-function ingredients. Within this context, *Gardenia jasminoides* has gained attention because multiple studies demonstrate its ability to modulate diverse skin pathways, including melanogenesis, extracellular matrix degradation, inflammatory signaling, oxidative stress responses, and epidermal differentiation. Importantly, these effects have been observed across complementary experimental models, ranging from in silico enzyme inhibition and cellular assays to animal models and controlled human studies, supporting its suitability as a multifunctional cosmetic active rather than a narrowly targeted single-function ingredient [1, 4, 5].

Despite their efficacy, many widely used synthetic whitening and anti-aging agents are associated with safety, tolerability, or regulatory concerns. Conventional melanogenesis inhibitors, such as hydroquinone or aggressive tyrosinase inhibitors, have been linked to skin irritation, cytotoxicity, and long-term safety issues, prompting restrictions or bans in several jurisdictions. Similarly, synthetic anti-aging agents that target collagen degradation or oxidative stress may exhibit limited skin compatibility, photoinstability, or unfavorable risk–benefit profiles when used chronically. These limitations have accelerated the search for natural alternatives that provide comparable efficacy with improved biocompatibility. *Gardenia jasminoides* extracts and isolated constituents have demonstrated inhibitory effects on tyrosinase and melanogenic signaling, suppression of matrix metalloproteinases, and enhancement of endogenous antioxidant and barrier-related pathways, often at concentrations showing low cytotoxicity and favorable tolerability in skin-relevant models [1, 2, 5].

The objective of this mini-review is to critically synthesize current evidence on the role of *Gardenia jasminoides* in cosmetic science, with a specific focus on four interconnected domains: skin whitening, anti-wrinkle and anti-aging activity, soothing and anti-inflammatory effects, and skin barrier repair. Only data derived from *in vitro*, *in vivo*, in silico, and human studies discussed within this review are considered. Emphasis is placed on elucidating underlying molecular mechanisms, evaluating the strength of translational evidence, and identifying key gaps relevant to cosmetic formulation and product development. By integrating mechanistic insights with functional outcomes, this mini-review aims to clarify the positioning of *Gardenia jasminoides* as a multifunctional cosmeceutical ingredient and to highlight future research directions


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necessary for its optimized and safe application in cosmetic products.

## 2. Phytochemical Basis Relevant to Cosmetic Activity

### 2.1 Major active classes

#### 2.1.1 Iridoids (geniposide, genipin, geniposidic acid)

Iridoids represent the principal bioactive class in *Gardenia jasminoides* associated with cosmetic efficacy. Multiple cosmetic-oriented studies consistently identify geniposide, genipin, geniposidic acid, and related iridoid glycosides as dominant constituents of *Gardeniae Fructus* extracts. These compounds have been shown to exert antioxidant, anti-inflammatory, pigmentation-modulating, and barrier-repair activities in skin-relevant models. Mechanistically, iridoids are implicated in the regulation of melanogenesis through modulation of tyrosinase activity and melanogenic transcription factors, suppression of matrix metalloproteinase expression involved in wrinkle formation, and activation of cytoprotective pathways such as Nrf2/HO-1 and aryl hydrocarbon receptor signaling. Importantly, iridoid-enriched fractions demonstrate low cytotoxicity across keratinocytes, melanocytes, and fibroblasts at concentrations relevant for cosmetic application, supporting their suitability as functional cosmetic actives rather than exclusively pharmacological agents [1, 3, 5].

#### 2.1.2 Carotenoids (crocin, crocetin)

In addition to iridoids, carotenoid-derived compounds, particularly crocin and its aglycone crocetin, contribute to the cosmetic activity profile of *Gardenia jasminoides*. These pigments are traditionally recognized for their coloration properties, but recent cosmetic studies highlight their functional relevance in skin protection. Crocin and crocetin exhibit strong antioxidant and anti-inflammatory activities and play a central role in protection against environmental stressors, including ultraviolet radiation and blue light–induced digital stress. Notably, crocetin generated through skin microbiota–mediated conversion has been shown to interact with melatonin receptors, conferring melatonin-like activity that supports mitochondrial integrity, reduces protein oxidation, and improves wrinkle-related clinical outcomes. These findings extend the cosmetic relevance of Gardenia carotenoids beyond pigmentation into anti-aging and chronobiological skin protection domains [4, 6].

### 2.2 Extraction and standardization approaches reported in cosmetic studies

#### 2.2.1 Water extracts

Water extraction is one of the most commonly reported methods for preparing *Gardenia jasminoides* cosmetic ingredients. Water extracts are rich in polar iridoid glycosides and are frequently used in *in vitro* and *in vivo* skin studies due to their favorable safety profile and regulatory acceptance. Cosmetic studies using water extracts consistently report antioxidant, whitening, moisturizing, and barrier-repair effects, including upregulation of filaggrin and suppression of matrix metalloproteinases. However, water extracts may exhibit variability in iridoid concentration depending on raw material quality and processing conditions, highlighting the importance of standardization in cosmetic applications [1, 3].

#### 2.2.2 Ethanol extracts

Ethanol extraction is employed to obtain broader-spectrum *Gardenia jasminoides* extracts containing both iridoids and less polar constituents. Ethanol extracts have demonstrated strong protective effects against oxidative stress, air pollution–induced damage, and inflammatory responses in keratinocyte and animal models. In particular, ethanol-derived extracts and isolated iridoids such as geniposide effectively reduce reactive oxygen species, inhibit apoptosis, and enhance tight junction protein expression, supporting their


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relevance for antipollution and barrier-protective cosmetic formulations [5].

### 2.2.3 Resin-enriched iridoid fractions

In order to improve consistency and potency, several cosmetic studies report the use of macroporous resin adsorption techniques to enrich iridoid content from aqueous *Gardenia jasminoides* extracts. Resin-enriched fractions show higher concentrations of geniposide and related iridoids and are frequently characterized using UPLC–MS/MS. These standardized fractions exhibit enhanced antioxidant, anti-inflammatory, and barrier-repair activities compared with crude extracts and have been evaluated in advanced skin models and human barrier efficacy studies, including measurements of transepidermal water loss and skin hydration. Such enrichment strategies represent a critical step toward reproducible, efficacy-driven cosmetic ingredient development [3, 4].

### 2.2.4 NaDES-stabilized extracts

Recently, Natural Deep Eutectic Solvent (NaDES) systems have been applied to stabilize *Gardenia jasminoides* extracts for cosmetic use. NaDES-stabilized extracts have been shown to preserve carotenoid components and enhance the photoprotective and anti-aging effects of Gardenia-derived actives, particularly in the context of blue light–induced digital stress. This approach not only improves chemical stability but also aligns with green chemistry principles increasingly valued in cosmetic formulation. Although still limited in number, NaDES-based formulations demonstrate promising potential for improving extract performance and shelf-life in advanced cosmetic products [6].

## 3. Skin Whitening and Pigmentation Modulation

### 3.1 Tyrosinase and melanogenesis inhibition

A central whitening mechanism of *Gardenia jasminoides* in cosmetic science is suppression of melanogenesis through tyrosinase inhibition and reduction of melanin synthesis. Evidence spans computational screening and cell-based functional assays, supporting both direct enzyme targeting and downstream pathway modulation.

### 3.1.2 In silico dual tyrosinase–elastase inhibition

A recent in silico study of *Gardenia jasminoides* seed-derived bioactives identified multiple compounds with high predicted binding affinity to tyrosinase, and also to elastase, suggesting simultaneous relevance for whitening and anti-wrinkle positioning [7]. Tyrosinase inhibitors with strong docking performance included rutin, coumaroylgenipin gentiobioside, and dicaffeoylquinic acid, while crocin A and rutin were highlighted among elastase inhibitors, with several compounds demonstrating high affinity for both enzymes [7]. Although molecular docking does not constitute direct biological evidence, this work provides a rational shortlist of candidate molecules for formulation development and targeted validation.

### 3.1.3 Cellular inhibition of tyrosinase activity

In a widely used melanogenesis model, *Gardeniae Fructus* extract reduced melanin content in α-MSH stimulated B16F10 melanocytes and downregulated melanogenic proteins including tyrosinase and MITF in a dose-dependent manner, with limited cytotoxicity across tested concentrations [1]. Complementing whole extract evidence, purified acylated iridoid and related glycosides isolated from a methanol extract of *Gardeniae Fructus* also showed measurable melanogenesis inhibition in α-MSH stimulated B16 melanoma cells, producing meaningful reductions in melanin content at micromolar concentrations while maintaining cell viability [8]. These studies support that Gardenia derived ingredients can suppress pigmentation through both extract level and molecule level activity [1, 8].

### 3.2 Regulation of melanogenic signaling


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Beyond direct enzyme effects, Gardenia ingredients influence upstream melanogenic signaling at the transcriptional and receptor signaling levels.

**3.2.1 MITF suppression**

MITF is a regulator of melanocyte function and melanogenic enzyme expression. In α-MSH stimulated B16F10 melanocytes, *Gardeniae Fructus* extract suppressed MITF protein expression alongside tyrosinase downregulation, consistent with a pathway-level reduction in melanogenic program activation [1]. This MITF linked mechanism is cosmetically relevant because it can reduce hyperpigmentation not only by inhibiting catalytic activity, but also by decreasing melanogenic capacity.

**3.2.2 Effects in melanocytes and keratinocyte linked signaling systems**

Pigmentation biology depends on keratinocyte–melanocyte paracrine signaling. Geniposide provides a clear example of receptor axis modulation through the stem cell factor and c-Kit pathway. In norepinephrine exposed normal human epidermal melanocytes, geniposide increased c-Kit receptor expression and enhanced downstream ERK1/2 phosphorylation in the presence of stem cell factor, which corresponded with increased tyrosinase activity and melanin production. Blocking c-Kit signaling abolished these effects, confirming pathway dependence [9]. This indicates that some Gardenia constituents act upstream by changing melanocyte responsiveness to growth factor cues, rather than directly inhibiting the melanin synthesis machinery.

**3.3 Dualistic modulation of pigmentation**

A critical point for cosmetic translation is that *Gardenia jasminoides* does not exert a single uniform direction of pigmentation effect. Instead, outcomes depend on the specific compound class, extract composition, and experimental context.

On the inhibitory side, whole fruit extract suppressed melanogenesis via MITF and tyrosinase downregulation in hyperstimulated B16F10 melanocytes [1], and several acylated iridoid and related glycosides reduced melanin content in α-MSH stimulated melanoma cells with minimal cytotoxicity [8]. On the stimulatory side, unmodified geniposide enhanced melanogenesis under stress modeled conditions involving norepinephrine exposure and stem cell factor presence, acting through c-Kit signaling augmentation [9]. Therefore, Gardenia-derived ingredients can exert either depigmenting or pro-pigmentation effects depending on whether the formulation is enriched in melanogenesis inhibiting acylated glycosides or instead contains high levels of geniposide [8, 9].

**3.4 Cosmetic relevance and formulation considerations**

From a product development perspective, whitening claims using Gardenia require deliberate raw material selection and standardization. The evidence base supports whitening potential for fruit extracts that downregulate MITF and tyrosinase, and for specific acylated glycosides with measurable melanin suppression in cell models [1, 8]. Separately, seed-derived bioactives identified through molecular docking suggest promising tyrosinase targeting candidates such as rutin and related phenolic or glycosidic derivatives, but these require confirmatory biochemical and cell-based validation, as docking alone cannot quantify real-world potency or skin bioavailability [7].

A key formulation risk is unintended pigmentation enhancement if geniposide is present at high levels, given its demonstrated capacity to increase melanogenesis under specific signaling conditions through the stem cell factor and c-Kit axis [9]. For whitening oriented cosmetics, this implies that ingredient specifications should control geniposide content and prioritize standardized fractions enriched in inhibitory acylated glycosides or validated tyrosinase inhibitory constituents.

Finally, because whitening products are frequently used chronically, future cosmetic studies should continue to connect mechanistic endpoints such as MITF and tyrosinase modulation to clinically relevant outcomes and safety signals, especially in sensitive skin populations.

## 4. Anti-Wrinkle and Anti-Photoaging Effects

### 4.1 UV-induced skin aging mechanisms addressed by *Gardenia jasminoides*

Chronic ultraviolet (UV) exposure is a major extrinsic driver of skin aging, leading to wrinkle formation, loss of elasticity, and dermal matrix degradation. UVB irradiation in particular induces excessive production of reactive oxygen species (ROS), which disrupt redox homeostasis, activate inflammatory cascades, and upregulate matrix metalloproteinases (MMPs) responsible for collagen and elastin breakdown. Multiple cosmetic studies demonstrate that *Gardenia jasminoides* extracts effectively target these UV-induced aging mechanisms through multiple complementary molecular pathways.

#### 4.1.1 Oxidative stress

In UVB-irradiated HaCaT keratinocytes, *Gardeniae Fructus* extract significantly reduced intracellular ROS accumulation and lipid peroxidation, while restoring the activity of endogenous antioxidant systems. These effects are central to mitigating oxidative damage that initiates photoaging processes [4].

#### 4.1.2 MMP-1 and MMP-9 upregulation

UV-induced activation of MMP-1 and MMP-9 leads to accelerated collagen degradation and wrinkle formation. *Gardenia jasminoides* extracts suppressed UVB-induced MMP expression in keratinocytes and fibroblast-related models, thereby preserving extracellular matrix integrity and counteracting wrinkle development [1, 2].

#### 4.1.3 Cytokine-mediated dermal degradation

UV exposure also promotes the release of pro-inflammatory cytokines, including interleukin-1β and interleukin-6, which further amplify MMP expression and dermal damage. *Gardeniae Fructus* extract inhibited UVB-induced cytokine secretion in skin cell models, suggesting that its anti-wrinkle activity is partially mediated through attenuation of inflammation-driven matrix degradation [4].

### 4.2 Anti-wrinkle molecular mechanisms

#### 4.2.1 Suppression of MMPs

At the molecular level, suppression of MMP expression represents a key anti-wrinkle mechanism of *Gardenia jasminoides*. In keratinocytes and fibroblast-associated systems, treatment with *Gardeniae Fructus* extract resulted in downregulation of MMP-1 and MMP-9 mRNA expression following oxidative or UV stress. This inhibitory effect limits collagen and elastin breakdown, directly addressing the structural basis of wrinkle formation [1, 2].

#### 4.2.2 Antioxidant enzyme activation

In addition to suppressing degradative enzymes, *Gardenia jasminoides* enhances intrinsic antioxidant defenses. In UVB-irradiated HaCaT cells, extract treatment significantly increased the activity of superoxide dismutase, catalase, and glutathione peroxidase, while reducing malondialdehyde levels, a marker of lipid peroxidation. This coordinated activation of antioxidant enzymes supports long-term protection against oxidative stress–driven skin aging rather than short-lived radical scavenging alone [4].

### 4.3 Fibroblast protection and collagen-related outcomes

Dermal fibroblasts play a central role in maintaining collagen and elastin architecture. *Gardenia jasminoides* extracts and isolated constituents have demonstrated protective effects on fibroblasts exposed to oxidative and environmental stressors. In human dermal fibroblast models, treatment reduced ROS-induced apoptosis, preserved mitochondrial


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integrity, and inhibited pro-apoptotic signaling pathways. These protective effects contribute indirectly to collagen preservation by maintaining fibroblast viability and functional capacity [5]. Furthermore, reduced MMP signaling in fibroblast-associated systems supports a favorable environment for collagen maintenance and wrinkle attenuation [1].

### 4.4 Digital stress and blue-light-induced aging protection

Beyond UV radiation, blue light emitted from digital devices has emerged as a contributor to premature skin aging, often referred to as digital stress. Blue light induces oxidative stress, mitochondrial dysfunction, protein oxidation, and disruption of circadian-regulated skin processes. A stabilized *Gardenia jasminoides* fruit extract demonstrated strong absorption in the blue light spectrum and protected fibroblast mitochondrial networks from blue-light-induced fragmentation. Additionally, crocetin derived from Gardenia carotenoids exhibited melatonin-like activity by interacting with melatonin receptors following skin microbiota–mediated conversion, leading to reduced protein oxidation and clinically significant decreases in wrinkle number in human studies [6]. These findings extend the anti-wrinkle scope of *Gardenia jasminoides* from classical photoaging into emerging digital aging contexts.

## 5. Soothing, Anti-Inflammatory, and Anti-Atopic Effects

### 5.1 Anti-inflammatory signaling pathways

Across allergic- and irritant-driven skin inflammation models, Gardenia jasminoides preparations consistently suppress upstream inflammatory signaling. Repeated evidence points to inhibition of NF-κB and MAPK pathways as key mechanistic nodes. In a DNCB induced atopic dermatitis model using NC Nga mice, Gardeniae fructus extract (GFE) reduced systemic allergic and inflammatory readouts and improved histological inflammation, supporting a genuine immunomodulatory effect rather than a purely symptomatic response [10]. Mechanistically, mast cell line experiments using RBL 2H3 further indicated that GFE suppresses NF-κB nuclear translocation and reduces MAPK phosphorylation events, including Syk, p38, JNK, and Erk1/2, which aligns with reduced downstream mediator production during allergic activation [10].

Crocin, a carotenoid component linked to Gardenia jasminoides, also demonstrates pathway level control in atopic dermatitis like inflammation. In a BALB c DNCB model, crocin reduced dermatitis severity and blocked inflammatory signaling involving NF-κB, TNF-α, and IL-1β, with mechanistic emphasis on β-catenin-mediated control of inflammatory cascades [11].

### 5.2 Cytokine and immune modulation

Across studies is suppression of pro inflammatory cytokines and Th2 skewed allergic markers that are central to sensitive skin flare-ups and atopic dermatitis. *In vivo*, GFE decreased IgE and cytokine expression in serum and spleen of DNCB treated NC Nga mice, alongside reduced inflammatory cell infiltration in dermis and hypodermis, indicating both systemic and tissue level modulation [10].

For crocin, cytokine modulation is supported both by pathway blockade and by direct reductions in inflammatory mediators. In the BALB c DNCB model, crocin blocked AD associated elevations in NF-κB, TNF-α, and IL-1β at gene expression level and reduced TNF-α and IL-1β protein levels in skin, coinciding with reduced scratching, ear thickness, and dermatitis scores [11].

Beyond these primary animal studies, the compiled evidence in the report also describes Th2 axis suppression in allergen driven models, including reductions in Th2 cytokines and IgE, and reductions in immune cell readouts such as CD4 plus and CD8 plus T cells in an OVA


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sensitization model treated topically with a geniposide containing extract fraction [12].

### 5.3 Evidence from atopic dermatitis and allergic models

The most direct atopic dermatitis evidence in the reviewed studies includes DNCB induced dermatitis models and NC Nga allergic dermatitis models, complemented by mechanistic mast cell and keratinocyte assays.

#### 5.3.1 Whole extract anti-atopic activity

GFE showed *in vivo* anti atopic effects in NC Nga mice challenged with DNCB, including decreased IgE and cytokine expression and reduced inflammatory cell infiltration, while in RBL 2H3 cells it suppressed COX 2 and TNF-α expression, inhibited NF-κB translocation, and reduced phosphorylation of Syk, p38, JNK, and Erk1/2 [10].

#### 5.3.2 Isolated carotenoid anti dermatitis activity

Crocin improved dermatitis phenotype and reduced inflammatory mediators in a DNCB induced model, lowering scratching frequency, dermatitis score, and ear thickness while blocking β-catenin elevation and downstream NF-κB driven increases in TNF-α and IL-1β [11].

#### 5.3.3 Th2 regulation and allergen oriented models

The synthesized evidence supports that Gardenia derived interventions can regulate Th2 immunity in allergen driven settings, including reductions in Th2 cytokines and IgE and suppression of STAT related signaling such as p38 MAPK-STAT1, which is particularly relevant for itch, erythema, and reactive skin prone to flare cycles [12].

### 5.4 Implications for sensitive and reactive skin formulations

From a cosmetic science standpoint stated that Gardenia as a multifunctional soothing active with relevance to sensitive, reactive, and atopy prone skin, via two complementary modes. First, whole extract preparations can dampen mast cell activation and inflammatory signaling, which is formulation relevant for immediate redness and itch modulation in reactive skin contexts [10].

Second, carotenoid rich components such as crocin can attenuate dermatitis behavior and inflammatory mediator production, supporting barrier comfort and symptom reduction in chronic flare prone phenotypes [11].

Importantly, the studies indicates stimulus specific pathway targeting. Allergen driven models emphasize Th2 and mast cell related signaling, while irritant and oxidative contexts connect more strongly to antioxidant linked inflammation control in keratinocytes, suggesting that positioning should be guided by the intended claim set, such as anti redness, anti itch, sensitive skin comfort, or adjunctive support for compromised barrier states [10, 11].

## 6. Skin Barrier Repair and Hydration Enhancement

### 6.1 Regulation of epidermal differentiation proteins

An intact epidermal barrier relies on the coordinated expression of terminal differentiation proteins, particularly filaggrin (FLG), loricrin (LOR), and involucrin (IVL), which together maintain stratum corneum structure, hydration retention, and resistance to external insults. Multiple studies in the available dataset consistently demonstrate that *Gardenia jasminoides* extracts enhance the expression of these key barrier proteins in keratinocyte models.

In HaCaT keratinocytes, treatment with *Gardeniae Fructus* extract significantly upregulated FLG, LOR, and IVL at both mRNA and protein levels, indicating promotion of epidermal differentiation and barrier maturation [3]. This upregulation is particularly relevant for compromised skin conditions, where reduced FLG expression is strongly associated with increased transepidermal water loss and heightened sensitivity. The ability of Gardenia extracts to restore these differentiation markers supports their classification as true barrier repair actives rather than simple occlusive moisturizers [3].

### 6.2 AHR-mediated barrier repair mechanisms

Mechanistically, barrier repair effects of *Gardenia jasminoides* are closely linked to activation of the aryl hydrocarbon receptor (AHR), a ligand activated transcription factor that regulates epidermal differentiation and skin homeostasis. In keratinocyte models, *Gardeniae Fructus* extract activated AHR signaling, leading to downstream induction of FLG, LOR, and IVL expression. Pharmacological inhibition or knockdown of AHR abolished these effects, confirming that the barrier enhancing activity is AHR dependent [3].

Importantly, AHR-mediated signaling represents a physiologically relevant pathway for long-term barrier normalization, as it integrates environmental sensing with epidermal differentiation. This distinguishes Gardenia extracts from barrier ingredients that act only through short-lived hydration effects, and positions them closer to emerging cosmeceutical strategies targeting skin resilience and adaptive barrier repair [3].

### 6.3 Clinical evidence

#### 6.3.1 TEWL reduction

Human clinical studies included in the reviewed studies provide direct translational evidence that the molecular barrier effects observed *in vitro* translate into functional improvements. In a controlled human study evaluating a topical formulation containing *Gardenia jasminoides* extract, regular application resulted in statistically significant reductions in transepidermal water loss, indicating improved barrier integrity and reduced water permeability of the stratum corneum [13].

#### 6.3.2 Stratum corneum hydration improvement

In the same clinical context, corneometric measurements demonstrated significant increases in stratum corneum hydration following topical use of the Gardenia extract formulation, without reports of irritation or sensitization. These improvements were sustained over the study period, supporting the suitability of Gardenia based actives for daily use products aimed at dry, sensitive, or barrier impaired skin [13].

### 6.4 Protection against environmental stressors

Beyond intrinsic barrier repair, *Gardenia jasminoides* confers protection against a range of external stressors that are known to compromise epidermal integrity.

#### 6.4.1 UVB

In UVB irradiated HaCaT keratinocytes, *Gardeniae Fructus* extract reduced ROS generation, suppressed inflammatory cytokine expression, and mitigated UV induced barrier disruption, supporting its role in preserving epidermal structure under photo stress conditions [4].

#### 6.4.2 Air pollution (diesel exhaust particles)

Geniposide, a major iridoid component of *Gardeniae Fructus*, protected human dermal fibroblasts from diesel exhaust particle induced oxidative damage by reducing ROS accumulation and preventing apoptosis. Although conducted in fibroblasts, these findings may indirectly support barrier-relevant outcomes, as pollution-induced oxidative stress is known to compromise epidermal barrier function through inflammatory and matrix-degrading signals [5].

#### 6.4.3 Blue light

Digital stress represents an emerging environmental challenge for skin barrier health. A stabilized *Gardenia jasminoides* extract demonstrated protective effects against blue light induced mitochondrial dysfunction and protein oxidation in skin cells. In human studies,


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this protection correlated with improvements in skin appearance and reduced signs of premature aging, indirectly supporting maintenance of barrier homeostasis under chronic blue light exposure [6].

## 7. Safety Profile and Cosmetic Development Considerations

### 7.1 Cytotoxicity and tolerability data

*Gardenia jasminoides* ingredients generally show low cytotoxicity in skin-relevant *in vitro* models at concentrations used to demonstrate efficacy. In a multi-cell line study, *Gardeniae Fructus* extract was evaluated in keratinocytes, melanocytes, and fibroblasts with WST 1 viability testing, supporting that functional activities (whitening, moisturizing, anti-wrinkle related endpoints) were observed without overt cytotoxicity in the tested ranges [1].

### 7.2 Skin irritation and sensitization observations

Human tolerability evidence in the reviewed studies is currently concentrated in topical product evaluation settings. A clinical study assessing the barrier repair efficacy and safety of a *Gardenia jasminoides* extract reported favorable tolerability in human application, supporting suitability for daily use products targeting sensitive or barrier-impaired skin [13].

### 7.3 Phototoxicity and data gaps

Despite strong efficacy signals for barrier repair, soothing, and anti-aging related protection, the studies highlight several safety evidence gaps that matter for commercialization. Phototoxicity and photosensitization testing is not consistently reported across the included Gardenia cosmetic studies, even though some use cases directly involve UV and blue light exposure contexts [6]. Additional gaps include long-term safety observations, comprehensive sensitization testing across diverse skin types, and standardized reporting of adverse events in human studies. These gaps does not inherently imply risk, but they do limit the certainty of safety positioning for wide market claims, especially for leave-on products intended for chronic use.

### 7.4 Formulation vehicles

#### 7.4.1 Gel systems

A clear example of a topical vehicle in studies is a gel based formulation used for barrier repair oriented human evaluation, linking functional improvements such as TEWL reduction and hydration increases with acceptable tolerability [13]. Gel vehicles are formulation relevant because they can support high water phase loading, light sensory profiles, and compatibility with sensitive skin positioning, which aligns with Gardenia's barrier and soothing claims.

#### 7.4.2 Extract stabilization strategies

Stabilization and delivery strategy can be a differentiator for Gardenia actives, particularly for carotenoid rich extracts. A notable approach in the reviewed studies is stabilization of *Gardenia jasminoides* fruit extract in a Natural Deep Eutectic Solvent (NaDES), supporting its use as a blue light filter and as a melatonin like anti-aging ingredient in digital stress applications [6]. This provides an example of how formulation technology can help preserve activity, improve performance under light exposure, and support modern claim frameworks such as digital aging protection.

### 7.5 Regulatory and commercialization considerations

For commercialization, the main practical requirement emerging from the current evidence base is the need for ingredient standardization aligned with the intended claim. Whitening oriented products may require controlling for specific constituents due to context dependent pigmentation effects, while barrier repair products benefit from standardized iridoid rich fractions linked to epidermal differentiation pathways. In parallel, safety dossiers for market access will be


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strengthened by adding missing testing commonly expected for leave-on cosmetics, particularly phototoxicity, sensitization screening in broader populations, stability under storage and light, and compatibility assessments in finished formulations. Overall, the studies stated that *Gardenia jasminoides* as a promising multifunctional cosmetic active, but translation into robust commercial claims will depend on closing these safety and formulation reporting gaps [6, 13].

## 8. Integrated Mechanistic Overview

### 8.1 Cross-talk between whitening, anti-aging, soothing, and barrier repair

The cosmetic activity of *Gardenia jasminoides* is best understood as an integrated, multi-layered mechanism rather than a set of isolated effects. Evidence across the collected studies shows substantial cross-talk between pigmentation control, photoaging protection, inflammation modulation, and epidermal barrier repair, with shared upstream regulators and reinforcing downstream outcomes.

At the oxidative stress level, antioxidant activity represents a common mechanistic foundation. Reduction of reactive oxygen species in keratinocytes and fibroblasts attenuates UV- and pollution-induced activation of NF-κB and MAPK signaling, which in turn suppresses pro-inflammatory cytokine release and matrix metalloprotein induction. This cascade links anti-aging outcomes such as reduced MMP-1 and MMP-9 expression and collagen preservation with soothing effects characterized by lower IL-1β, IL-6, and TNF-α production, ultimately supporting both wrinkle mitigation and inflammation control [1, 4, 10].

Pigmentation modulation is also mechanistically intertwined with barrier and inflammatory pathways. Inhibition of melanogenesis through tyrosinase and MITF suppression occurs most clearly under inflammatory or hyperstimulated conditions, suggesting that whitening efficacy is enhanced when oxidative and cytokine-driven melanocyte activation is dampened. Conversely, geniposide-driven activation of the stem cell factor–c-Kit axis under stress conditions illustrates that pigmentation outcomes are context dependent, reinforcing the importance of formulation-driven control of pathway balance [1, 8, 9].

Barrier repair provides a stabilizing endpoint that feeds back into both soothing and anti-aging performance. AHR-mediated upregulation of filaggrin, loricrin, and involucrin strengthens the stratum corneum, reduces transepidermal water loss, and limits penetration of irritants and allergens. This improved barrier integrity lowers baseline inflammatory tone and reduces susceptibility to environmental triggers such as UV radiation, air pollutants, and blue light, thereby indirectly reinforcing whitening stability, wrinkle prevention, and comfort in sensitive skin [3, 5, 13].

These studies support a systems-level model in which *Gardenia jasminoides* simultaneously targets oxidative stress, inflammatory signaling, melanogenic regulation, extracellular matrix degradation, and epidermal differentiation. These interconnected effects explain why Gardenia extracts consistently demonstrate benefits across multiple cosmetic endpoints rather than excelling in only a single functional category.

### 8.2 Positioning *Gardenia jasminoides* as a multifunctional cosmetic active

From a cosmetic science perspective, *Gardenia jasminoides* can be positioned as a multifunctional active suited for modern formulations addressing complex skin needs. Unlike single-target actives, Gardenia-derived ingredients exhibit coordinated activity across whitening, anti-aging, soothing, and barrier repair domains, supported by mechanistic data from *in vitro*, *in vivo*, and human studies.

This multifunctionality aligns particularly well with products designed for sensitive, urbanexposed, or prematurely aging skin, where pigmentation irregularities, inflammation, barrier dysfunction, and wrinkle formation frequently coexist. The presence of both iridoids and carotenoid derivatives enables flexible formulation strategies, allowing ingredient designers to emphasize depigmenting, calming, or barrier-centric claims through selective extraction, enrichment, and stabilization approaches [6, 13].

The integrated evidence base positions *Gardenia jasminoides* not merely as a traditional botanical with isolated effects, but as a scientifically supported, pathway-active cosmetic ingredient capable of addressing multiple skin concerns within a single formulation framework.

## 9. Limitations and Research Gaps

Despite the growing body of evidence supporting the cosmetic potential of *Gardenia jasminoides*, several important limitations and research gaps remain that should be addressed to strengthen scientific credibility and support broader cosmetic translation.

Current barrier-related studies focus predominantly on epidermal differentiation markers such as filaggrin, loricrin, and involucrin, with limited investigation into lipid-mediated barrier components. Ceramides are critical to stratum corneum integrity and long-term hydration retention, yet direct evidence linking *Gardenia jasminoides* extracts or isolated constituents to ceramide synthesis, metabolism, or lamellar lipid organization is absent from the available dataset. This represents a significant mechanistic gap, as comprehensive barrier repair claims increasingly require combined protein and lipid pathway validation [3, 13].

Although one study highlights microbiota-mediated conversion of Gardenia-derived carotenoids into melatonin-like metabolites relevant for digital stress protection, broader interactions between *Gardenia jasminoides* and the skin microbiome remain underexplored. There is currently no systematic evaluation of how Gardenia extracts influence microbial composition, microbial-derived metabolites, or host–microbiome cross-talk in the context of inflammation, pigmentation, or barrier function. Given the increasing importance of microbiome-friendly cosmetic positioning, this represents a significant opportunity for future research [6].

While short-term human studies and *in vitro* cytotoxicity assays indicate favorable tolerability, long-term human safety data are limited. Most available clinical evidence focuses on relatively short application periods and small cohorts, with insufficient data on chronic use, cumulative exposure, or use in highly sensitive or compromised skin populations. In addition, phototoxicity and photosensitization assessments are not consistently reported, despite frequent claims related to UV and blue-light protection. Addressing these gaps will be essential for robust safety dossiers and regulatory confidence [6].

A recurring limitation across whitening, soothing, anti-aging, and barrier repair studies is the lack of standardized extract definitions. Extracts vary widely in solvent system, plant part, processing method, and phytochemical composition, making cross-study comparison difficult. In addition, context-dependent effects on pigmentation, particularly involving geniposide, underscore the need for precise compositional benchmarks aligned with intended cosmetic claims. Future work would benefit from defining reference materials or minimum specification ranges for key active classes, enabling reproducibility, clearer structure–function relationships, and more reliable formulation translation [1, 8].

## 10. Conclusion

The current studies demonstrates that *Gardenia jasminoides* is supported by a comparatively strong scientific foundation among botanical cosmetic actives, with convergent data from *in vitro*, *in vivo*, and human studies showing efficacy across whitening, anti-aging, soothing, and skin barrier repair domains. Its most promising cosmetic applications lie in multifunctional formulations targeting sensitive, environmentally stressed, or prematurely aging skin, where oxidative stress, inflammation, pigmentation imbalance, and barrier dysfunction coexist and reinforce one another. Mechanistic insights highlight antioxidant regulation, inflammatory pathway suppression, melanogenic modulation, extracellular matrix preservation, and AHR-mediated epidermal differentiation as interconnected drivers of these benefits. The priority research directions should focus on expanding lipid barrier biology including ceramide pathways, elucidating interactions with the skin microbiome, generating long-term human safety and efficacy data, and establishing standardized extract benchmarks aligned with specific cosmetic claims. Addressing these gaps will not only strengthen regulatory confidence but also enable more precise product development, positioning *Gardenia jasminoides* as a next-generation, science-driven botanical active in cosmetic and cosmeceutical innovation.

**Acknowledgement**

The authors wish to acknowledge the Kanghong Biotechnology Group Co., Ltd. and UNITAR University College Kuala Lumpur.

**References**

[1] Hong, S. H., Ku, J. M., Lee, S. H., Shim, H. J., Park, D. S., Sung, J. W., Shin, Y. C., & Ko, S.-G. (2019). Skin improvement effects of Gardeniae fructus extract in HaCaT keratinocytes, B16F10 melanocytes, and CCD-986sk fibroblast cells. Cosmetics, 6 (3), 48.

[2] Park, J., Seok, J. K., Suh, H.-J., & Boo, Y. C. (2014). Gardenia jasminoides extract attenuates the UVB-induced expression of cytokines in keratinocytes and indirectly inhibits matrix metalloproteinase-1 expression in human dermal fibroblasts. Evidence-Based Complementary and Alternative Medicine, 2014, 429246.

[3] Zong, K., Zhou, F., Xu, K., Dong, J., Huang, Q., & Wu, J. (2025a). Gardeniae Fructus enhances skin barrier function via AHR-mediated FLG/LOR/IVL expression. Molecules, 30 (18), 3764.

[4] Zong, K., Li, X., Zhou, F., Dong, J., Huang, Q., & Wu, J. (2025b). Photoprotective effect and potential mechanisms of Gardeniae Fructus extract in UVB-irradiated HaCaT cells. Cosmetics, 12 (2), 72.

[5] Nguyen, L. T. H., Ahn, S. H., Nguyen, U. T., Yang, I. J., & Shin, H. M. (2021). Geniposide, a principal component of Gardeniae Fructus, protects skin from diesel exhaust particulate matter-induced oxidative damage. Evidence-Based Complementary and Alternative Medicine, 2021, 8847358.

[6] De Tollenaere, M., Chapuis, E., Martinez, J., Paulus, C., Dupont, J., Don Simoni, E., Robe, P., Sennelier-Portet, B., Auriol, D., Scandolera, A., & Reynaud, R. (2023). Gardenia jasminoides extract, with a melatonin-like activity, protects against digital stress and reverses signs of aging. International Journal of Molecular Sciences, 24, 4948.

[7] Na, J. S., Song, B. R., Choi, W. S., Lee, T. H., Choe, D., & Lee, S. H. (2025). In silico analysis of dual tyrosinase and elastase inhibition by bioactive ingredients from Gardenia jasminoides seeds. Food Science and Preservation, 32(2), 328–343.

[8] Akihisa, T., Watanabe, K., Yamamoto, A., Zhang, J., Matsumoto, M., & Fukatsu, M. (2012). Melanogenesis inhibitory activity of monoterpene glycosides from Gardeniae Fructus. Chemistry and Biodiversity, 9(8), 1490–1499.

[9] Lan, W. J., Wang, H. Y., Lan, W., & Wang, K. Y. (2008). Geniposide enhances melanogenesis by stem cell factor/c-Kit signalling in norepinephrine-exposed normal

human epidermal melanocyte. Basic and Clinical Pharmacology and Toxicology, 103(1), 88–93.

[10] Debnath, T., Lee, Y. M., Lim, J. H., Lim, B. O. (2018). Anti-allergic and anti-atopic dermatitis effects of Gardenia Fructus extract. Food and Agricultural Immunology, 29 (1), 1-10.

[11] Alyoussef, A. (2020). Crocin ameliorated skin tissue inflammation in atopic dermatitis in mice. International Journal of Research in Dermatology, 6(2), 142 - 146.

[12] Park, S. H., Song, H. K., Ji, K. Y., Jung, D. H., Jang, S., Kim, T., & Kim, H. K. (2023). Topical administration of Gardenia jasminoides extract regulates Th2 immunity in OVA-induced mice. Cells, 12 (6), 941.

[13] Dong, J., Li, B., Xu, P., Kong, L., Zhang, W., Wu, D., Tian, Y., & Wang, X. (2024). Skin barrier repair efficacy and safety evaluation of an extract from Gardenia jasminoides J. Ellis. Natural Product Research, 30: 1 - 7.