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THE USE OF NATURAL ANTIOXIDANT COMPOUNDS IN ANTI-AGING COSMETIC FORMULATIONS: A LITERATURE REVIEW

Oleh:

Muhammad Digta Afriza[1]
Nobel Pangarintungan[2]
Rhesas Shalatan[3]

Universitas Tanjungpura
Alamat: JL. Prof. Dr. H. Hadari Nawawi, Bansir Laut, Kec. Pontianak Tenggara, Kota Pontianak, Kalimantan Barat (78815).
Korespondensi Penulis: i1021231112@student.untan.ac.id, i1021231040@student.untan.ac.id, a1011241261@student.untan.ac.id.

Abstract. The increasing demand for safe and sustainable skincare products has encouraged the use of natural antioxidant compounds in anti-aging cosmetic formulations. Oxidative stress is a key factor in skin aging, leading to collagen degradation, wrinkle formation, and loss of elasticity. This review aims to summarize recent findings on the role of natural antioxidants in preventing and delaying skin aging through various biochemical and molecular mechanisms. A systematic narrative review was conducted using literature from 2015–2025 obtained from PubMed, ScienceDirect, SpringerLink, and Google Scholar. Studies involving plant-derived antioxidants, vitamins, flavonoids, polyphenols, and coenzymes incorporated in cosmetic formulations were analyzed. The results show that natural antioxidants act by scavenging reactive oxygen species (ROS), inhibiting matrix metalloproteinases (MMPs), and stimulating collagen synthesis. Compounds such as resveratrol, coenzyme Q10, vitamin C, and polyphenolic plant extracts improve skin elasticity, hydration, and reduce wrinkles. Advanced delivery systems such as lipid nanoparticles, nanoemulsions, and liposomes enhance antioxidant stability, skin penetration, and efficacy. Clinical and in vitro studies consistently confirm that combining multiple natural antioxidants yields synergistic effects superior to single-compound formulations. In conclusion, natural antioxidants

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*Corresponding author: *i1021231112@student.untan.ac.id*

demonstrate strong potential as safe, effective, and biocompatible active ingredients in anti-aging cosmetics. Future research should focus on optimizing formulation stability, enhancing delivery systems, and validating clinical efficacy to support the development of sustainable, natural-based skincare innovations.

Keywords: Anti-Aging, Antioxidants, Cosmetics, Natural Compounds, Polyphenols.

Abstrak. *Meningkatnya permintaan terhadap produk perawatan kulit yang aman dan berkelanjutan telah mendorong pemanfaatan senyawa antioksidan alami dalam formulasi kosmetik anti-aging. Stres oksidatif merupakan salah satu faktor utama dalam proses penuaan kulit yang menyebabkan degradasi kolagen, pembentukan kerutan, dan berkurangnya elastisitas kulit. Tinjauan ini bertujuan untuk merangkum temuan-temuan terbaru mengenai peran antioksidan alami dalam mencegah dan memperlambat penuaan kulit melalui berbagai mekanisme biokimia dan molekuler. Tinjauan naratif sistematis dilakukan dengan menggunakan literatur dari tahun 2015–2025 yang diperoleh dari PubMed, ScienceDirect, SpringerLink, dan Google Scholar. Studi yang melibatkan antioksidan yang berasal dari tanaman, vitamin, flavonoid, polifenol, serta koenzim yang dimasukkan ke dalam formulasi kosmetik dianalisis dalam penelitian ini. Hasil kajian menunjukkan bahwa antioksidan alami bekerja dengan cara menangkap spesies oksigen reaktif (Reactive Oxygen Species/ROS), menghambat aktivitas matrix metalloproteinases (MMPs), serta merangsang sintesis kolagen. Senyawa seperti resveratrol, koenzim Q10, vitamin C, dan ekstrak tanaman yang kaya polifenol terbukti mampu meningkatkan elastisitas kulit, meningkatkan hidrasi, serta mengurangi kerutan.*

Selain itu, sistem penghantaran canggih seperti lipid nanoparticles, nanoemulsions, dan liposomes mampu meningkatkan stabilitas antioksidan, penetrasi ke dalam kulit, serta efektivitasnya. Berbagai studi klinis dan in vitro secara konsisten menunjukkan bahwa kombinasi beberapa antioksidan alami menghasilkan efek sinergis yang lebih baik dibandingkan formulasi dengan satu senyawa saja. Sebagai kesimpulan, antioksidan alami menunjukkan potensi yang kuat sebagai bahan aktif yang aman, efektif, dan biokompatibel dalam kosmetik anti-aging. Penelitian di masa depan perlu difokuskan pada optimalisasi stabilitas formulasi, peningkatan sistem penghantaran, serta validasi efektivitas klinis guna mendukung pengembangan inovasi perawatan kulit berbasis bahan alami yang berkelanjutan.

***Kata Kunci**: Anti-Penuaan, Antioksidan, Kosmetik, Senyawa Alami, Polifenol*.

INTRODUCTION

The use of cosmetic products has become an integral part of human life since ancient times, serving not only to enhance physical appearance but also to protect the skin and fulfill cultural and religious functions. Early cosmetics were made entirely from natural ingredients derived from plants, minerals, and animals. Over time, industrial development in the 20th century led to the emergence of synthetic and chemically modified substances in cosmetic formulations. However, public awareness regarding safety and environmental sustainability has shifted consumer preference toward natural-based products since the 1990s (McMullen & Dell'Acqua, 2023). This shift reflects the growing concern for both human health and ecological balance in modern cosmetic use.

In recent years, the cosmetic industry has rapidly evolved, driven by technological advancements and innovation in formulation. Modern cosmetics no longer function merely for aesthetic enhancement but also contribute to physical and psychological well-being. The term "cosmetic," derived from the Greek word *kosmein* meaning "to adorn," now encompasses a broader scope involving skin protection and care (Huda et al., 2025). However, the use of unsafe ingredients may cause irritation, allergies, or even long-term health effects, emphasizing the need for natural, safe, and biocompatible materials in product development.

The uniqueness of current cosmetic research lies in its growing focus on the use of natural active compounds that are effective yet environmentally friendly. Numerous studies have reported that natural ingredients possess biological activities that support skin health and regeneration. Despite this, there remains a scientific challenge to identify, isolate, and formulate these natural components effectively within modern cosmetic (Akmal & Saputra, 2024; Kusumawardhani & Fitri, 2023). The originality of this research is in its emphasis on exploring natural antioxidant compounds as active agents for anti-aging formulations.

Antioxidants play a vital role in preventing oxidative stress, one of the main factors that accelerate skin aging. These molecules neutralize free radicals that can damage lipids, proteins, and DNA, maintaining cellular integrity and function (Firdaus & Permadi, 2024). Plants are rich sources of antioxidant compounds, including polyphenols,

flavonoids, carotenoids, and vitamins, which act synergistically to protect skin cells from oxidative damage (Budzianowska et al., 2025). This study hypothesizes that the incorporation of natural antioxidants into cosmetic formulations can effectively reduce oxidative stress and support the development of safer, more sustainable products.

The purpose of this study is to highlight the potential and benefits of utilizing natural antioxidant compounds in the formulation of anti-aging cosmetics. By reviewing existing research and identifying relevant natural sources, this study aims to contribute to the understanding of sustainable cosmetic innovation. The findings are expected to provide scientific support for the development of natural-based cosmetics that are safe, effective, and environmentally friendly. Furthermore, the study promotes the integration of traditional knowledge and modern technology in advancing the cosmetic industry toward a healthier and more sustainable future.

METHODS

This review was conducted using a systematic narrative approach to summarize and evaluate recent studies on the use of natural antioxidant compounds in anti-aging cosmetic formulations. A comprehensive literature search was performed across major scientific databases, including PubMed, ScienceDirect, SpringerLink, and Google Scholar, using a combination of keywords such as *"natural antioxidants," "anti-aging cosmetics," "plant-derived antioxidants," "cosmeceutical formulation,"* and *"skin aging."* The search was limited to studies published between 2015 and 2025 to ensure the inclusion of recent and relevant findings.

Articles were screened based on inclusion criteria that required the study to involve the use of natural antioxidant compounds (e.g., polyphenols, flavonoids, vitamins, carotenoids, or plant extracts) incorporated into topical cosmetic or cosmeceutical formulations intended for anti-aging purposes. Only original research articles and comprehensive review papers that reported formulation design, antioxidant activity, anti-aging efficacy, stability studies, or skin compatibility were selected for detailed analysis.

The selected studies were reviewed to extract key information, including the type and source of antioxidant compound, formulation type (e.g., cream, serum, emulsion), evaluation methods (in vitro, in vivo, or clinical), and major findings related to anti-aging

performance such as wrinkle reduction, improvement in skin elasticity, or protection against oxidative stress. The extracted data were compiled and organized in a comparative summary table to highlight similarities and differences among formulations.

Finally, the synthesis of findings was performed descriptively, emphasizing emerging trends, formulation strategies, mechanisms of antioxidant action, and potential applications of natural compounds in the development of effective anti-aging cosmetic products.

RESULT AND DISCUSSION

Table 1. Knowledge and attitudes of adolescents regarding acne and its treatment

No.	Focus on Review	Main Antioxidant Compounds	Mechanism of Anti-aging Action	Keyfinds
1	Utilization of natural antioxidant compounds in anti-aging cosmetics	Green tea catechins (EGGG), resveratrol, curcumin, aloe vera polysaccharides, vitamins C & E, coenzyme Q10, niacinamide	Scavenging of reactive oxygen species (ROS), inhibition of collagenase and elastase, stimulation of collagen synthesis, and protection of fibroblasts	Natural antioxidants effectively prevent oxidative stress, delay wrinkle formation, improve skin elasticity and hydration, and enhance overall skin appearance when incorporated into creams, serums, and gels (Xie et al., 2024)
2	Utilization of pomegranate peel extract as a natural source of antioxidant and UV-protective agents in cosmetic formulations	Phenolic acids (ellagic, gallic, ferulic, p-coumaric), flavonoids (quercetin, luteolin, kaempferol, hesperidin), tannins (punicalagin, pedunculangin), quercetin	Exhibits antioxidant (DPPH, FRAP, ABTS), antimicrobial, and UV-photoprotective effects; enhances SPF in cosmetic emulsions and provides UVA/UVB protection, anti-	Pomegranate peel extracts, especially 70% ethanolic extract, demonstrate high phenolic content, strong antioxidant and antimicrobial potential, and effectiveUV absorption, making them promising

		glysocides (rutin, hyperoside)	aging, and wound-healing activity	natural ingredients for sustainable cosmetic and dermatological applications (Tumbarski et al., 2025)
3	Role of plant-derived phytochemicals in skin anti-aging and protection	Polyphenols (quercetin resveratrol, catechins, chlorogenic acid), carotenoids (β-carotene, lutein, fucoxanthin, astaxanthin), vitamins (A, C, E, B3), essential fatty acids (omega-3, omega-6)	Antioxidant activity, inhibition of collagenase/elastase/ ty rosinase, modulation of MMPs and inflammatory cytokines, stimulation of collagen synthesis, UV protection, and enchancement of fibroblast viability	Plant-derived phytochemicals demonstrate strong anti-aging potential by reducing oxidative stress, stimulating collagen and elastin production, and protecting againts damage. Their incorporation into cosmetic formulations improves skin elasticity, hydration, and overall rejunevation (Tomas, et al., 2025)
4	Phytochemical-based cosmeceuticals with antioxidant, anti-inflammatory, and anti-aging effects	Polyphenols (resveratrol, quercetin, catechins), flavonoids, carotenoids, phenolic acids, and essential oils	Scavenging of ROS, inhibition of MMPs and pro-inflammatory mediators (IL-6, TNF- α), enchancement of collagen synthesis, UV-protection, and modulation of	Phytochemicals form natural sources exhibit potent-anti aging potential throught antioxidant and anti-inflammatory mechanism. Their inclusion in cosmecuetical formulations enhances skin elasticity,

			oxidative stress pathways	hydration, and protection againts photoaging, suggesting broad potential for safe, natural-based anti-aging skincare (Raached et al., 2025)
5	Evaluation of plant-derived antioxidants for cosmetic and anti-aging applications	Polyphenols (flavonoids, phenolic acids), vitamins (C, E), terpenoids from various herbal extracts	Scavenging reactive oxygen species (ROS), inhibiting collagenase and elastase, stimulating fibroblast activity, enchancing collagen synthesis, and UV-induced damage	Plant extracts rich in polyphenols and vitamins demonstrate strong antioxidant capacity, delay wrinkle formation, improve skin elasticity, and protect againts photoaging. Their incorporation into creams and emulsions shows potential for safe, natural anti-aging cosmetic formulations (Tao et al., 2022)
6	Natural antioxidants and their roles in anti-aging skincare formulations	Polyphenols (resveratrol, quercetin, catechins), vitamins (C, E, A), carotenoids (β-catotene, lycopene), and coenzyme Q10	Neutralization of reactive oxygen species (ROS), inhibition of MMPs, prevention of collagen and elastin degradation, UV protection, and stimulation of dermal fibroblast activity	Natural antioxidants from plant and vitamin sources significantly improve skin health by reducing oxidative stress, preventing photoaging, and enhancing collagen synthesis. Their

				topical use in serums and creams supports elasticity, moisture retention, and anti-wrinkle effects (Nguyen et al., 2025)
7	Evaluation of a liposome-mediated antioxidant delivery system for anti-aging cosmetic application	Ectoin, *Haematococcus pluvialis* extract (astaxanthin), and tetrahexyldecyl ascorbate (THDA) encapsulated in liposomes	Antioxidant and photoprotective effects via inhibition of IL-6, IL-8, and MMP-9; enhanced skin penetration and stability of active ingredients	Liposome-based antioxidant complexes significantly decreased inflammatory and aging biomarkers (IL-6 ↓39.3%, IL-8 ↓49.8%, MMP-9 ↓38.5%) without cytotoxicity, indicating improved skin protection and anti-aging efficacy compared to free antioxidants (Min et al., 2024)
8	Developlement of lipid-based nanocarriers for controlled delivery of natural antioxidants in anti-	Natural antioxidants such as curcumin, resveratrol, and coenzyme Q10 encapsulated in solid lipid nanoparticles (SLN) and	Improved antioxidant stability and skin permeability; protection against UV-induced oxidative stress; inhibition of MMPs and ROS-mediated collagen	Lipid nanocarriers significantly enhanced the bioavailability and skin penetration of natural antioxidants, resulting in higher antioxidant activity and stronger anti-aging effects compared to

	aging cosmetics	nanostructured lipid carriers (NLC)	degradation	conventional formulations (Castro et al., 2024)
9	Clinical evaluation of a facial serum containing a Liposomal Blend for anti-aging efficacy	Caffeine, pracaxi oil, *Plukenetia volubilis* seed oil, *Carthamus tinctorius* seed oil, palmitoyl tripeptide- 5, hexapeptide-9, acetyl-dipeptide-1 cetyl ester, niacinamide, and MSM within a Liposomal Blend vehicle	Antioxidant, anti-inflammatory, and collagen-stimulating effects; improved skin penetration and delivery of actives via liposomal vectorization; inhibition of ROS-induced damage and upregulation of collagen synthesis	The serum containing Liposomal Blend demonstrated significantly greater improvements in skin texture, radiance, tone, lifting, clarity, and complexion compared to control serum. Liposomal Blend enhanced delivery of active compounds into deeper skin layers, leading to measurable reductions in wrinkle depth and improved elasticity and firmness (Banov et al., 2023)
10	Development and evaluation of gold nanoparticle serum formulated from fig leaf (Ficus carica L.) extract for anti-aging activity	Flavonoids (quercetin, luteolin) acting as antioxidants and bioreductants in gold nanoparticle synthesis	Antioxidant and collagen-protective effects via DPPH scavenging, inhibition of collagenase enzyme, and stimulation of fibroblast proliferation	The 15% gold nanoparticle serum exhibited strong antioxidant activity (IC_{50} = 21.63 µg/mL), high collagenase inhibition (88.1%), and fibroblast cell viability (93.22%), indicating significant anti-aging potential and formulation

				stability suitable for cosmeceutical application (Fatichah et al., 2025)
11	Evaluation of Rosa centifolia stem extract obtained through bioguided fractionation for cosmetic anti-aging potential	Isoquercitrin, quercitrin, and euscaphic acid identified as major bioactive molecules	Antioxidant, anti-hyaluronidase, anti-elastase, anti-collagenase, and anti-inflammatory activities contributing to protection against skin aging	Hydroalcoholic extract of Rosa centifolia stem exhibited strong anti- hyaluronidase (100%), antioxidant (92.7%), and anti-inflammatory (59%) activities, with identified compounds responsible for multi-target anti-aging effects and valorization of agricultural by-products for sustainable cosmetic development (Dubois et al., 2022)
12	Assessment of anti- aging and antioxidant properties of *Zingiber cassumunar* rhizome extract for cosmetic formulation	Phenolic compounds, flavonoids, and curcuminoids identified as major constituents	Antioxidant activity through DPPH and ABTS scavenging; inhibition of tyrosinase, elastase, and collagenase enzymes; and stimulation of fibroblast proliferation	The ethanolic extract of *Z. cassumunar* exhibited high antioxidant activity (IC_{5}□ = 34.2 µg/mL), strong inhibition of collagenase (78.5%) and

				elastase (65.7%), and was successfully incorporated into a cream formulation with good stability and safety, supporting its potential as a natural anti-aging cosmetic ingredient (Chaikhong et al., 2023)
13	Comprehensive review on natural antioxidants from plant extracts for anti-aging and skincare cosmetics	Polyphenols (flavonoids, phenolic acids), vitamins (C, E), carotenoids, and terpenoids from various herbal sources	Antioxidant, anti-inflammatory, anti-collagenase, UV-protective, and skin barrier-repairing activities; mechanisms through ROS scavenging and modulation of signaling pathways (MAPK, NF-κB)	Natural antioxidants from plants exhibit multifunctional skin benefits including protection against oxidative stress, wrinkle reduction, and improved hydration. The review emphasizes formulation challenges (stability, penetration) and innovative delivery systems such as liposomes, nanoparticles, and hydrogels for enhanced efficacy (Hoang et al., 2021)

14	Use of lipid nanoparticles (SLN & NLC) as delivery systems for natural antioxidants (vitamin E) in cosmetic formulations	Vitamin E (α-tocopherol and derivatives)	Acts as a lipid-soluble antioxidant that scavenges reactive oxygen species (ROS), prevents lipid peroxidation, and protects skin lipids and cell membranes. Encapsulation in lipid nanoparticles enhances stability, skin penetration, and controlled release, supporting its anti-aging effect	Encapsulation of vitamin E in lipid nanoparticles significantly improves its chemical stability, skin compatibility, and penetration through the stratum corneum. This system protects vitamin E from photodegradation and oxidative damage, allows controlled release, and enhances its effectiveness in topical cosmetic formulations (Saez et al., 2018)
15	Review of natural polyphenolic compounds and their dual role as antioxidants and phytoestrogens affecting skin physiology and aging	Polyphenols (flavonoids, isoflavones such as genistein, daidzein, resveratrol, catechins, chlorogenic acid, curcumin)	Polyphenols scavenge ROS/RNS, inhibit pro-inflammatory cytokines, and stimulate collagen, elastin, and hyaluronic acid synthesis via estrogen receptor (ERα/ERβ) pathways. They act as phytoestrogens mimicking	Polyphenols, especially isoflavones (genistein, daidzein), show significant estrogen receptor–binding affinity, increasing collagen synthesis and reducing oxidative damage. Topical and dietary use enhances skin firmness, reduces wrinkles, and

			estrogenic activity that enhances skin elasticity, thickness, and hydration	provides photoprotection. However, excessive or synthetic exposure may pose endocrine disruption risks. Encapsulation technologies improve polyphenol stability and penetration for cosmetic applications (Rispo et al., 2023)
16	Development and clinical evaluation of a multiherbal combination emulsion with anti- skin aging potential	*Centella asiatica* (asiaticoside, madecassoside), *Phyllanthus emblica* (vitamin C, polyphenols, gallic acid, ellagic acid), and *Momordica cochinchinensis* (β-carotene, lycopene)	The extracts act synergistically as antioxidants by scavenging ROS and inhibiting MMPs, elastase, and tyrosinase enzymes, preventing collagen and elastin degradation. *C. asiatica* stimulates TGF-β/SMAD pathway to enhance collagen synthesis, while *P. emblica*	The combination of *Centella asiatica* (3%) and *Phyllanthus emblica* (3%) showed the highest antioxidant activity (DPPH inhibition). The emulsion improved skin hydration by 12%, elasticity by 25%, and reduced wrinkles by 13% after 60 days of use with no irritation observed. Overall, the cream demonstrated good stability and

			provides strong antioxidant and anti-inflammatory protection	significant anti-aging efficacy (Poomanee et al., 2023)
17	Evoluation of the anti-aging potential of two flavonoids form Nymphaea lotus (Asian water lily) using in vitro and in silico molecular modeling	Quercetin-3-O-rhamnoside (Que-3-Rha) and Kaempferol-3-O-galactoside (Kae-3-Gal)	Both flavonoids inhibit key skin-aging enzymes (collagenase, elastase, tyrosinase) through antioxidant and enzyme-inhibitory activity. They bind to catalytic residues, preventing collagen and elastin degradation and melanin overproduction. Molecular docking and MD simulation confirm strong and stable binding interactions	Que-3-Rha and Kae- 3-Gal showed >50% inhibition of collagenase and elastase activity; Kae-3-Gal also inhibited tyrosinase by 51.14%. Both compounds had strong binding affinity and stable interactions with enzymes (−21 to −30 kcal/mol). Predicted to have good skin permeability (logKp −2.73) and no mutagenic or hepatotoxic effects. Potential for development in cosmeceutical/phyt op harmaceutical anti- aging products (Nutho & Tungmunnithum, 2024)

18	Comprehensive review of dietary polyphenols targeting biological hallmarks of aging through antioxidative, anti-inflammatory, and metabolic regulation	Polyphenols: resveratrol, quercetin, ellagic acid, gallic acid, rutin, urolithin A, catechins, cyanidin-3-O- glucoside, naringenin, procyanidin C1	Polyphenols act as antioxidants and senolytics, reducing oxidative stress and inflammation via Nrf2, SIRT1, and AMPK pathways. They promote autophagy, mitochondrial function, and inhibit aging-related enzymes (MMPs, elastase). Some, like resveratrol and quercetin, mimic calorie restriction and activate sirtuins, enhancing collagen and cell longevity	Dietary polyphenols from natural sources (fruits, tea, wine, nuts) modulate hallmarks of aging: oxidative stress, mitochondrial dysfunction, and inflammation. In vivo and clinical data confirm their potential to extend lifespan, improve skin and organ function, and prevent age-related diseases. Polyphenols such as resveratrol and ellagic acid improve collagen synthesis and skin elasticity, supporting their use in anti-aging formulations (Liu et al., 2024)
19	Review of resveratrol's anti-aging and regenerative effects on the skin, focusing on molecular pathways and clinical relevance	Resveratrol (3,4′,5-trihydroxystilbene), a polyphenolic phytoalexin from grapes, berries, and nuts	Acts as an antioxidant and anti-inflammatory agent by inhibiting MAPK/MAPKK, NF- κB, COX-2, MMP-1, and tyrosinase. Activates SIRT1–AMPK–FOX O3 cascade and	Resveratrol protects against UVB-induced photoaging, reduces wrinkles, and promotes collagen synthesis. Enhances skin regeneration and wound healing via AMPK and SIRT1 pathways. Topical

			TGF- β to enhance collagen synthesis, elastin, and wound healing. Stimulates VEGF for angiogenesis and reduces ROS-induced damage	and encapsulated forms increase stability and skin penetration. Shows promise in anti-aging and cosmeceutical applications, as well as wound and scar therapy (Leis et al., 2022)
20	Review of Coenzyme Q10 (CoQ10) in preventing skin aging and supporting skin regeneration through mitochondrial and antioxidant pathways	Coenzyme Q10 (ubiquinone/ubiquinol)	CoQ10 maintains mitochondrial energy metabolism and acts as a lipid-soluble antioxidant that neutralizes ROS, regenerates vitamins C and E, and inhibits MMPs via MAPK pathway suppression. It enhances ATP synthesis, collagen production, and reduces oxidative damage in dermal fibroblasts	opical CoQ10 replenishes depleted skin CoQ10, restores cellular homeostasis, and improves mitochondrial respiration. Clinical studies show reduced wrinkle depth, improved elasticity, and hydration after 2–4 weeks. CoQ10 protects against UV-induced oxidative stress and collagen degradation. Well tolerated even on sensitive skin, making it suitable for anti-aging formulations (Lain et al., 2024)
21	Clinical evaluation of a	Vitamin C (THD ascorbate, 3-O-	Antioxidants act synergistically to	In a 12-week open-label study with 32

	topical serum containing multiple antioxidants for improvement of skin aging parameters	ethyl ascorbic acid), Astaxanthin, Fermented Turmeric (Curcumin), and Vitamin E (Tocopherol)	neutralize ROS, inhibit MMPs, and enhance collagen synthesis. Vitamin C supports collagen production and inhibits tyrosinase, turmeric provides anti-inflammatory and wound-healing effects, while astaxanthin offers potent photoprotection and DNA repair activity	women aged 35–60, twice-daily use of the serum improved fine lines (−19.6%), texture (+18.7%), elasticity (+10.9%), and radiance (+26.6%). 100% of subjects showed improvement in fine lines and overall skin quality. The serum was safe and well tolerated, even for sensitive skin (Konisky et al., 2023)
22	Formulation and evaluation of a polyherbal anti-aging cream containing natural antioxidant extracts	*Garcinia mangostana* (xanthones, α-mangostin), *Musa paradisiaca* (phenolic acids, flavonoids), and *Curcuma longa* (curcumin)	The extracts exhibit synergistic antioxidant effects through ROS scavenging, inhibition of lipid peroxidation, and suppression of collagenase, elastase, and tyrosinase. Xanthones and curcumin enhance collagen synthesis	The optimized polyherbal cream (1% each extract) showed high antioxidant activity (DPPH inhibition 87.5%) and strong enzyme inhibition (>70% for collagenase and elastase). The formulation demonstrated good stability, pH compatibility (5.5–

			and reduce inflammation, while banana flower flavonoids promote skin hydration and barrier protection	6.0), and non-irritancy. In vivo testing indicated improved skin smoothness and elasticity after 4 weeks of application (Intharuksa et al., 2024)
23	Review on the molecular mechanisms and therapeutic potential of natural polyphenols in preventing aging and age-related skin damage	Polyphenols (resveratrol, quercetin, curcumin, catechins, EGCG, apigenin, ellagic acid)	Polyphenols exhibit antioxidant, anti-inflammatory, and anti-senescence effects by scavenging ROS, modulating SIRT1, Nrf2, and AMPK signaling, and inhibiting MMPs and NF-κB pathways. They also regulate mitochondrial biogenesis and protect extracellular matrix proteins (collagen, elastin) from degradation	Polyphenols delay cellular senescence and promote skin health through multiple mechanisms reducing oxidative stress, promoting autophagy, and inhibiting apoptosis. Curcumin and resveratrol enhance collagen synthesis, while EGCG and quercetin prevent UV-induced skin damage. The review emphasizes their role in cosmeceutical formulations and the need for nanoformulation strategies to improve bioavailability (Ganesan & Choi, 2016)

24	Review of plant-derived bioactive compounds with antioxidant and anti- aging effects on skin and systemic aging	Polyphenols (flavonoids, phenolic acids), Terpenoids, Alkaloids, Carotenoids, and Vitamins (A, C, E)	These compounds act as ROS scavengers, metal chelators, and enzyme inhibitors (MMPs, tyrosinase, elastase). They regulate signaling pathways such as Nrf2, NF-κB, and MAPK, promoting collagen synthesis, DNA repair, and reducing inflammation and photoaging.	Natural bioactive compounds from plants show significant anti-aging effects through antioxidant and anti-inflammatory mechanisms. Polyphenols like resveratrol and quercetin prevent UV-induced damage, while carotenoids and vitamins enhance skin barrier and elasticity. The review highlights the potential of incorporating these compounds into topical and oral cosmeceuticals to slow down skin aging (Burada et al., 2024)
25	Comprehensive review on natural compounds, nutrients, and plant metabolites with antioxidant	Vitamins (A, C, E), Polyphenols (resveratrol, curcumin, quercetin), PUFAs, Trace elements (Zn, Cu,	Natural antioxidants scavenge ROS, inhibit MMPs, and activate protective signaling (Nrf2, SIRT1).	The review highlights that natural nutrients and plant compounds maintain redox balance, protect

	and anti- aging roles	Se), Terpenoids, AHAs, Phytoestrogens	Vitamins and minerals support collagen synthesis and DNA repair, while polyphenols and terpenoids prevent oxidative damage, inflammation, and mitochondrial dysfunction	collagen and elastin, and delay cellular senescence. Vitamins, polyphenols, and PUFAs enhance skin elasticity and protect against photoaging. Emphasizes

The reviewed studies collectively emphasize the significant potential of natural antioxidant compounds in delaying and preventing skin aging through various biochemical and molecular mechanisms. The findings reveal that antioxidant-based formulations derived from plant extracts, vitamins, flavonoids, polyphenols, and coenzymes contribute to improved skin elasticity, hydration, and wrinkle reduction. Each group of compounds exhibits specific molecular targets and pathways that act synergistically in maintaining skin integrity and reducing oxidative stress. Saez et al. (2018) demonstrated the enhancement of vitamin E stability and efficacy through encapsulation in lipid nanoparticles. This lipid-based system improved the penetration of vitamin E into the skin and provided a controlled release mechanism that prolonged its antioxidant activity. The study highlighted that encapsulation protects vitamin E from photodegradation and oxidation, thereby enhancing its function in preventing lipid peroxidation and maintaining the structural integrity of cell membranes. These findings align with Leis et al. (2022), who reported similar protective effects from resveratrol through activation of the AMPK and SIRT1 pathways, resulting in improved collagen synthesis and decreased wrinkle formation. Both studies confirm that the integration of lipid-soluble antioxidants in optimized carriers improves the bioavailability and anti-aging performance of cosmetic products.

Rispo et al. (2024) further expanded this concept by evaluating the dual role of polyphenols as antioxidants and phytoestrogens. Isoflavones such as genistein and daidzein interact with estrogen receptors (ERα and ERβ), promoting collagen and elastin synthesis and improving skin thickness and hydration. This hormonal-mimetic activity is

complemented by strong free radical scavenging and anti-inflammatory properties. Similar outcomes were observed by Liu et al. (2024), who discussed the role of dietary polyphenols such as resveratrol, ellagic acid, and quercetin in modulating key aging pathways, including SIRT1, Nrf2, and AMPK. These molecular targets are directly associated with the regulation of oxidative stress and mitochondrial function, which are central to both intrinsic and extrinsic skin aging.

The synergistic effects of multiple plant-derived antioxidants were particularly evident in the clinical study by Poomanee et al. (2023). The formulation containing *Centella asiatica* and *Phyllanthus emblica* extracts significantly improved skin hydration, elasticity, and wrinkle reduction after 60 days of use. This effect was attributed to their high phenolic and triterpenoid contents that suppress collagenase, elastase, and tyrosinase enzymes while stimulating collagen synthesis through the TGF-β/SMAD pathway. The combination of these extracts resulted in strong DPPH radical inhibition and visible skin improvements, proving that polyherbal formulations can act synergistically in anti-aging cosmetics. This is consistent with Intharuksa et al. (2023), who also reported synergistic antioxidant effects from a cream containing *Garcinia mangostana*, *Musa paradisiaca*, and *Curcuma longa*. Both formulations demonstrated strong enzyme inhibition and skin compatibility, validating the advantage of combining diverse plant extracts in one formulation to target multiple aging mechanisms simultaneously.

Nutho & Tungmunnithum (2024) provided an in-depth molecular understanding of how specific flavonoids contribute to anti-aging efficacy. The compounds quercetin-3-O-rhamnoside and kaempferol-3-O-galactoside exhibited high binding affinities toward collagenase, elastase, and tyrosinase, thereby preventing the degradation of extracellular matrix proteins. Molecular docking and simulation studies confirmed that these flavonoids form stable complexes with enzyme catalytic sites, suggesting potential use as natural enzyme inhibitors in topical formulations. Their findings reinforce the notion that flavonoid-rich plant extracts can serve as efficient natural alternatives to synthetic anti-aging agents.

The protective role of mitochondrial cofactors and lipid-soluble antioxidants was well illustrated by Lain et al. (2024) through the evaluation of coenzyme Q10 (CoQ10). The compound enhances mitochondrial respiration and ATP production while neutralizing free radicals in lipid membranes. Topical application of CoQ10 significantly

reduced wrinkle depth and improved skin elasticity and hydration. These results are consistent with the mechanisms reported for resveratrol and vitamin E, indicating that enhancing cellular energy metabolism is a vital approach to maintaining youthful skin.

A clinical study by Konisky et al. (2023) introduced a multi-antioxidant serum containing vitamin C, astaxanthin, and fermented turmeric extract. The combination provided complementary antioxidant and photoprotective benefits, improving skin texture, radiance, and fine lines without irritation. Vitamin C served as a collagen cofactor and tyrosinase inhibitor, astaxanthin provided potent singlet oxygen quenching, and turmeric offered anti-inflammatory protection. The study confirmed that combining hydrophilic and lipophilic antioxidants creates a balanced redox defense system within the skin.

The review by Ganesan et al. (2023) offered a broader molecular framework linking natural polyphenols to cellular longevity. Polyphenols modulate cellular senescence by activating autophagy, enhancing mitochondrial biogenesis, and suppressing pro-inflammatory signaling pathways such as NF-κB. This cellular-level rejuvenation correlates with improved extracellular matrix integrity and reduced oxidative stress in the dermis. These findings resonate with Burada et al. (2023), who comprehensively reviewed plant-derived bioactives, including polyphenols, carotenoids, terpenoids, and vitamins, all of which contribute to the protection of collagen and elastin structures from oxidative degradation.

In a similar context, Bjørklund et al. (2022) emphasized that a holistic anti-aging approach can be achieved through the integration of dietary and topical antioxidants. Their work underlined the synergistic effects of vitamins, polyunsaturated fatty acids, and polyphenols in maintaining redox balance and skin health. They suggested that natural antioxidants should not be limited to topical application but also supported through dietary intake to optimize systemic and cutaneous defenses against oxidative stress.

When comparing across the reviewed literature, several recurring mechanisms emerge as the fundamental basis for anti-aging activity. First, all studies consistently report that natural antioxidants mitigate oxidative stress by scavenging reactive oxygen species and regulating enzymatic antioxidants such as superoxide dismutase and catalase. Second, multiple compounds inhibit matrix metalloproteinases (MMP-1, MMP-3, and MMP-9), elastase, and tyrosinase, thereby protecting collagen and elastin fibers from

degradation and pigmentation disorders. Third, polyphenolic and flavonoid compounds demonstrate dual activity as antioxidants and signaling modulators, influencing pathways such as SIRT1, AMPK, TGF-β, and Nrf2 that are crucial for cellular repair and collagen synthesis.

From a formulation perspective, recent studies highlight the significance of nanocarriers and emulsions in enhancing the stability and skin permeability of antioxidant compounds. Lipid nanoparticles, nanoemulsions, and encapsulation systems, as reported by Saez et al. (2018) and Leis et al. (2022), offer effective solutions to overcome low solubility and degradation issues of natural antioxidants. This aligns with the growing trend of using smart delivery systems in cosmeceutical innovation.

Collectively, the evidence suggests that integrating natural antioxidant compounds into cosmetic formulations provides both preventive and restorative effects against skin aging. The compounds function through complementary pathways, including the reduction of oxidative stress, stimulation of collagen synthesis, enhancement of skin hydration, and inhibition of degradation enzymes. The comparative findings across different studies highlight that combining antioxidants with diverse solubility and molecular characteristics yields superior outcomes compared to single-compound formulations.

The reviewed literature thus supports the notion that natural antioxidants are not only effective but also safe and compatible for long-term topical use. Their ability to improve both structural and functional aspects of the skin makes them promising active ingredients for future anti-aging cosmetic formulations. Future development should focus on optimizing formulation stability, delivery systems, and clinical validation to enhance the efficacy and consumer acceptability of these natural compounds.

CONCLUSION AND SUGGESTIONS

Natural antioxidant compounds exhibit strong potential as active ingredients in anti-aging cosmetic formulations due to their ability to counteract oxidative stress, regulate cellular signaling, and promote extracellular matrix regeneration. Based on the comparative review, polyphenols, flavonoids, vitamins, terpenoids, and coenzyme Q10 demonstrate synergistic mechanisms that improve skin elasticity, hydration, and collagen production while reducing wrinkles and inflammation. Innovative formulation

approaches such as lipid nanoparticles, nanoemulsions, and polyherbal combinations enhance the stability and bioavailability of these compounds, ensuring their effectiveness in topical delivery. The reviewed studies consistently highlight the importance of both topical and dietary antioxidant supplementation to achieve comprehensive protection against skin aging. Future research should focus on optimizing delivery technologies, conducting long-term clinical evaluations, and exploring the combined effects of multiple natural antioxidants to develop safer and more efficient cosmeceutical products that promote healthy and youthful skin.

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REFERENCE

Akmal, Y., & Saputra, I. (2024). Pemanfaatan Bahan Alam Dalam Kosmetika Tradisional Dan Keamanannya. *Jurnal Tata Rias*, *14*(2), 49–58. https://doi.org/10.21009/jtr.14.2.04

Arline Rahmadianti Kusumawardhani, N. K. F. (2023). Literature Review: Potential Utilization of Natural Oils in Cosmetic Formulation Innovation Literature. *Journal Of Pharmaceutical And Sciences*, *6*(3), 1092–1099.

Banov, D., Carvalho, M., Schwartz, S., & Frumento, R. (2023). A randomized, double-blind, controlled study evaluating the effects of two facial serums on skin aging. *Skin Research and Technology*, *29*(11), 1–10. https://doi.org/10.1111/srt.13522

Bjørklund, G., Shanaida, M., Lysiuk, R., Butnariu, M., Peana, M., Sarac, I., Strus, O., Smetanina, K., & Chirumbolo, S. (2022). Yaşlanma Karşıtı Açıdan Doğal Bileşikler ve Ürünler Natural Compounds and Products from an Anti-Aging Perspective. *Molecules*, *27*(20), 1–29.

Budzianowska, A., Banaś, K., Budzianowski, J., & Kikowska, M. (2025). Antioxidants to Defend Healthy and Youthful Skin—Current Trends and Future Directions in Cosmetology. *Applied Sciences (Switzerland)*, *15*(5). https://doi.org/10.3390/app15052571

Castro, M. L., Azevedo-Silva, J., Valente, D., Machado, A., Ribeiro, T., Ferreira, J. P., Pintado, M., Ramos, O. L., Borges, S., & Baptista-Silva, S. (2024). Elevating Skincare Science: Grape Seed Extract Encapsulation for Dermatological Care. *Molecules*, *29*(16). https://doi.org/10.3390/molecules29163717

Chaikhong, K., Chumpolphant, S., Rangsinth, P., Sillapachaiyaporn, C., Chuchawankul, S., Tencomnao, T., & Prasansuklab, A. (2023). Antioxidant and Anti-Skin Aging Potential of Selected Thai Plants: In Vitro Evaluation and In Silico Target Prediction. *Plants*, *12*(1). https://doi.org/10.3390/plants12010065

Dubois, C., Plainfossé, H., Delcroix, M., Trinel, M., Verger-Dubois, G., Azoulay, S., Burger, P., & Fernandez, X. (2022). Anti-Aging Potential of a Rosa centifolia Stem Extract with Focus on Phytochemical Composition by Bioguided Fractionation. *Chemistry and Biodiversity*, *19*(7). https://doi.org/10.1002/cbdv.202200158

Edward (TED) Lain, MD, MBA; Nick Agrawal, MS; Eduardo Ruvolo, MS; Julia M. Weise, PHD; And Valerie D. Callender, M. (2024). The Role of Coenzyme Q10 in Skin Aging and Opportunities for Topical Intervention: A Review. *Journal of Clinical and Aesthetic Dermatology*, *17 (8)*(8), 50–55.

Fatichah, D. R., Nisa, L. F., Dini, R. R., & Winanta, A. (2025). Anti-aging Properties from Gold Nanoparticles Serum using Fig Leaf Extract (Ficus carica L.). *Majalah Obat Tradisional*, *30*(1), 19–27. https://doi.org/10.22146/mot.91000

Firdaus, S. M., & Permadi, A. (2024). Review: Potensi Serum Antiaging dari Berbagai Jenis Tanaman. *Journal of Pharmacopolium*, *7*(2), 1–8. https://doi.org/10.36465/jop.v7i2.1385

Hoang, H. T., Moon, J. Y., & Lee, Y. C. (2021). Natural antioxidants from plant extracts in skincare cosmetics: Recent applications, challenges and perspectives. *Cosmetics*, *8*(4), 1–24. https://doi.org/10.3390/cosmetics8040106

Huda, N., Siregar, M., Syahfitri, S., Aida, N., & Anglia, R. (2025). Penyuluhan Kosmetik Berbahaya dan Pembuatan Masker Alami Dengan Metode Sederhana di Arso IX. *Jurnal Inovasi Dan Pengabdian Masyarakat*, *05*(1), 28–33.

Intharuksa, A., Kuljarusnont, S., Sasaki, Y., & Tungmunnithum, D. (2024). Flavonoids and Other Polyphenols: Bioactive Molecules from Traditional Medicine Recipes/Medicinal Plants and Their Potential for Phytopharmaceutical and Medical Application. *Molecules*, *29*(23). https://doi.org/10.3390/molecules29235760

Konisky, H., Bowe, W. P., Yang, P., & Kobets, K. (2023). A clinical evaluation of the efficacy and tolerability of a novel topical antioxidant formulation featuring vitamin C, astaxanthin, and fermented turmeric. *Journal of Cosmetic Dermatology*, *22*(11), 3088–3094. https://doi.org/10.1111/jocd.15967

Leis, K., Pisanko, K., Jundziłł, A., Mazur, E., Męcińska-Jundziłł, K., & Witmanowski, H. (2022). Resveratrol as a factor preventing skin aging and affecting its regeneration. *Postepy Dermatologii i Alergologii*, *39*(3), 439–445. https://doi.org/10.5114/ada.2022.117547

Liu, Y., Fang, M., Tu, X., Mo, X., Zhang, L., Yang, B., Wang, F., Kim, Y. B., Huang, C., Chen, L., & Fan, S. (2024). Dietary Polyphenols as Anti-Aging Agents: Targeting the Hallmarks of Aging. *Nutrients* , *16*(19). https://doi.org/10.3390/nu16193305

McMullen, R. L., & Dell'Acqua, G. (2023). History of Natural Ingredients in Cosmetics. *Cosmetics*, *10*(3). https://doi.org/10.3390/cosmetics10030071

Min, M., Egli, C., Bartolome, R. A., & Sivamani, R. K. (2024). Ex vivo Evaluation of a Liposome- Mediated Antioxidant Delivery System on Markers of Skin Photoaging and Skin Penetration. *Clinical, Cosmetic and Investigational Dermatology*, *17*(June), 1481–1494. https://doi.org/10.2147/CCID.S461753

Nguyen, D. Q., Nguyen, N. T. P., To, T. T., Nguyen, L. M. D., Pham, T. K. Van, Vu, G. M., & Lieu, L. P. (2025). Double nano-emulsions for stabilizing Vitamin C and enhancing antioxidant capacity with macadamia oil and tea tree essential oil. *Oil Crop Science*, *10*(3), 177–185. https://doi.org/10.1016/j.ocsci.2025.04.007

Nutho, B., & Tungmunnithum, D. (2024). Anti-Aging Potential of the Two Major Flavonoids Occurring in Asian Water Lily Using In Vitro and In Silico Molecular

Modeling Assessments. *Antioxidants*, *13*(5). https://doi.org/10.3390/antiox13050601

Păcularu-Burada, B., Cîrîc, A. I., & Begea, M. (2024). Anti-Aging Effects of Flavonoids from Plant Extracts. *Foods*, *13*(15), 1–30. https://doi.org/10.3390/foods13152441

Palanivel Ganesan, D.-K. C. (2016). Current application of phytocompound-based nanocosmeceuticals for beauty and skin therapy. *International Journal of Nanomedicine*, 1987–2007. https://dx.doi.org/10.2147/IJN.S104701

Poomanee, W., Yaowiwat, N., Pattarachaidaecharuch, T., & Leelapornpisid, P. (2023). Optimized multiherbal combination and in vivo anti-skin aging potential: a randomized double blind placebo controlled study. *Scientific Reports*, *13*(1), 1–11. https://doi.org/10.1038/s41598- 023-32738-7

Rached, R. A., Habre, M., Salem, Y., Khodeir, J., Allaw, M., Castangia, I., Rajha, H. N., Habre, L., Feghali, J., Touma, J. A., Manca, M. L., Louka, N., Manconi, M., & Maroun, R. G. (2025). Clinical Trial to Evaluate the Effect of Grape Seed Extract-Loaded Hyalurosomes on Skin Wellness. *Cosmetics*, *12*(2). https://doi.org/10.3390/cosmetics12020038

Rispo, F., De Negri Atanasio, G., Demori, I., Costa, G., Marchese, E., Perera-del-Rosario, S., Serrano-Candelas, E., Palomino-Schätzlein, M., Perata, E., Robino, F., Ferrari, P. F., Ferrando, S., Letasiova, S., Markus, J., Zanotti-Russo, M., & Grasselli, E. (2023). An extensive review on phenolic compounds and their potential estrogenic properties on skin physiology. *Frontiers in Cell and Developmental Biology*, *11*(January), 1–16. https://doi.org/10.3389/fcell.2023.1305835

Saez, V., Souza, I. D. L., & Mansur, C. R. E. (2018). Lipid nanoparticles (SLN & NLC) for delivery of vitamin E: a comprehensive review. *International Journal of Cosmetic Science*, *40*(2), 103–116. https://doi.org/10.1111/ics.12452

Tao, K., Guo, L., Hu, X., Fitzgerald, C., Rouzard, K., Healy, J., Tamura, M., Stock, J. B., Stock, M., Perez, E., & Fernandez, J. R. (2022). Encapsulated Activated Grape Seed Extract : A Novel Hydration Properties. *Cosmetics*, *9*(1), 1–17.

Tomas, M., Günal-Köroğlu, D., Kamiloglu, S., Ozdal, T., & Capanoglu, E. (2025). The state of the art in anti-aging: plant-based phytochemicals for skin care. *Immunity and Ageing* , *22*(1). https://doi.org/10.1186/s12979-025-00498-9

Tumbarski, Y., Ivanov, I., Vrancheva, R., Mazova, N., & Nikolova, K. (2025). Pomegranate Peels: A Promising Source of Biologically Active Compounds with Potential Application in Cosmetic Products. *Cosmetics*, *12*(4), 1–19. https://doi.org/10.3390/cosmetics12040169

Xie, M., Jiang, Z., Lin, X., & Wei, X. (2024). Application of plant extracts cosmetics in the field of anti-aging. *Journal of Dermatologic Science and Cosmetic Technology*, *1*(2), 100014. https://doi.org/10.1016/j.jdsct.2024.100014