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Review

Synthetic to Natural Alternative for Antioxidants in Cosmetic

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	Abstract
Published on: 12 Sep 2025	<p>Antioxidants are crucial ingredients in cosmetic formulations because they shield the skin from environmental harm and stop ingredients from degrading oxidatively. Because of their efficacy and affordability, synthetic antioxidants including tert-butylhydroquinone (TBHQ), butylated hydroxyanisole (BHA), and butylated hydroxytoluene (BHT) have been used traditionally. However, as concerns about their potential toxicity, allergic reactions, and long-term impacts increase, there is now growing interest in natural alternatives. With an emphasis on plant-based substances like polyphenols, flavonoids, tannins, carotenoids, and natural vitamins, this review examines the transition in the cosmetics industry from synthetic to natural antioxidants. Green tea, turmeric, rosemary, pomegranate, and grape seed are among the botanicals that are emphasized for their skin-improving properties and antioxidant effectiveness. The article promotes a safer, more sustainable approach in cosmetic science by going over the mechanisms, benefits, and formulation challenges of using natural antioxidants.</p>
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Keywords: Antioxidants, Natural Antioxidants, Synthetic Antioxidants, Cosmetic Formulations, Green Tea, Pomegranate, Grape Seed Extract, Turmeric, Rosemary, Polyphenols, Flavonoids, Carotenoids, Anti-Aging, Free Radical Scavenging, Photoprotection, Skin Care.	

INTRODUCTION

The chemical compounds known as antioxidants stop oxidation of other molecules from damaging cells. Oxidation is a chemical reaction that transfers from one molecule to an oxidizing agent. Oxidation reaction are known to produce free radicals. The free radical receives an electron from antioxidants, which then transform it into a harmless molecule. They suppress radical formation and reduce the energy of the free radical, break chain propagation, repair damage[1]. The pharmaceutical industry is very interested in antioxidants compounds. Because of their properties, antioxidants can be included in cosmetic preparation because of the activity against the free radicals.

Synthetic antioxidants are currently on the market, synthetic antioxidants are substances that are created chemically to stop lipid oxidation. A number of synthetic antioxidants have been used to stabilize fats and oils[2] their use has been limited due to their negative health effects, Additionally, synthetic antioxidants are moderately active and poorly soluble.[3], pose a potential health risk due to formation of hazardous by products, contamination with chemical precursors and toxic solvents[4]. Natural antioxidants are now preferred over synthetic antioxidants in cosmetics. Extracts of plant-derived antioxidants generally contain a mixture of natural compounds, which could have synergetic effects, therefore, they can have better effects and less toxicity[5]. Food and medical plants, including fruits, vegetables, cereals, flowers, spices, mushrooms, drinks, and traditional medicinal herbs, are the primary sources of exogenous antioxidants. Natural antioxidants from plants materials are carotenoids (xanthophyllus and carotenes), polyphenols (phenolic acids, flavonoids, anthocyanins, lignans and stilbenes), vitamins (vitamin E,C)[6].

CLASSIFICATION OF ANTIOXIDANTS

1. SYNTHETIC ANTIOXIDANTS

- PHENOLIC DERIVATIVES
 - BHA (Butylated hydroxyanisole)
 - BHT (Butylated hydroxytoluene)
 - TBHQ (Tert-butylhydroquinone)
- GALLATES
 - Propyl gallate
 - Octyl gallate
- OTHER SYTHETIC AGENTS
 - EDTA
 - Synthec Vitamin E (DL-alpha-tocopherol acetate)

2. NATURAL ANTIOXIDANTS

- PLANT-BASED
 - Vitamin C
 - Vitamin E
 - Polyphenols (Flavonoids, Tannins,phenolic acids,lignans and others)
 - Carotenoids (Beta-carotene,Lycopene)
 - Curcumin
 - Essential oils (Eugenol,Carosenic acid)
- ANIMAL-BASED
 - Glutathione
 - Superdioxide dismutase(SOD)
 - Catalase
- MICROBIAL-BASED
 - Antioxidant pepotides
 - Exopolysaccharides[7].

SYNTHETIC ANTIOXIDANTS IN COSMETICS

Synthetic antioxidants are widely used in cosmetic formulations to stabilize oils and fats, avoid rancidity, and extend product shelf life. Butylated Hydroxyanisole (BHA), a phenolic compound that works by scavenging free radicals and preventing lipid oxidation, is one of the most popular synthetic antioxidants. Notwithstanding its efficacy, BHA has sparked serious health concerns, such as the possibility of endocrine disruption and the carcinogenicity of high dosages, as shown in rodent studies. Butylated Hydroxytoluene (BHT), which shares structural similarities with BHA, is another frequently used antioxidant[8].

It is preferred because of its stability and ability to stop oxidative deterioration in lotions and creams. In animal studies, BHT has also been connected to hepatic and renal toxicity, and extended exposure to it may irritate the skin[9]. Another artificial antioxidant used in the food and cosmetics industries is propyl gallate, which is an ester of gallic acid. It works especially well to stop unsaturated fatty acids in cosmetic emulsions from oxidizing[10]. It is a known contact allergen, though, and some people may experience hypersensitivity reactions. Tertiary butylhydroquinone (TBHQ) is a strong antioxidant that is usually found in food but is also infrequently found in cosmetics. Despite its effectiveness, TBHQ has sparked worries because of its links to DNA damage, cytotoxicity, and possible cancerous effects[11].

Synthetic tocopherol, also known as vitamin E, is also commonly used in formulations as a skin conditioner and antioxidant. Tocopherols are generally thought to be safe, but their safety profile may be compromised by synthetic forms that contain impurities added during chemical synthesis. All things considered, synthetic antioxidants work well, but because of their possible toxicological hazards, there is now more demand for safer, natural substitutes in cosmetics[12].

NATURAL ANTIOXIDANTS AS ALTERNATIVES

Plants were the main source of all cosmetics prior to the use of synthetic substances with similar properties. Natural antioxidants can be a single pure compound or isolate, a mixture of compounds, or plant extracts. These antioxidants are widely used in cosmetic products[13]. Natural antioxidant sources, which are more affordable and in closer proximity to nature. These discoveries will provide a better alternative to artificial supplements in the food, pharmaceutical, and cosmetic sectors. Commonly consumed fruits, vegetables, herbs, spices, and edible mushrooms are examples of natural sources. The list of these natural sources also includes marine sources like seagrass and algae. A class of low- and high-molecular-weight compounds with antioxidant qualities that stop lipid oxidation, polyphenols are found in fruits and vegetables. Teas, especially green and red teas, and fruits like grapes are good sources of this important class of natural antioxidants[14].

Cereals, oilseeds, Lamiaceae plants, coffee, tea, legumes, tree nuts, berries, and fruits are the main sources of natural antioxidants. Whether plant materials contain antioxidants or whether the antioxidant activity of the extracts is impacted depends on the amount of phenolic compounds present in the extracts or plants [15]. By reacting with lipid and peroxy radicals and changing them into more stable, non-radical products, antioxidants can prevent lipid oxidation. Antioxidants can also dissipate UV light, remove peroxidative metal ions, deplete molecular oxygen, inactivate singlet oxygen, and convert hydrogen into other antioxidants. Because ROS production is changed during tumorigenesis, antioxidants can be used to treat cancer because they have antimicrobial and anti-inflammatory properties. It is commonly known that plants produce natural antioxidant compounds that can lessen the amount of oxidative stress brought on by oxygen and sunlight. Plant extracts are used in several commercial cosmetic goods and patents. Plant extracts are used in several commercial cosmetic goods and patents.. Plant extracts such as milk thistle, acerola seed, pine wood, blueberries, tomatoes, green tea, rosemary, and grape and basil seeds are commonly utilized in cosmetic compositions. Plant extracts (including carotenoids and essential oils) contain natural antioxidants called polyphenols, flavonoids, flavanols, stilbenes, and terpenes[16].

GREEN TEA (CAMELLIA SINENSIS)



Fig 1: Green tea [17]

BOTANICAL NAME: *Camellia sinensis*.

FAMILY: Theaceae.

GEOGRAPHICAL SOURCE

Originated in southeast china, now widely cultivated in, India, sri lanka, Assam, Darleeling, Japan, Vietnam and Kenya. [18]

ANTIOXIDANT CAPACITY

Green tea leaves had a total antioxidant activity of 660.75 mmol-eqv./mres.determined using a photometric technique [19].

ACTIVE ANTIOXIDANT COMPOUND

Green tea has greater concentrations of polyphenoles, also contain catechins called epigallocatechingallate (EGCG), Epicatechin (EC), epigallocatechine(EGC), epicatechingallate (ECG) Flavonoids like quercetin,

Myricetin and kaempferol as well as Tannins, alkaloids (Caffeine, Theobromine, Theophylline, Amino acid, phenolic acids, vitamin C and E, Chlorophyll, carotenoids[20]

MECHANISM OF ACTION

Increased activity of antioxidant enzymes, inhibition of lipid peroxidation, scavenging of free radicals in conjunction with other nutrients, and reduction of oxidation through metal ion chelation are some of the processes through which polyphenols produce antioxidant effects. Phenolic chemicals work as antioxidants through a single electron transfer via protons or a transfer based on hydrogen atoms. [21]

COSMETIC USES

Skin microcirculation, anti-inflammatory, anti-oxidant, slimming, blood vessel sealing, photoprotective, anticellulite, and anti-aging qualities. [22]

POMEGRANATE



Fig 2: Pomegranate [23]

BOTANICAL NAME: *Punica granatum*.

FAMILY: punicaceae.

GEOGRAPHICAL SOURCE

Originating in Iran, the pomegranate plant is grown throughout the Near and East Asia region, China, India, Tunisia, Turkey, Spain, Egypt, and Morocco[24].

ANTIOXIDANT ACTIVITY

The methanol extract of peels showed 83 and 81% antioxidant activity at 50 ppm, respectively, using the β -carotene-linoleate and DPPH model systems. Similarly, the methanol extract of seeds showed 22.6 and 23.2% antioxidant activity at 100 ppm, respectively, using the β -carotene-linoleate and DPPH model systems [25].

ACTIVE ANTIOXIDANT COMPOUND:

The primary Polyphenolic compounds with well-known antioxidant qualities include Anthocyanins (delphinidin, cyaniding, pelargonidin), Flavonols (quercetin, kaempferol), Leucoanthocyanidins, Proanthocyanidins, Hydroxybenzoic and Hydroxycinnamic acids, and condensed and Hydrolyzable Tannins (gallotannins, ellagitannins, Vitamin c, Ellagic acid, Catechin, Pedunculagin, α and β punicalagin, α and β punicalin, gallagic acid, ellagic acid, and Garantin A and B [26].

MECHANISM OF ACTION

Pomegranate uses a variety of methods to produce its antioxidant benefits. First, it reduces oxidative stress by acting as a free radical scavenger, where substances like ellagic acid and punicalagin donate hydrogen atoms or electrons to neutralize reactive oxygen species (ROS). Second, through their ability to bind pro-oxidant metal ions like iron (Fe^{2+}) and copper (Cu^{2+}), pomegranate polyphenols have metal chelating activity. This helps stop the production of dangerous hydroxyl radicals through Fenton-type reactions. Pomegranates also strengthen the body's defenses by activating the Nrf2 signaling pathway, which in turn upregulates endogenous antioxidant enzymes like glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase (SOD). By blocking oxidative enzymes involved in the production of ROS, such as cyclooxygenase (COX), lipoxygenase (LOX), and xanthine oxidase, it also promotes oxidative balance. Finally, by inhibiting NF- κ B activation, pomegranates also exhibit anti-inflammatory properties, lowering oxidative damage brought on by inflammation and shielding cells from aging and illness[27].

USES

Aids healing wounds, analgesic, anti-bacterial properties, anti-inflammatory, anti-fungal effect, treatment of UV-induced hyperpigmentation, decreased skin elasticity and skin wrinkling, skin whitening and anti-aging[28].

GRAPE SEED EXTRACT



Fig 3: Grape seed extract [29]

BOTANICAL NAME: *Vitis vinifera*

FAMILY: Vitaceae.

GEOGRAPHICAL SOURCE

Originated in the Mediterranean basin and parts of southwestern Asia, current major growing regions USA, China, India, Italy, Spain, Australia, Iran, Turkey[30].

ANTI-OXIDANT ACTIVITY

The linoleic acid peroxidation method and a β -carotene-linoleate model system were used to assess the extracts' antioxidant activity. Several extracts exhibited 65–90% antioxidant activity at 100 ppm concentration [31].

ACTIVE CHEMICAL CONSTITUENTS

Proanthocyanidins (oligomeric flavan-3-ols), Catechins (catechin, epicatechin, epicatechin gallate), phenolic acids (gallic acid, protocatechuic acid, vanillic acid), Flavonoids (Quercetin, kaempferol, rutin), Tannins, Resveratrol [32].

MECHANISM OF ACTION

Flavonoids, which have the ability to scavenge free radicals (superoxide, hydroxyl, and 1,1-diphenyl-2-picrylhydrazyl (DPPH)), metal chelate, reduce hydroperoxide formation, and have an impact on gene expression and cell signaling pathways, are the main source of GSE's antioxidant qualities [33].

COSMETIC USES

Anti-aging, Improve skin hydration, reduction in wrinkle, slight decrease in melanin and erythema level, Protect against UV harm, also used to treat Psoriasis, eczema, skin cancer, Anti-inflammatory, Anti-microbial properties [34].

TURMERIC



Fig 4: Turmeric [35]

BOTANICAL NAME: *Curcuma longa*.

FAMILY: Zingiberaceae.

GEOGRAPHICAL SOURCE

Origin to the south Asia, particularly India, which is the largest producer and exporter. It is also cultivated in tropical and subtropical regions like Sri Lanka, Bangladesh, Indonesia, China and Thailand [36].

ACTIVE CHEMICAL CONSTITUENTS

borneol, α -phellandrene, zingiberene, sabinene, cineole, and sesquiterpenes, curcumin is a mixture of three curcuminoids [i.e., curcumin I (C₂₁H₂₀O₆, diferuloylmethane), curcumin II (C₂₀H₁₈O₅, demethoxycurcumin) and curcumin III (C₁₉H₁₆O₄, bis-demethoxycurcumin)) is a major curcuminoid, Phenolic compounds (Ferulic acid, Caffeic acid, Vanillic acid), Flavonoids (kaempferol, quercetin [37] .

MECHANISM OF ACTION

In addition to reducing the level of oxidative stress, curcumin is an efficient antioxidant that may interact with a variety of molecular pathways, chelate heavy metals, and regulate the activity of numerous enzymes. These components efficiently scavenge free radicals, prevent lipid peroxidation, and boost the body's antioxidant enzymes, including catalase and superoxide dismutase [38].

COSMETIC USES

Reduces pigmentation and dark spots, anti-inflammatory, helps acne, redness, swelling, wound healing and skin repair, anti-aging protects collagen and reduces fine lines [39].

ROSEMARY



Fig 5: Rosemary [40]

BOTANICAL NAME: *Rosmarinus officinalis*.

FAMILY: lamiaceae.

GEOGRAPHICAL SOURCE:

Primarily belong to the Mediterranean regions, now largely cultivated in regions of Morocco, Tunisia, Spain, Portugal, Turkey, Tunisia, Algeria and India [41].

CHEMICAL CONSTITUENTS:

Rosmarinic acid, ursolic acid, Rosmanol, Carnosol, Carnosic acid, include verbenone, limonene, bornyl, α -pinene, α -terpineol, and 1,8-cineole, camphor, terpinolene, and acetate, oleanolic acid, caffeic acid, flavonoids [42]

MECHANISM OF ACTION

Compounds like carnosic acid, carnosol, and rosmarinic acid are the main reasons why rosemary (*Rosmarinus officinalis*) exhibits strong antioxidant activity. These shield cells from oxidative damage by scavenging free radicals, chelating metal ions (such as Fe²⁺ and Cu²⁺), and preventing lipid peroxidation. Additionally, by strengthening antioxidant enzymes like SOD, CAT, and GPx, rosemary strengthens the body's defenses. Furthermore, it stimulates the expression of protective antioxidant genes by activating cellular pathways such as Nrf2. Because of these combined effects, rosemary is a potent natural antioxidant that is particularly useful in skincare and cosmetic products [43].

COSMETIC USES

Prevent oxidative damage, anti-aging, anti-inflammatory, act as a natural preservative, Anti-microbial and Anti-bacterial, controls the sebum production [44].

CONCLUSION

The move in cosmetics from artificial to natural antioxidants reflects the rising demand from consumers for ingredients that are sustainable, safe, and multipurpose. In addition to being strong free radical scavengers, plant-derived substances like polyphenols, flavonoids, carotenoids, and essential oils also have anti-inflammatory and photoprotective properties. Developments in extraction and delivery technologies show promise for their wider use in upcoming cosmetic formulations, notwithstanding issues with stability, formulation, and cost.

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