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A Mini Review on *Gardenia jasminoides* Essential Oil and Fruit Oil: Composition, Quality Indices, and Cosmetic Industrial Value

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Abstract: *Gardenia jasminoides Ellis* has long been valued for its fragrant flowers and bioactive fruits; however, information regarding its essential oil and fruit-derived oil remains fragmented across studies on extraction, chemical composition, quality evaluation, and cosmetic applications. This mini review aimed to critically summarize and integrate current knowledge on the extraction technologies, chemical composition, quality indices, and cosmetic-relevant bioactivities of Gardenia jasminoides essential oil and fruit oil. A narrative literature review was conducted using peer-reviewed studies focusing on extraction methods, compositional analyses, quality assessment, and biological activities relevant to cosmetic applications. The reviewed evidence indicates that flower essential oils obtained through hydrodistillation, solvent extraction, and enfleurage possess complex volatile profiles dominated by alcohols and terpenes, including linalool, α-farnesene, methyleugenol, and jasminelactone. Advanced analytical techniques such as GC–MS and HS-GC-MS have identified more than 100 volatile compounds, while sensory evaluation and relative odour activity value analyses confirmed key aroma-active constituents. Fruit oils extracted using supercritical CO_2 and ultrasound-assisted extraction exhibited favorable unsaturated fatty acid profiles and contained lipophilic bioactive compounds, including crocetin derivatives. Quality evaluation was based on chromatographic fingerprinting, extraction yield optimization, fatty acid composition, and antioxidant capacity assays. Preclinical studies further suggested anti-inflammatory, antioxidant, and skin barrier-supportive activities through modulation of nitric oxide, TNF-α, PGE_2, and tight junction protein ZO-1 pathways. Overall, the available evidence highlights the potential of *Gardenia jasminoides* oils as multifunctional botanical ingredients for fragrance, soothing, antioxidant, and skin-conditioning cosmetic applications. Nevertheless, further standardization, safety assessment, and clinical validation are required to ensure consistent quality, efficacy, and industrial applicability.

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1. Introduction

Botanical oils have become central to modern cosmetic formulation due to their multifunctional properties, including fragrance, antioxidant activity, anti-inflammatory effects, and skin barrier enhancement. Increasing consumer preference for plant-derived and naturally sourced ingredients has stimulated research into essential oils and fixed oils that offer both sensory appeal and functional efficacy. Essential oils rich in terpenes and aromatic alcohols are widely used in perfumery and personal care products for their characteristic olfactory profiles, while fruit oils provide emollient properties, essential fatty acids, and lipophilic bioactives that contribute to skin conditioning and repair. Analytical advances such as gas chromatography–mass spectrometry (GC–MS), headspace GC–MS, and high-performance liquid chromatography have enabled detailed compositional profiling and quality evaluation of botanical oils intended for cosmetic applications, allowing correlation between chemical markers and biological performance [1, 2].

Gardenia jasminoides Ellis (Rubiaceae) is an evergreen shrub native to East Asia and widely cultivated for its ornamental, aromatic, and medicinal value. Its white fragrant flowers and bioactive fruit have been extensively used in traditional medicine and, more recently, investigated for phytochemical and functional properties [1]. Chemical investigations have revealed a rich diversity of volatile compounds in the flowers, including linalool, α-farnesene, cis-3-hexenyl derivatives, jasminelactone, and other aroma-active constituents that contribute to its sweet-green floral scent [3, 4, 5]. More than 100 volatile compounds have been identified in flower extracts using GC–MS techniques, with certain key odorants confirmed through sensory evaluation and relative odour activity value analysis [5, 7]. Beyond fragrance, studies have demonstrated antioxidant, anti-inflammatory, and antimicrobial activities associated with gardenia essential oil and extracts [2, 6].

A clear distinction must be made between flower-derived essential oil and fruit-derived fixed oil, as they differ substantially in extraction methods, chemical composition, and functional applications. Flower essential oil is typically obtained via hydrodistillation, solvent extraction, or enfleurage, yielding a volatile fraction rich in alcohols, terpenes, esters, and aroma-active compounds [3, 4, 7]. In contrast, fruit oil is extracted using techniques such as supercritical CO_2 extraction and ultrasound-assisted extraction, producing a lipophilic oil characterized by fatty acids and bioactive constituents including crocetin derivatives and other lipid-soluble compounds [8, 9]. Optimization approaches, including response surface methodology, have been applied to improve yield and preserve bioactive integrity in fruit oil extraction [8, 9]. These compositional differences underpin distinct cosmetic functions: essential oil primarily contributes fragrance and anti-inflammatory activity, while fruit oil provides emollient, antioxidant, and barrier-supportive effects.

The objective of this mini review is to integrate current knowledge on the extraction technologies, chemical composition, quality indices, and cosmetic-relevant bioactivities of *Gardenia jasminoides* essential oil and fruit oil. By synthesizing compositional data with biological activity and quality evaluation parameters, this review aims to clarify the multifunctional cosmetic potential of gardenia-derived oils and highlight key considerations for standardization and industrial application.

2. Extraction Technologies Relevant to Cosmetic-Grade Oils

2.1 Flower Essential Oil Extraction

The extraction method strongly influences the chemical profile, yield, and sensory quality of *Gardenia jasminoides* flower essential oil, which is critical for cosmetic applications. Hydrodistillation is one of the most commonly employed techniques for isolating volatile oils. Using this method, complex mixtures of monoterpenes, sesquiterpenes, aromatic alcohols, and esters have been identified through GC–MS analysis, including linalool, α-farnesene, and other key aroma constituents [2, 6]. Hydrodistillation offers simplicity and solvent-free processing, which aligns with cosmetic regulatory preferences; however, prolonged heating may result in partial degradation or loss of thermolabile compounds.

Enfleurage and solvent extraction have historically been used to obtain gardenia flower absolutes with a richer and more complete aromatic profile. Early compositional studies of gardenia absolute revealed a high diversity of volatile constituents, including alcohols, esters, lactones, and trace aroma-active compounds that contribute significantly to fragrance quality [3, 4]. Compared to hydrodistillation, solvent extraction typically yields a broader spectrum of semi-volatile and less volatile constituents, enhancing depth and persistence of aroma, which is desirable in perfumery and luxury cosmetic formulations. However, solvent residues and process control must meet cosmetic-grade purity requirements.

More recent investigations using headspace GC–MS and sensory analysis have demonstrated that extraction technique affects not only total yield but also odor-active composition. Volatile profiling studies have identified over one hundred compounds in flower extracts, with key odorants such as jasminelactone and cis-3-hexenyl derivatives contributing significantly to the characteristic sweet-green floral note [5, 7]. Relative odour activity value analysis further confirms that a small number of compounds disproportionately influence perceived fragrance intensity. Yield differences between extraction methods are therefore not merely quantitative but qualitatively linked to aromatic performance, an essential consideration for cosmetic fragrance applications.

2.2 Fruit Oil Extraction

In contrast to the volatile-rich flower essential oil, fruit oil of *Gardenia jasminoides* is a fixed oil composed primarily of fatty acids and lipophilic bioactive compounds. Supercritical CO_2 extraction (SFE) has been widely investigated as a green and efficient method for recovering gardenia fruit oil. Optimization studies using response surface methodology have demonstrated that extraction pressure, temperature, and time significantly influence oil yield and bioactive preservation [8]. SFE offers advantages relevant to cosmetic-grade production, including low solvent residue, controlled selectivity, and improved retention of thermosensitive components.

Ultrasound-assisted extraction (UAE) has also been applied to enhance extraction efficiency. By disrupting plant cell structures and improving mass transfer, UAE increases oil recovery while reducing extraction time [9]. Analytical characterization using HPLC-DAD/ESI-MS^2 has enabled identification and quantification of bioactive constituents in fruit oil extracts, providing a scientific basis for quality control and functional evaluation [9]. Compared to conventional extraction methods, ultrasound-assisted approaches may offer improved scalability and cost-effectiveness for industrial cosmetic manufacturing.

Overall, extraction optimization plays a decisive role in determining yield, compositional integrity, and functional performance of gardenia fruit oil. Parameters such as solvent type, pressure, temperature, and extraction duration must be carefully controlled to ensure reproducible quality suitable for cosmetic formulations. Supercritical and ultrasound-assisted techniques, in particular, demonstrate strong potential for scalable, high-purity production of cosmetic-grade gardenia oil with preserved bioactivity.

3. Chemical Composition and Quality Indices

3.1 Essential Oil Composition

The chemical composition of *Gardenia jasminoides* flower essential oil is characterized by a complex mixture of monoterpenes,

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sesquiterpenes, aromatic alcohols, esters, and trace lactones that collectively determine fragrance quality and functional performance. GC–MS analyses of flower oils and absolutes have consistently identified linalool, α-farnesene, methyleugenol, and cis-3-hexenyl derivatives among the major volatile constituents [2, 3, 4, 6]. Linalool contributes a fresh floral note, whereas α-farnesene and related sesquiterpenes provide depth and persistence. Methyleugenol, although present in measurable quantities, requires careful monitoring due to regulatory considerations in cosmetic applications.

Alcohols and terpenes represent dominant chemical classes in the volatile fraction. Earlier compositional studies of gardenia absolutes demonstrated a relatively high proportion of aromatic alcohols and esters compared to simple hydrocarbon terpenes, contributing to a soft and sweet olfactory profile [3, 4]. More recent profiling confirms that the alcohol/terpene balance significantly influences aroma perception and stability [7]. Variations in relative abundance of these chemical groups can be attributed to extraction technique and processing conditions.

Aroma-active compounds constitute a small but critical subset of the total volatile composition. Sensory analysis combined with relative odour activity value assessment has identified key contributors such as jasminelactone and cis-3-hexenyl esters, which disproportionately affect fragrance intensity and characteristic floral-green notes [5, 7]. These findings highlight that cosmetic fragrance performance depends not solely on total volatile concentration but on the presence and balance of specific odorants.

Genotype and processing conditions further influence essential oil composition. Comparative evaluations between *Gardenia jasminoides* varieties and related forms have demonstrated differences in volatile profiles and relative abundance of principal compounds [6]. Additionally, hydrodistillation, solvent extraction, and headspace methods yield compositional variations due to differences in thermal exposure and solvent selectivity [3, 7]. Such variability underscores the importance of standardized extraction and raw material selection for consistent cosmetic-grade essential oil production.

3.2 Fruit Oil Composition

Unlike the volatile-rich essential oil, fruit oil of *Gardenia jasminoides* is composed primarily of fatty acids and lipophilic bioactive constituents. Supercritical CO_2 extraction and ultrasound-assisted extraction studies have revealed that the oil fraction contains a favorable fatty acid profile, with a predominance of unsaturated fatty acids relative to saturated ones [8, 9]. A higher unsaturated/saturated ratio is generally associated with improved skin-conditioning and emollient properties in cosmetic formulations.

In addition to fatty acids, fruit oil contains lipophilic bioactive compounds, including crocetin derivatives and other minor constituents with potential antioxidant and functional relevance [8, 9]. Analytical identification using HPLC-DAD/ESI-MS^2 has enabled the characterization and quantification of specific bioactive markers within the oil matrix [8, 9]. These markers provide a scientific basis for linking compositional features to potential cosmetic benefits such as antioxidant protection and skin-supportive activity.

The compositional profile of fruit oil is influenced by extraction parameters such as pressure, temperature, solvent system, and ultrasound intensity. Optimization through response surface methodology has demonstrated that controlled extraction conditions improve oil yield while preserving bioactive integrity [8]. Consequently, compositional stability and reproducibility are critical considerations for cosmetic ingredient development.

3.3 Quality Evaluation Parameters

Quality evaluation of gardenia essential oil and fruit oil relies on integrated analytical and functional assessment. GC–MS fingerprinting serves as a primary tool for essential oil authentication, allowing identification of major volatiles and detection of compositional deviations associated with adulteration or processing variability [2, 3]. Establishing a reproducible chromatographic profile is essential for cosmetic quality control.

For fruit oil, HPLC-based quantification of bioactive constituents provides a complementary quality index [9]. The determination of specific chemical markers ensures batch-to-batch consistency and supports functional claims. Extraction yield and compositional ratios, including unsaturated/saturated fatty acid balance, further contribute to quality assessment [8].

Antioxidant capacity represents an additional functional quality parameter. Essential oil from *Gardenia jasminoides* has demonstrated measurable antioxidant activity in DPPH and related assays [2], linking chemical composition to biological performance. Similarly, anti-inflammatory activity observed in alveolar macrophage models provides functional validation of compositional markers in essential oil fractions [6]. Chromatographic profiling, quantitative marker analysis, and bioactivity assays form a multidimensional framework for evaluating cosmetic-grade gardenia oils and linking chemical markers to functional efficacy.

4. Cosmetic-Relevant Bioactivities

4.1 Anti-Inflammatory Activity

Inflammation is a central mechanism underlying sensitive, irritated, and barrier-compromised skin conditions. Essential oils of *Gardenia jasminoides* have demonstrated significant anti-inflammatory activity in cellular models. In particular, flower essential oil was shown to inhibit nitric oxide (NO) production in lipopolysaccharide-stimulated alveolar macrophages, indicating suppression of inflammatory mediator release [6]. In the same study, modulation of pro-inflammatory cytokines including tumor necrosis factor-α (TNF-α) and prostaglandin E_2 (PGE_2) was observed, supporting a multi-target anti-inflammatory mechanism [6].

Such inhibition of NO and cytokine pathways is directly relevant to cosmetic applications aimed at soothing irritated or inflamed skin. Excessive NO and TNF-α production are associated with redness, barrier disruption, and inflammatory dermatoses. Therefore, the demonstrated downregulation of these mediators suggests that gardenia essential oil may contribute to calming formulations designed for sensitive or reactive skin. Additionally, antioxidant-associated anti-inflammatory effects have been reported in essential oil profiling studies, further supporting its dermal protective potential [2].

4.2 Antioxidant Activity

Oxidative stress plays a critical role in skin aging, inflammation, and environmental damage. Essential oil of *Gardenia jasminoides* has shown measurable antioxidant activity in DPPH radical scavenging assays, as well as in total antioxidant capacity (TAC) evaluations [2]. These assays demonstrate the ability of the oil to neutralize free radicals and reduce oxidative burden.

The presence of aromatic alcohols, phenylpropanoids, and other oxygenated constituents likely contributes to its radical-scavenging activity [2]. Antioxidant capacity is particularly relevant in cosmetic formulations targeting photoaging, pollution defense, and overall skin protection. By mitigating reactive oxygen species, gardenia-derived oils may help preserve cellular integrity and support long-term skin health.

4.3 Skin Barrier Repair

Beyond anti-inflammatory and antioxidant properties, extracts of *Gardenia jasminoides* have demonstrated skin barrier repair potential. Studies evaluating skin barrier-related proteins reported upregulation of zonula occludens-1 (ZO-1), a tight junction protein critical for epidermal barrier integrity. Increased expression of ZO-1 indicates enhanced intercellular cohesion and improved barrier function.

Importantly, safety evaluation demonstrated no significant cytotoxicity under tested conditions, suggesting suitability for topical cosmetic applications. Enhancement of tight junction proteins is particularly relevant for formulations addressing compromised barrier conditions such as dryness, irritation, and sensitivity. The ability to simultaneously reduce inflammation and support barrier structure positions gardenia-derived ingredients as multifunctional cosmetic actives.

4.4 Fragrance and Sensory Value

Fragrance is a defining characteristic of *Gardenia jasminoides*, and its sensory profile represents a major driver of cosmetic value. Volatile profiling combined with sensory evaluation and relative odour activity value (rOAV) analysis has identified key odorants responsible for its sweet, creamy, and green floral notes [5, 7]. Compounds such as jasminelactone, linalool, and cis-3-hexenyl derivatives contribute disproportionately to perceived aroma intensity despite not always being the most abundant components.

The studies and sensory characterization indicate strong acceptability of gardenia aroma extracts for perfumery and personal care products [7]. The balance between alcohols, esters, and sesquiterpenes plays a critical role in fragrance depth and persistence. Therefore, chemical composition not only influences biological activity but also determines olfactory quality, making compositional control essential for cosmetic fragrance development.

5. Cosmetic Industrial Value and Development Potential

The integration of compositional profiling, functional bioactivity, and sensory evaluation positions *Gardenia jasminoides* essential oil and fruit oil as promising multifunctional ingredients for cosmetic development. Their industrial value arises from the combination of fragrance performance, antioxidant capacity, anti-inflammatory activity, and barrier-supportive properties demonstrated in experimental studies.

5.1 Fragrance Applications

The flower essential oil of *Gardenia jasminoides* is primarily valued for its distinctive sweet, creamy, and green floral aroma. GC–MS and sensory analyses have identified key odor-active compounds, including linalool, jasminelactone, cis-3-hexenyl derivatives, and α-farnesene, which collectively define its characteristic olfactory profile [5, 7]. Relative odour activity value analysis confirms that certain compounds exert a disproportionate influence on fragrance perception, highlighting the importance of compositional balance rather than total volatile concentration.

Historically, gardenia absolutes obtained through solvent extraction have been used in perfumery due to the richer and more persistent aroma compared to hydrodistilled oils [3, 4]. In modern cosmetic formulations, gardenia essential oil may serve as a natural fragrance component in perfumes, creams, lotions, and hair care products, where floral top and middle notes are desired. The demonstrated consumer acceptability of gardenia aroma extracts further strengthens its industrial potential [7].

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5.2 Anti-Aging Potential

Oxidative stress is a central contributor to extrinsic skin aging, including wrinkle formation, loss of elasticity, and photoaging. Essential oil of *Gardenia jasminoides* has shown measurable antioxidant activity in DPPH radical scavenging and total antioxidant capacity assays [2]. The presence of oxygenated terpenes and aromatic compounds likely contributes to this radical-neutralizing effect.

By reducing reactive oxygen species, gardenia-derived oils may help protect dermal cells from oxidative damage and support anti-aging cosmetic strategies. Additionally, the anti-inflammatory activity demonstrated through inhibition of NO, TNF-α, and PGE_2 pathways [6] may indirectly contribute to anti-aging benefits, as chronic low-grade inflammation is increasingly recognized as a factor in skin aging.

5.3 Soothing and Repair Formulations

The modulation of inflammatory mediators by gardenia essential oil suggests relevance for soothing formulations targeting sensitive or irritated skin [6]. Inhibition of NO production and pro-inflammatory cytokines indicates potential application in calming creams and serums designed to reduce redness and discomfort.

Furthermore, extracts of *Gardenia jasminoides* have demonstrated upregulation of the tight junction protein ZO-1, indicating improved barrier integrity. Enhancement of epidermal tight junctions supports barrier repair and moisture retention, both essential attributes in dermocosmetic products. The reported absence of significant cytotoxicity under experimental conditions supports the feasibility of topical cosmetic use.

5.4 Standardization Challenges

Despite promising bioactivities, variability in chemical composition presents a significant challenge for industrial application. Essential oil composition is influenced by genotype, geographical origin, and extraction method [6, 7]. Differences in relative abundance of key volatiles such as linalool and α-farnesene can alter fragrance profile and functional performance.

Similarly, fruit oil composition depends on extraction parameters including pressure, temperature, and solvent system [8, 9]. Establishing standardized extraction protocols and chromatographic fingerprinting benchmarks is therefore essential to ensure batch-to-batch consistency. GC–MS profiling and HPLC-based quantification of bioactive markers provide practical tools for quality control and regulatory compliance.

5.5 Safety Considerations

Safety assessment is critical for cosmetic ingredient development. Studies evaluating anti-inflammatory and antioxidant activity of gardenia essential oil have not reported significant cytotoxicity at tested concentrations [2, 6]. Extracts used in barrier-related studies similarly demonstrated favorable safety profiles under experimental conditions.

However, certain constituents such as methyleugenol require careful monitoring due to regulatory scrutiny in cosmetic applications. Comprehensive compositional analysis and adherence to international cosmetic safety standards are therefore necessary before large-scale commercialization. Proper control of extraction processes and chemical profiling ensures that potentially restricted compounds remain within acceptable limits.

Overall, the convergence of fragrance appeal, biological efficacy, and modern extraction technologies supports the development of *Gardenia jasminoides* oils as high-value cosmetic ingredients. Continued efforts toward compositional standardization, safety validation, and genotype selection will further enhance their industrial applicability.

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6.0 Conclusion

The collective evidence reviewed indicates that *Gardenia jasminoides* essential oil and fruit oil possess a valuable combination of fragrance properties, bioactive constituents, and cosmetic-relevant functions. The flower essential oil is characterized by diverse volatile compounds that contribute to its distinctive floral aroma and demonstrate antioxidant and anti-inflammatory potential in preclinical studies. Meanwhile, the fruit oil contains favorable unsaturated fatty acids and lipophilic bioactives that may support emollient, antioxidant, and skin barrier-related functions. Together, these characteristics highlight the potential of gardenia-derived oils as multifunctional botanical ingredients for fragrance, soothing, antioxidant, and dermocosmetic applications. Despite these promising findings, several challenges remain. Most evidence is derived from chemical characterization and preclinical studies, while clinical validation of efficacy and safety is still limited. Further research is needed to confirm cosmetic benefits in humans, optimize formulation stability, and establish standardized quality control protocols to address variability associated with genotype, cultivation conditions, and extraction methods. In addition, compliance with cosmetic safety and regulatory requirements remains essential for commercial development. Overall, continued advances in extraction technology, formulation science, safety assessment, and clinical evaluation will further support the development of *Gardenia jasminoides* oils as high-value natural ingredients for the cosmetic industry.

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