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THE GREEN REVOLUTION IN COSMETICS: A COMPREHENSIVE REVIEW ON THE POTENTIAL OF NATURAL INGREDIENTS

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ABSTRACT

The rising demand for safer and sustainable skincare solutions has positioned natural compounds, particularly antioxidants and tyrosinase inhibitors, at the forefront of cosmetic innovation. These bioactive ingredients, derived from plants, offer multifaceted benefits by addressing key skin concerns such as oxidative stress, aging, and hyperpigmentation. Antioxidants like flavonoids, phenolics, and vitamins C and E provide robust protection against environmental aggressors, enhance collagen synthesis, and maintain skin hydration and elasticity. Simultaneously, natural tyrosinase inhibitors, such as chlorogenic acid and ellagic acid, effectively reduce melanin production, promoting an even skin tone without the adverse effects associated with synthetic chemicals. The synergy between these compounds allows for comprehensive skincare solutions that cater to diverse skin needs while aligning with the global shift toward eco-conscious and sustainable beauty. Advances in formulation technologies, including nanoemulsions and phytosomes, have further amplified the efficacy and stability of these natural ingredients, ensuring optimal consumer satisfaction. This review explores the potential of natural antioxidants and tyrosinase inhibitors in revolutionizing the cosmetic industry, highlighting their role in fostering innovative, effective, and environmentally responsible skincare formulations for the future.

Keywords: Natural compounds; Antioxidant activity; Tyrosinase inhibitors; Cosmetics formulations; Future technologies.

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INTRODUCTION

Skin aging and pigmentation disorders affect over 50% of individuals aged 30 and above globally, with prevalence rising due to UV exposure, pollution, and oxidative stress.[1] These external aggressors trigger an overproduction of reactive oxygen species (ROS), which leads to lipid peroxidation, DNA damage, and premature cellular aging. In response, antioxidants have become fundamental ingredients in modern skincare formulations to counteract oxidative damage and preserve skin health.[2] Synthetic antioxidants, although effective, raise safety concerns due to potential cytotoxicity and long-term instability.[3] Consequently, attention has shifted toward natural antioxidants from plant sources, which offer biocompatibility and multifunctional therapeutic benefits. Flavonoids, phenolics, tannins, and vitamins derived from various botanicals demonstrate potent antioxidant, anti-inflammatory, and tyrosinase-inhibiting properties.[4] Plants such as banana peel, moringa leaves, rice bran, and aloe vera have been scientifically validated for their skin-protective effects. These compounds not only neutralize ROS but also improve skin tone, texture, and elasticity, making them suitable for anti-aging and brightening applications. With growing consumer preference for clean-label cosmetics, incorporating plant-derived antioxidants has become both a scientific and commercial priority.[5] Therefore, exploring and characterizing natural antioxidants is vital for advancing safe, effective, and sustainable skincare solutions.

Natural Antioxidant in Cosmetics

Flavonoids

Flavonoids are essential antioxidants widely found in plants like banana peel, moringa leaves,

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chrysanthemum flowers, and morus alba. These compounds are highly effective in neutralizing free radicals, primarily through hydrogen atom donation, which reduces oxidative stress and prevents cellular damage.[6,7] In banana peel (*Musa paradisiaca* var. *Sapientum*), the combination of flavonoids, phenolics, and tannins provides an impressive antioxidant activity, as evidenced by an IC_{50} value of 44.91 ppm at a 5% concentration.[8] This highlights its suitability for anti-aging and protective skincare formulations, particularly for preventing oxidative stress-induced skin damage. Moringa leaves (*Moringa oleifera* Lam.), rich in quinic acid and flavonoids, further demonstrate the antioxidant capacity to protect the skin from environmental pollutants and improve elasticity, though specific IC_{50} values are not provided.[9] Similarly, chrysanthemum flower (*Chrysanthemum indicum* L.) contains flavonoids and triterpenoids, which significantly neutralize reactive oxygen species (ROS), achieving IC_{50} values between 73.51-114.02 ppm.[10] This makes it effective in calming inflamed skin and promoting regeneration. Flavonoids in Morus alba contribute to tyrosinase inhibition, reducing melanin production and brightening skin tone. With IC_{50} values ranging from 50-100 ppm, Morus alba is widely used in brightening and even-toned skincare products.[11] Furthermore, flavonoids provide a multifaceted approach to skincare by combating oxidative damage, improving skin tone, and promoting elasticity, making them indispensable in anti-aging and protective skincare formulations.

Phenolics

Phenolic compounds are powerful natural antioxidants found in various plants, including dragon fruit peel, stevia, and rice bran. These compounds protect the skin by scavenging free radicals and inhibiting enzymes like elastase, which degrade proteins essential for skin firmness and elasticity.[12,13] Dragon fruit peel (*Hylocereus polyrhizus* (F.A.C.Weber) Britton & Rose) showcases robust antioxidant activity, with IC_{50} values ranging from 74.27 to 144.60 ppm.[14] This high activity level helps prevent the breakdown of elastin, supporting the skin's structural integrity and reducing signs of aging. Stevia (*Stevia rebaudiana* (Bertoni) Bertoni), known for its phenolic content, demonstrates significant antioxidant effects, with an IC_{50} of less than 0.75 mg/mL.[15] It offers anti-inflammatory and skin-repair benefits, making it valuable in formulations targeting oxidative damage. Rice bran (Oryzanol and tocopherols) is another noteworthy source of phenolics, offering strong photoprotection and antioxidant activity, with a reported effectiveness of up to 87.23%.[16] Its combination of phenolics and tocopherols helps combat lipid peroxidation, ensuring long-lasting hydration and protection from environmental stressors. Phenolic compounds also play a critical role in reducing hyperpigmentation by inhibiting tyrosinase activity, as seen in mulberry (*Morus alba* L.)[17] These versatile compounds are essential for anti-aging, brightening, and soothing skincare formulations, delivering comprehensive protection and repair benefits for the skin.

Tannins

Tannins are polyphenolic compounds renowned for their antioxidant and astringent properties, commonly found in plants such as banana peel, chrysanthemum flower, and Morus alba. These compounds form protective layers on the skin, helping tighten pores and reduce the appearance of wrinkles.[18] Chrysanthemum flower (*Chrysanthemum indicum* L.) tannins work alongside flavonoids to neutralize ROS and support skin regeneration, achieving IC_{50} values between 73.51-114.02 ppm.[10] This activity level makes chrysanthemum extracts ideal for anti-aging and calming formulations, promoting smoother and healthier skin. In Morus alba, tannins contribute to skin-brightening effects by inhibiting tyrosinase activity and reducing melanin production. These properties make Morus alba a popular ingredient in formulations targeting uneven skin tone and hyperpigmentation.[19,20] Banana peel tannins, combined with phenolics and flavonoids, further enhance the peel's antioxidant capacity, providing both anti-aging and firming benefits. The astringent properties of tannins also make them suitable for toners and masks aimed at refining skin texture.[21,22] By reducing oxidative stress, calming inflammation, and promoting skin firmness, tannins offer comprehensive benefits for anti-aging and soothing skincare formulations.

Vitamins (Tocopherols and Ascorbic Acid)

Vitamins such as tocopherols (vitamin E) and ascorbic acid (vitamin C) are essential components in skincare formulations, offering potent antioxidant and regenerative properties. Rice bran (Kalpatali and Padi 64) is a rich source of tocopherols and oryzanol, known for their photoprotective abilities and antioxidant activity,

with effectiveness rates of up to 87.23%.[16] Tocopherols prevent lipid peroxidation and protect the skin from oxidative damage caused by UV radiation, making rice bran a key ingredient in sunscreens and anti-aging products.[23] Ascorbic acid, present in high concentrations in aloe vera (*Aloe barbadensis* Mill.), synergistically works with vitamin E to promote collagen synthesis, brighten skin tone, and reduce hyperpigmentation.[24] Ascorbic acid's mechanism involves neutralizing ROS and inhibiting tyrosinase, crucial for achieving an even skin tone. Aloe vera's blend of flavonoids, polyphenols, and vitamins enhances its antioxidant capacity, making it a multifunctional ingredient for hydration, repair, and skin protection.[25] These vitamins' ability to protect, repair, and rejuvenate the skin highlights their indispensable role in anti-aging and brightening formulations.

Brazilin

Brazilin, a phenolic compound derived from sappan wood (*Caesalpinia sappan* L.), is widely recognized for its potent antioxidant and anti-inflammatory properties. It works by scavenging reactive oxygen species (ROS) and reducing oxidative stress, protecting the skin from environmental pollutants and preventing premature aging.[26,27] Brazilin also inhibits tyrosinase, a key enzyme in melanin production, making it effective for treating hyperpigmentation and uneven skin tone. With an IC_{50} value of 24.8% at 650 ppm, brazilin demonstrates strong efficacy in neutralizing oxidative damage.[28] This dual action of reducing oxidative stress and suppressing melanin synthesis underscores its versatility in anti-aging and skin-brightening products. In addition, brazilin promotes skin healing by calming inflammation and repairing damaged tissues, further enhancing its appeal in modern skincare formulations.[29,30] Its ability to reduce fine lines and wrinkles makes it an excellent ingredient in anti-aging serums and creams.[31] By combining antioxidant, anti-inflammatory, and melanin-inhibiting properties, brazilin serves as a comprehensive solution for achieving healthy, youthful skin. Its inclusion in both protective and restorative skincare products highlights its potential to address multiple skin concerns effectively.

Table-1: Antioxidant Activity and Potential Applications of Natural Compounds in Skincare Formulations.

Plant Name	Active Compounds	Antioxidant Mechanism	Antioxidant Activity Percentage (IC_{50})	Reference
Banana peel (*Musa paradisiaca* var. *Sapientum*)	Flavonoids, phenolics, tannins	DPPH radical scavenging through hydrogen donation	5% concentration: 44.91 ppm, 7.5%: 10.887 ppm, 10%: 61.93 ppm	8
Moringa leaves (*Moringa oleifera* Lam.)	Quinic acid, linoleic acid, flavonoids	Reduces free radicals via phenolic and flavonoid compounds	Highest inhibition at 35%: 66.04%	9
Chrysanthemum flower (*Chrysanthemum indicum* L.)	Flavonoids, triterpenoids	Neutralizes reactive oxygen species (ROS) and scavenges free radicals	Extract: 32.78 ppm, serum gel: 73.51-114.02 ppm	10
Dragon fruit peel (*Hylocereus polyrhizus* (F.A.C.Weber) Britton & Rose)	Phenols	Scavenging DPPH radicals and elastase inhibition	74.27-144.60 ppm	14
Aloe vera (*Aloe barbadensis* Mill.)	Flavonoids, polyphenols, vitamins	Inhibits lipid membrane oxidation, reduces redox imbalance	Not explicitly stated	24
Stevia rebaudiana (Bertoni) Bertoni	Phenolics, flavonoids	Phenolic and flavonoid-based free radical scavenging	48.18 µg/ml	15
Chlorella vulgaris Beijerinck	Chlorophyll, proteins	Chlorophyll-based scavenging of free radicals	57.25 ppm (in acetone)	32
Jotang herb (*Acmella paniculata* (Wall. ex DC.) R.K.Jansen)	Flavonoids, alkaloids, tannins	DPPH radical scavenging through flavonoids and tannins	21.959 µg/ml	33

Arbutus unedo L.	Phenolics, tannins, flavonoids	Phenolic compounds with strong total antioxidant activity	Not explicitly provided	[34]
Morus alba L.	Flavonoids, phenolics	Scavenging of reactive oxygen species (ROS)	50-100 ppm	[17]
Rice bran (Kalpatali and Padi 64)	Oryzanol, tocopherols, ferulic acid	Prevention of oxidation via oryzanol and tocopherols	FI: 87.23%, FII: 64.08%	[16]
Corn silk (*Zea mays* L. *Saccharata*)	Phenolics, flavonoids	Free radical scavenging and UV protection	SPF of 11.1, antioxidant activity not explicitly provided	[35]
Sappan wood (*Caesalpinia sappan* L.)	Brazilin, phenolic compounds	Inhibition of ROS and MMP-1/3 expression	24.8% at 650 ppm	[28]
Pepino fruit (*Solanum muricatum* Aiton)	Phenolic, flavonoids	Free radical scavenging (DPPH)	0.16 mg/mL	[36]
Brazilian pine (*Araucaria angustifolia* (Bertol.) Kuntze)	Flavonoids, biflavonoids	Flavonoids acting as free radical scavengers and UV protection	Not provided explicitly	[37]
Arabica coffee (*Coffea arabica* L.)	Flavonoids, tannins, saponins, alkaloids, steroidal compounds	Prevention of oxidation via flavonoid and tannins	Extract: 8.13 ppm, serum: 250 ppm	[38]
Cocoa pod (*Theobroma cacao* L.)	Polyphenol	Free radical scavenging and tyrosinase inhibition	17.21 ppm	[39]
Andrographis paniculata (Burm.f.) Nees	Andrographolide, flavonoids	Reduces oxidative stress and regulates antioxidant enzymes like SOD, CAT	52.10 µg/mL	[40]
Syzygium aromaticum (L.) Merr. & L.M.Perry	Eugenol, β-caryophyllene, α-humulene	Free radical scavenging and reducing oxidative chain reactions	4.82 µg/mL	[40]
Pogostemon cablin (Blanco) Benth.	Patchoulol, monoterpenes	Free radical scavenging through monoterpenes	1.21 mg/mL	[40]

Chlorophyll and Proteins

Chlorophyll, found in *Chlorella vulgaris* Beijerinck, is a powerful antioxidant known for its detoxifying and skin-soothing properties. It effectively neutralizes ROS, protecting the skin from environmental aggressors like pollution and UV radiation.[41] With an IC_{50} value of 57.25 ppm, chlorophyll demonstrates significant antioxidant activity, making it ideal for anti-aging and hydrating formulations.[32] Chlorella vulgaris also contains proteins that support collagen synthesis, essential for maintaining skin elasticity and firmness. This dual action of detoxification and hydration makes Chlorella an excellent choice for face masks, serums, and creams targeting stressed or aging skin. Chlorophyll also promotes the regeneration of damaged skin cells, reducing redness and enhancing overall skin tone.[42,43] These properties make it suitable for sensitive skin formulations designed to calm irritation and provide long-term protection. The combination of chlorophyll and proteins in Chlorella supports comprehensive skin repair and rejuvenation.[44] Its ability to address hydration, elasticity, and antioxidant defense underscores its value in restorative skincare. By promoting a radiant and youthful complexion, Chlorella is a critical ingredient in modern skincare formulations.

Oryzanol and Tocopherols

Oryzanol and tocopherols, found in rice bran (Kalpatali and Padi 64), are potent antioxidants that protect the skin from oxidative stress and environmental damage. Oryzanol absorbs UV light, preventing photoaging by reducing the formation of ROS that can damage skin cells.[45] Tocopherols, or vitamin E, work synergistically with oryzanol to neutralize free radicals and prevent lipid peroxidation, which is essential for maintaining skin hydration and integrity. The combination of oryzanol and tocopherols ensures robust photoprotection, making rice bran an excellent ingredient in sunscreens and anti-aging products.[46,47] While specific IC_{50} values are not provided, the reported antioxidant effectiveness of up to 87.23% highlights rice

bran's efficacy in skincare.[16] These compounds also enhance skin elasticity and reduce fine lines, contributing to smoother and firmer skin. Oryzanol's ability to protect against oxidative damage complements tocopherols' role in supporting collagen synthesis.[48] Together, they ensure long-term skin health by promoting hydration and reducing signs of aging. The versatility of oryzanol and tocopherols in targeting sun damage, premature aging, and oxidative stress makes rice bran extracts essential in comprehensive skincare formulations.

Andrographolide

Andrographolide, the primary active compound in *Andrographis paniculata* (Burm.f.) Nees is renowned for its strong antioxidant and anti-inflammatory properties. It protects the skin from oxidative stress by scavenging ROS and inhibiting pro-inflammatory cytokines, making it particularly effective for sensitive or acne-prone skin.[49,50] Although the specific IC_{50} value is not mentioned, andrographolide's role in calming inflammation and promoting skin healing is well-documented.[40] This compound also stimulates collagen synthesis, improving skin elasticity and reducing the appearance of fine lines and wrinkles. Its dual ability to protect against oxidative stress and support skin repair makes it an excellent ingredient in anti-aging formulations.[51,52] Andrographolide is particularly useful in formulations targeting stressed or aging skin, offering comprehensive protection and rejuvenation. Its inclusion in skincare products ensures both immediate soothing effects and long-term benefits for skin health.[53] The ability to address multiple skin concerns highlights andrographolide's versatility as a key ingredient in modern skincare. By promoting a healthy, radiant complexion, it becomes indispensable in formulations designed for restorative and anti-aging care.

Eugenol and β-Caryophyllene

Eugenol and β-caryophyllene, found in clove (*Syzygium aromaticum* (L.) Merr. & L.M.Perry), exhibit strong antioxidant and anti-inflammatory properties, making them highly effective in skincare. Eugenol, a phenolic compound, scavenges free radicals and reduces oxidative stress while also providing antimicrobial benefits.[54] These properties make eugenol particularly suitable for formulations targeting acne-prone or inflamed skin. β-Caryophyllene complements eugenol by reducing inflammation, promoting healing, and calming irritated skin. Although specific IC_{50} values are not listed, their combined antioxidant and anti-inflammatory activities are well-recognized.[40] Eugenol also protects the skin from UV-induced damage by neutralizing ROS, maintaining a youthful appearance. Together, these compounds are widely used in serums, creams, and toners designed for skin repair and protection. β-Caryophyllene's ability to enhance tissue repair further supports its use in anti-aging and soothing formulations.[55,56] The dual mechanism of action, encompassing antioxidant protection and inflammation reduction, underscores the versatility of clove extract in addressing multiple skin concerns. Its inclusion in skincare formulations ensures comprehensive care for acne, aging, and stressed skin.

Patchoulol and Monoterpenes

Patchoulol and monoterpenes, derived from patchouli (*Pogostemon cablin* (Blanco) Benth.), are valued for their potent antioxidant and anti-inflammatory properties. Patchoulol neutralizes ROS and reduces oxidative stress, preventing collagen breakdown and maintaining skin elasticity. Monoterpenes contribute by calming inflammation, making patchouli extract suitable for sensitive or irritated skin formulations.[57,58] Although the specific IC_{50} values for these compounds are not provided, their documented effectiveness in skincare is well-established.[40] Patchoulol's role in preventing oxidative damage and promoting collagen synthesis makes it a key ingredient in anti-aging serums and creams. This combination of antioxidant and anti-inflammatory properties supports patchouli's use in formulations designed to restore and rejuvenate the skin.[59,60] Monoterpenes enhance patchouli's effectiveness by providing additional soothing benefits, ensuring long-term skin health. Patchouli's ability to improve skin texture, firmness, and hydration underscores its importance in modern skincare. Its versatility in addressing aging, irritation, and environmental damage makes it an essential ingredient in comprehensive skincare products.

Natural Tyrosinase Inhibitors in Cosmetics

Polyphenols and Flavonoids

Polyphenols and flavonoids, abundant in plants like cocoa pods, are highly effective in inhibiting tyrosinase

activity and reducing melanin synthesis. These compounds work by suppressing the oxidation processes necessary for melanogenesis, the biochemical pathway responsible for melanin production.[61,62] Cocoa-derived polyphenols exhibit a strong inhibitory effect with an IC_{50} value of 199.98 ppm, showcasing their potential in skin-brightening formulations.[39] Flavonoids provide additional benefits by protecting the skin from oxidative damage caused by environmental stressors, including UV exposure. Their antioxidative properties not only combat free radicals but also strengthen the skin's barrier function, reducing transepidermal water loss and maintaining hydration. Polyphenols enhance skin elasticity and slow down the signs of premature aging, such as fine lines and wrinkles.[63,64] These compounds are particularly valued for their gentle mechanism of action, making them suitable for sensitive skin. Regular use of polyphenols and flavonoids in skincare ensures a brighter, even-toned complexion with long-lasting protective effects.

Chlorogenic Acid and Caffeine

Chlorogenic acid and caffeine, found in coffee plants, inhibit tyrosinase activity through complementary mechanisms that reduce melanin synthesis. Chlorogenic acid directly interacts with melanin substrates, decreasing pigmentation and achieving an IC_{50} value of 250 ppm.[38] This compound also helps minimize dark spots, promoting an even skin tone and improving the overall radiance of the complexion. Caffeine enhances these effects by refreshing the skin, improving microcirculation, and reducing puffiness, especially around pigmentation-prone areas like the under-eyes. Together, they combat oxidative stress and protect against UV-induced damage, preserving collagen and preventing premature aging. Caffeine also accelerates skin cell regeneration, helping the skin appear revitalized and youthful.[65,66] This combination is highly effective in brightening and revitalizing skincare products designed for daily use. The synergistic benefits of chlorogenic acid and caffeine make them indispensable for addressing pigmentation and fatigue-related skin concerns. Their gentle yet powerful effects are suitable for all skin types, including sensitive skin.

Stevioside and Rebaudioside

Stevioside and rebaudioside, extracted from the Stevia plant, are effective natural inhibitors of tyrosinase, reducing melanin production through competitive enzyme binding. These compounds have a demonstrated IC_{50} value of 0.75 mg/mL, highlighting their efficacy at relatively low concentrations.[67] Stevioside and rebaudioside are gentle on the skin, making them ideal for sensitive skin formulations. Their antioxidant properties provide additional protection against oxidative stress, which can lead to hyperpigmentation and premature aging. Stevia's calming effects on the skin further enhance its suitability for treating pigmentation caused by inflammation or environmental damage.[68,69] These compounds promote an even skin tone while maintaining the skin's natural hydration and barrier function. Stevioside and rebaudioside offer a sustainable and natural alternative to synthetic brighteners in skincare products. Their dual action of brightening and protecting the skin ensures long-term benefits for users seeking gentle yet effective solutions for pigmentation issues.

Quinic Acid and Linoleic Acid

Quinic acid and linoleic acid inhibit tyrosinase activity by interfering with the oxidation processes necessary for melanin synthesis. Quinic acid acts as a competitive inhibitor, directly reducing pigmentation and brightening the skin. Linoleic acid complements this by strengthening the skin's barrier function, retaining moisture, and reducing free radical damage.[70,71] This combination is particularly beneficial for addressing pigmentation in dry or sensitive skin types. Linoleic acid also exhibits anti-inflammatory properties, calming redness and irritation often associated with pigmentation issues. Together, they enhance skin texture, hydration, and brightness, making them ideal for formulations aimed at maintaining healthy skin. By reducing melanin production while preserving the skin's natural defenses, these compounds offer comprehensive care for pigmentation concerns.[72,73] Their ability to protect and repair the skin ensures long-term results, particularly in products targeting hyperpigmentation and uneven skin tone. Quinic acid and linoleic acid's synergistic effects provide an effective solution for brighter, healthier skin.

Ascorbic Acid and Ellagic Acid

Ascorbic acid (Vitamin C) and ellagic acid are powerful natural inhibitors of tyrosinase that work synergistically to reduce melanin production and brighten the skin. Ascorbic acid prevents the oxidation of

melanin precursors, while ellagic acid provides complementary antioxidant effects, protecting the skin from UV-induced damage.

Table-2: Natural Tyrosinase Inhibitors for Skin Brightening Applications

Plant Name	Active Compounds	Inhibition of Tyrosinase Mechanism	Inhibition Tyrosinase Percentage	Reference
Cocoa pod (*Theobroma cacao* L.)	Polyphenols, flavonoids	Inhibits melanogenesis via polyphenolic compounds	IC_{50}: 199.98 ppm	[39]
Moringa leaves (*Moringa oleifera* Lam.)	Quinic acid, linoleic acid	Flavonoids and phenolic compounds reduce tyrosinase activity	Not explicitly stated	[74]
Arabica coffee (*Coffea Arabica* L.)	Chlorogenic acid, caffeine	Inhibits tyrosinase via chlorogenic acid	IC_{50}: 250 ppm	[38]
Pepino fruit (*Solanum muricatum* Aiton)	Flavonoids, phenolics	Flavonoid-based inhibition of oxidation process in melanogenesis	IC_{50}: 0.16 mg/mL	[36]
Stevia rebaudiana (Bertoni) Bertoni	Stevioside, rebaudioside	Interferes with tyrosinase enzyme via stevioside	IC_{50}: 0.75 mg/mL	[75]
Phyllanthus emblica L.	Ascorbic acid, ellagic acid	Potent inhibition when L-DOPA is used as substrate	%inhibition: 53.1%	[75]
Chrysanthemum flower	Flavonoids, triterpenoids	Inhibits tyrosinase by reducing DOPA oxidation	IC_{50}: 73.51-114.02 ppm	[10]
Syzygium aromaticum (L.) Merr. & L.M.Perry	Eugenol, β-caryophyllene	Inhibits tyrosinase through essential oil components	Not explicitly stated	[40]
Pogostemon cablin (Blanco) Benth.	Patchoulol, monoterpenes	Competitive inhibition at enzyme's active site	Not explicitly stated	[40]
Gynostemma pentaphyllum (Thunb.) Makino	Ginsenosides	Tyrosinase inhibition through ginsenosides affecting melanin synthesis pathways	%inhibition: 39.9%	[75]
Rosa damascene Mill.	Quercetin, kaempferol	Reduces melanin synthesis by inhibiting tyrosinase	%inhibition: 35.6%	[75]
Hibiscus sabdariffa L.	Phenolic acids, anthocyanins	Flavonoid-based inhibition of tyrosinase and melanin formation	Not explicitly stated	[75]
Morus alba L.	Flavonoids, phenolics	Inhibits tyrosinase through interactions with phenolic compounds	Not explicitly stated	[75]
Aloe vera (*Aloe barbadensis* Mill.)	Flavonoids, polyphenols, vitamins	Inhibits lipid membrane oxidation, reducing melanogenesis-related oxidative stress	Not explicitly stated	[76]
Acmella paniculata (Wall. ex DC.) R.K.Jansen	Flavonoids, saponins	Inhibits tyrosinase and melanogenesis in skin cells	Not explicitly stated	[33]
Echinacea purpurea (L.) Moench	Alkylamides, caffeic acid derivatives	Reduces melanogenesis through anti-inflammatory and antioxidant effects	Not explicitly stated	[75]
Jasminum sambac (L.) Aiton	Flavonoids, essential oils	Essential oil-based inhibition of tyrosinase	Not explicitly stated	[75]
Pandanus amaryllifolius Roxb.	Flavonoids, alkaloids, saponins	Reduces tyrosinase activity by inhibiting melanin production	Not explicitly stated	[75]

This combination demonstrates significant inhibition at low concentrations, making it effective for achieving a brighter and more even complexion.[77,78] Ascorbic acid is widely used in skincare products to lighten dark spots, reduce hyperpigmentation, and improve skin tone. Ellagic acid enhances these effects by neutralizing free radicals and reducing oxidative stress, which contributes to premature aging. Together, they strengthen the skin's resilience against environmental damage, promoting long-term health and radiance. Their inclusion in anti-aging and brightening formulations ensures both immediate and lasting

benefits.[79] By combining protection, repair, and brightening effects, ascorbic and ellagic acids are essential components in comprehensive skincare routines.

Flavonoids, Alkaloids, and Tannins

Flavonoids, alkaloids, and tannins are a group of compounds that effectively inhibit tyrosinase activity and reduce melanin synthesis. Flavonoids and alkaloids work by suppressing the oxidation processes required for melanogenesis, while tannins act as astringents, tightening pores and improving skin clarity. These compounds also provide additional benefits such as UV protection, preventing pigment formation, and reducing signs of aging.[80,81] Alkaloids offer anti-inflammatory and antioxidant properties, calming irritated skin and protecting against oxidative stress.[82] Flavonoids and tannins support skin cell regeneration, making them effective for addressing pigmentation caused by acne scars or environmental damage. This combination is particularly beneficial for oily or acne-prone skin, as it reduces inflammation and pigmentation simultaneously.[83] The synergistic effects of these compounds provide brightening, soothing, and protective benefits. Their versatility makes them valuable in formulations targeting uneven skin tone and pigmentation caused by external factors.

Eugenol and β-Caryophyllene

Eugenol and β-caryophyllene, found in clove oil, are potent natural inhibitors of tyrosinase. Eugenol reduces melanin synthesis by suppressing oxidation processes, while β-caryophyllene provides anti-inflammatory benefits, calming irritated skin. Together, they effectively target hyperpigmentation and offer soothing effects for sensitive skin. Eugenol's antimicrobial properties make it particularly suitable for acne-prone skin, where it helps prevent bacterial growth and reduces inflammation.[84,85] β-Caryophyllene enhances tissue repair, promoting skin healing and preventing pigmentation related to irritation or scarring. This combination delivers pigmentation control without irritation, making it ideal for long-term use in brightening formulations. Their ability to balance pigmentation reduction with skin protection ensures comprehensive care for users. By combining antioxidant, anti-inflammatory, and antimicrobial properties, eugenol and β-caryophyllene are versatile ingredients for addressing multiple skin concerns.[86,87]

Patchoulol and Monoterpenes

Patchoulol and monoterpenes, derived from patchouli, are natural compounds with potent tyrosinase-inhibiting and antioxidative properties. Patchoulol neutralizes ROS, preventing oxidative stress that leads to pigmentation and collagen degradation. Monoterpenes complement this by reducing melanin synthesis and calming inflammation, making this combination suitable for sensitive and dry skin.[88,89] Together, they improve skin hydration and elasticity while promoting a brighter complexion. Patchoulol's role in preventing collagen breakdown enhances its effectiveness in anti-aging formulations.[90] Monoterpenes also provide soothing benefits for irritated skin, ensuring comprehensive care for users. This combination is ideal for skincare products that target pigmentation while maintaining skin moisture and health. Their dual action of brightening and rejuvenation highlights their versatility in modern skincare. Patchoulol and monoterpenes are essential for achieving a youthful, radiant appearance.

CONCLUSION

Natural compounds offer transformative potential in shaping the future of cosmetics by addressing the growing demand for safe, effective, and environmentally friendly skincare solutions. Beyond their functional benefits, these compounds enable the development of innovative, multi-targeted formulations that align with evolving consumer expectations for personalized care. Advances in extraction and delivery technologies, such as encapsulation and nanoemulsions, have further enhanced the bioavailability and efficacy of natural ingredients, ensuring better absorption and long-lasting results. Moreover, the shift towards eco-conscious production practices amplifies the appeal of natural compounds as sustainable alternatives to synthetic chemicals, contributing to the reduction of environmental footprints in the cosmetic industry. Their adaptability to diverse skin types, combined with low toxicity and reduced risk of irritation, makes them accessible to a broad demographic. As natural cosmetics continue to evolve, they hold the potential to integrate seamlessly with emerging trends in biotechnology, enabling breakthroughs in skin health optimization. This integration underscores the critical role of natural bioactives not only in enhancing skin aesthetics but also in promoting a balanced relationship between nature, science, and beauty. Looking

ahead, the fusion of tradition and innovation will drive the widespread adoption of these compounds, making them central to future skincare advancements.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

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REFERENCES

1. A. Y. Lee, *International Journal of Molecular Sciences,* **22(7)**, 3727(2021), https://doi.org/10.3390/ijms22073727
2. S. Afzal, A. S. Abdul Manap, A. Attiq, I. Albokhadaim, M. Kandeel and S. M. Alhojaily, *Frontiers in Pharmacology,* **14**, 1269581(2023), https://doi.org/10.3389/fphar.2023.1269581
3. S. Sharma, S. F. Cheng, B. Bhattacharya and S. Chakkaravarthi, *Trends in Food Science and Technology,* **91**, 333(2019), https://doi.org/10.1016/j.tifs.2019.07.030
4. L. Yuniarti, T. M. Fakih, M. Tejasari, R. A. Indriyanti, E. Maryam and B. H. Nugroho, *Drug Design, Development and Therapy,* **19**, 1195(2025), https://doi.org/10.2147/DDDT.S507658
5. R. Sasounian, R. M. Martinez, A. M. Lopes, J. Giarolla, C. Rosado, W. V. Magalhães, M. V. R. Velasco and A. R. Baby, *Clean Technologies,* **6(1)**, 11(2024), https://doi.org/10.3390/cleantechnol6010011
6. A. Roy, A. Khan, I. Ahmad, S. Alghamdi, B. S. Rajab, A. O. Babalghith, M. Y. Alshahrani, S. Islam and M. R. Islam, *BioMed Research International,* 5445291(2022), https://doi.org/10.1155/2022/5445291
7. R. Novalia Rahmawati Sianipar, L. Suryanegara, W. Fatriasari, E. Tangke Arung, I. Wijaya Kusuma, S. Setiati Achmadi, N. Izyan Wan Azelee and Z. Ain Abdul Hamid, *Saudi Pharmaceutical Journal,* **31(3)**, 382(2023), https://doi.org/10.1016/j.jsps.2023.01.006
8. J. Pusmarani, F. Wulandari, F. S. Siharis, N. H. Awaliyah and J. Risky, *Indonesian Journal of Pharmaceutical Science and Technology,* **1(1)**, 35(2023).
9. Y. N. Azizah and N. K. Hapsari, *Jurnal Kimia Valensi,* **6(2)**, 198(2021). https://doi.org/10.15408/jkv.v6i2.16982
10. S. Taurhesia, D. N. Rosdiana and D. K. Pratami, *Journal of Natural Product for Degenerative Disease,* **1(2)**, 57(2024), https://doi.org/10.58511/jnpdd.v1i2.6376
11. A. Budiman, A. Praditasari, D. Rahayu and D. L. Aulifa, *Journal of Pharmacy and Bioallied Sciences,* **11(3)**, 216(2019), https://doi.org/10.4103/jpbs.JPBS_57_18
12. W. Tang, W. Li, Y. Yang, X. Lin, L. Wang, C. Li and R. Yang, *Foods,* **10(6)**, 1183(2021), https://doi.org/10.3390/foods10061183
13. F. Gai, M. A. Janiak, K. Sulewska, P. G. Peiretti and M. Karamać, *Molecules,* **28(4)**, 1807(2023), https://doi.org/10.3390/molecules28041807
14. A. N. Yuliawati and K. D. Cahyadi, *Traditional Medicine Journal,* **25(3)**, 146(2020), https://doi.org/10.22146/mot.51763
15. Mutmainah, L. Kusmita, Y. Martono, Y. D. Franyoto, R. P. Wulandari and T. D. Kusumaningrum, *Journal of Physics: Conference Series,* **1217**, 012152(2019), https://doi.org/10.1088/1742-6596/1217/1/012152

16. Suhery, W. N. Lestari, H. Fernando and A. Aryani, *Traditional Medicine Journal,* **28(2)**, 151(2023), https://doi.org/10.22146/mot.84715
17. Thi, N. Hanh, M. Kim, N. Phung, P. Ngo and Q. D. Phuong, *American Journal of Plant Sciences,* **8 (6)**, 1319(2017), https://doi.org/10.4236/ajps.2017.86088
18. F. Corral, M. Otero, P. Cassani, L. Echave, J. G. Oliveira, P. Carpena, M. Chamorro, F. L. Lopes, C. Prieto and M. A. S. Gandara, *Journal Foods,* **10(2),** 251(2021), https://doi.org/10.3390/foods10020251
19. Kornhauser, A. Coelho and S. G. Hearing, *Journal Clinical, Cosmetic and Investigational Dermatology,* **2010(3)**, 135(2010), https://doi.org/10.2147/CCID.S9042
20. K. T. Choi, J. H. Kim, H. T. Cho, S. S. Lim, S. S. Kwak and Y. J. Kim, *Journal of Cosmetic Dermatology,* **15(2)**, 162(2016), https://doi.org/10.1111/jocd.12211
21. Madhuri, D. Nagarajan and G.B. Babu, *International Journal of Research in Pharmaceutical Sciences,* **9(2)**, 378(2018), https://doi.org/10.26452/ijrps.v9i2.1495
22. F. C. Abdullah, L. Rahimi, Z. A. Zakaria and A. L. Ibrahim, *Novel Plant Bioresources: Application in Food, Medicine and Cosmetics,* **26(6),** 371(2014), https://doi.org/10.1002/9781118460566.ch26
23. N. I. Ghazali, R. Z. Mohd Rais, S. Makpol, K. Y. Chin, W. N. Yap and J. A. Goon, *Frontiers in Pharmacology,* **13**, 1006198(2022), https://doi.org/10.3389/fphar.2022.1006198
24. M. M. Rahman, R. Amin, T. Afroz and Das, *Journal of Pharmaceutical Research International,* **371A(33)**, 109(2021), https://doi.org/10.9734/jpri/2021/v33i37a31986
25. M. Hęś, K. Dziedzic, D. Górecka, A. J. Golińska and E. Gujska, *Plant Foods for Human Nutrition,* **74(3)**, 255(2019), https://doi.org/10.1007/s11130-019-00747-5
26. N. P. Nirmal, M. S. Rajput, R. G. S. V. Prasad and M. Ahmad, *Asian Pacific Journal of Tropical Medicine,* **8(6)**, 421(2015), https://doi.org/10.1016/j.apjtm.2015.05.014
27. N. P. Nirmalva and P. Panichayupakaranant, *Pharmaceutical Biology,* **52(9)**, 1204(2014), https://doi.org/10.3109/13880209.2014.884607
28. D. Y. Sari and R. Widyasari, *Indonesian Journal of Pharmacy,* **34(2)**, 261(2023), https://doi.org/10.22146/ijp.4552
29. Y. Chang, S. K. H. Huang, W. J. Lu, C. L. Chung, W. L. Chen, S. H. Lu, K. H. Lin and J. R. Sheu, *Journal of Biomedical Science,* **20(4)**, 1(2013), https://doi.org/10.1186/1423-0127-20-4
30. P. N. Nirmal, G. S. V. Prasad and S. Keokitichai, *Journal of Chemical and Pharmaceutical Research,* **6(10)**, 195(2014).
31. N. P. L. Laksmiani, N. P. E. Leliqia, N. L. P. V. Paramita, G. K. N. Arijana, I.Wijayanti, N. P. A. D. Adiwibawa, P. I. M. H. Putra and P. A. A. C. Pratama, *Journal of Pharmacognosy Research,* **10(5)**, 922(2022), https://doi.org/10.56499/jppres22.1456_10.5.922
32. E. Mayasari and I. Raya, *Materials Science and Engineering,* **1011**, 012057(2021), https://doi.org/10.1088/1757-899X/1011/1/012057
33. E. Kholifah, V. Fitriani and A. N. Shobah, *Fundamental and Applied Pharmaceutical Science,* **4(2)**, 70-80(2024), https://doi.org/10.18196/jfaps.v4i2.19341
34. E. Habachi, I. B. Rebey, S. Dakhlaoui, M. Hammami and S. Sawsen, *Cosmetics,* **9(6)**, 143(2022), https://doi.org/10.3390/cosmetics9060143
35. M. Lailiyah, A. S. Saputra and F. Sari, *Pharmaciana,* **10(3)**, 371(2020), https://doi.org/10.12928/pharmaciana.v10i3.17780
36. N. Sugihartini, G. R. Firsty, W. K. Laila and S. Mulyaningsih, *Pharmaceutical Sciences and Research,* **11(1)**, 27(2024), https://doi.org/10.7454/psr.v11i1.1311
37. G. Sprada, A. B. Arantes, G. Sacchetti, A. Spagnoletti, P. Ziosi, E. Scalambra, S. Vertuani and S. Manfredini, *Journal of Cosmetics, Dermatological Sciences and Applications,* **4(3)**, 190(2014), http://dx.doi.org/10.4236/jcdsa.2014.43027
38. H. N. Usman, L. Pratiwi and B. Wijianto, *Traditional Medicine Journal,* **28(2)**, 93(2023), https://doi.org/10.22146/mot.83120
39. S. E. Priani, S. Aprilia, R. Aryani and L. Purwanti, *Journal of Applied Pharmaceutical Science,* **9(10)**, 110(2019), https://doi.org/10.7324/JAPS.2019.91015
40. O. R. Adianingsih, V. Yurina, O. E. Puspita, D. Widasmara, D. Hariyono and J. A. W. Dhinata, *Tropical Journal of Natural Product Research,* **8(6)**, 7575(2024), https://doi.org/10.26538/tjnpr/v8i6.38
41. K. H. Cha, S. W. Kang, C. Y. Kim, B. H. Um, Y. R. Na and C. H. Pan, *Journal of Agricultural and Food Chemistry,* **58(8)**, 4756(2010), https://doi.org/10.1021/jf100062m

42. M. A. Wan, A. Lorwirachsutee, C. Theodoropoulos and M. G. Miquel, *ACS Sustainable Chemistry and Engineering,* **7(5)**, 5018(2019), https://doi.org/10.1021/acssuschemeng.8b05642
43. S. Şahin, T. B. M. Nasir, I. Erken, Z. E. Çakmak and T. Çakmak, *Materials Research Express,* **6(9)**, 095404(2019), https://doi.org/10.1088/2053-1591/ab2def
44. H. M. Wang, J. L. Pan, C. Y. Chen, C. C. Chiu, M. H. Yang, H. W. Chang and J. S. Chang, *Process Biochemistry,* **45(12)**, 1865(2010), https://doi.org/10.1016/j.procbio.2010.05.023
45. Z. Xu, N. Hua and J. S. Godber, *Journal of Agricultural and. Food Chemistry,* **49(4)**, 2077(2001), https://doi.org/10.1021/jf0012852
46. H. Ahsan, A. Ahad, J. Iqbal and W. A. Siddiqui, *Nutrition and Metabolism,* **52(11)**, 1(2014), https://doi.org/10.1186/1743-7075-11-52
47. C. M. Seppanen, Q. Song and A. S. Csallany, *Journal of the American Oil Chemists' Society,* **87(5)**, 469(2010), https://doi.org/10.1007/s11746-009-1526-9
48. S. S. Salimath, T. B. Romsdahl, A. R. Konda, W. Zhang, E. B. Cahoon, M. K. Dowd, T. C. Wedegaertner, K. D. Hake and K. D. Chapman, *Plant Biotechnology Journal,* **19(6)**, 1268(2021), https://doi.org/10.1111/pbi.13557
49. E. Mussard, A. Cesaro, E. Lespessailles, B. Legrain, S. B. Raboin and H. Toumi, *Antioxidants,* **8(12)**, 571(2019), https://doi.org/10.3390/antiox8120571
50. G. Messire, R. Serreau and S. B. Raboin, *Antioxidants,* **12(7)**, 1317(2023), https://doi.org/10.3390/antiox12071317
51. B. Zeng, A. Wei, Q. Zhou, M. Yuan, K. Lei, Y. Liu, J. Song, L. Guo and Q. Ye, *Phytotherapy Research,* **36(1)**, 336(2022), https://doi.org/10.1002/ptr.7324
52. M. Malahubban, A. R. Alimon, A. Q. Sazili, S. Fakurazi and F. A. Zakry, *Tropical Biomedicine,* **30(3)**, 467(2013), https://doi.org/10.1186/s12906-015-0914-y
53. A. O. Owoade, *African Journal of Life Science,* **5(2)**, 246(2021), https://doi.org/10.36108/pajols/1202.50.0220
54. V. K. Pandey, S. Srivastava, Ashish, K. K. Dash, R. Singh, A. H. Dar, T. Singh, A. Farooqui, A. M. Shaikh and B. Kovacs, *Heliyon,* **10(1)**, e22437(2024), https://doi.org/10.1016/j.heliyon.2023.e22437
55. E. Stoleru, C. Vasile, A. Irimia and M. Brebu, *Molecules,* **26(15)**, 4500(2021), https://doi.org/10.3390/molecules26154500
56. M. F. A. El-Maati, S. A. Mahgoub, S. M. Labib, A. M. A. Al-Gaby and M. F. Ramadan, *European Journal of Integrative Medicine,* **8(4)**, 494(2016), https://doi.org/10.1016/j.eujim.2016.02.006
57. F. Erwan, S. Muhammad, R. D. Lufika, E. Oktaviana, N. Azizah, E. B. Miftah, F. Mubin, L. Z. Larosa and S. E. Hajar, *Journal Patchouli Essential Oil Products,* **1(1)**, 14(2022), https://doi.org/10.24815/jpeop.v1i1.23748
58. N. Isnaini, V. Prajaputra and S. Maryam, *Jurnal Penelitian Pendidikan IPA,* **9(10)**, 8001(2023), https://doi.org/10.29303/jppipa.v9i10.4292
59. N. Isnaini, K. Khairan, M. Faradhilla, E. Sufriadi, B. Ginting, V. Prajaputra, F. Erwan, R. D. Lufika and S. Muhammad, *Journal of Patchouli Essential Oil Products,* **1(1)**, 22(2022). https://doi.org/10.24815/jpeop.v1i1.23762
60. N. H. Abdurahman and S. Sundarajan, *IOP Conference Series: Materials Science and Engineering,* **702**, 012042(2019), https://doi.org/10.1088/1757-899X/702/1/012042
61. R. A. Rahim, P. A. Jayusman, N. Muhammad, F. Ahmad, N. Mokhtar, I. N. Mohamed, N. Mohamed and A. N. Shuid, *International Journal of Environmental Research and Public Health,* **16(24)**, 4962(2019), https://doi.org/10.3390/ijerph16244962
62. A. W. Indrianingsih, M. P. Wulanjati, A. Windarsih, D. K. Bhattacharjya, T. Suzuki and T. Katayama, *Biocataysisi and Agricultural Biotechnology,* **33,** 101995(2021), https://doi.org/10.1016/j.bcab.2021.101995
63. J. H. Lee, J. Park and D. W. Shin, *Molecules,* **27(14)**, 4351(2022), https://doi.org/10.3390/molecules27144351
64. A. Yessenkyzy, T. Saliev, M. Zhanaliyeva, A. R. Masoud, B. Umbayev, S. Sergazy, E. Krivykh, A. Gulyayev and T. Nurgozhin, *Nutrients,* **12(5)**, 1344(2020), https://doi.org/10.3390/nu12051344
65. E. M. Vogel, L. L. M. Marques, A. A. Droval, A. M. Gozzo and F. A. R. Cardoso, *Brazilian Journal of Biology,* **82**, e241043(2022), https://doi.org/10.1590/1519-6984.241043
66. E. M. Vogel, M. Bronoski, L. L. Marques and F. A. R. Cardoso, *Brazilian Journal of Biology,* **82**,

e241025(2022), https://doi.org/10.1590/1519-6984.241025
67. C. Gardana, P. Simonetti, E. Canzi, R. Zanchi and P. Pietta, *Journal Agricultural and Food Chemistry,* **51(22)**, 6618(2003), https://doi.org/10.1021/jf0303619
68. E. Koyama, K. Kitazawa, Y. Ohori, O. Izawa, K. Kakegawa, A. Fujino and M. I. Ui, *Food and Chemical Toxicology,* **41(3)**, 359(2003), https://doi.org/10.1016/S0278-6915(02)00235-1
69. E. Gupta, S. Purwar, S. Sundaram, P. Tripathi and G. Rai, *Czech Journal of Food Sciences,* **34(4),** 281(2016), https://doi.org/10.17221/335/2015-CJFS
70. A. C. M. Castro, F. B. Oda, M. G. J. A. Cincotto, M. G. Davanço, B. G. C. Andréo, R. M. B. Cicarelli, R. G. Peccinini, G. J. Zocolo, P. R. V. Ribeiro, M. A. Corrêa, V. L. B. Isaac and A. G. Santos, *Food Chemistry,* **246**, 48(1028), https://doi.org/10.1016/j.foodchem.2017.10.153
71. Z. Ullah, S. Ali, A. Hussain, M. Öztürk, A. Ertas, M. Alamzeb, M. U. Rashid, H. Ullah, R. Zaman and M. Imtiaz, *South African Journal of Botany,* **148**, 537(2022), https://doi.org/10.1016/j.sajb.2022.05.012
72. Y. Arab, B. Sahin, O. Ceylan, A. Zellagui, O. T. Olmez, S. Kucukaydin, A. N. Tamfu, M. Ozturk, N. Gherraf, *Biodiversitas,* **23(7)**, 3498(2022), https://doi.org/10.13057/biodiv/d230724
73. F. Grina, Z. Ullah, E. Kaplaner, A. Moujahid, R. Eddoha, B. Nasser, P. Terzioğlu, M. A. Yilmaz, A. Ertaş, M. Öztürk and A. Essamadi, *South African Journal of Botany,* **128**, 152(2020), https://doi.org/10.1016/j.sajb.2019.10.021
74. G. S. T. da Mota, A. B. Arantes, G. Sacchetti, A. Spagnoletti, P. Ziosi, E. Scalambra, S. Vertuani and S. A. Manfredini, *Journal of Cosmetics, Dermatological Science and Applications,* **04(03)**, 190-202(2014), https://doi.org/10.4236/jcdsa.2014.43027
75. W. Chaiyana, W. Charoensup, S. Sriyab, C. Punyoyai and W. Neimkhum, *Chemistry & Biodiversity,* **18(5)**, e2100245(2021), https://doi.org/10.1002/cbdv.202100245
76. K. B. Kang, D. Y. Lee, T. B. Kim, S. H. Kim, H. J. Kim, J. Kim and S. H. Sung, *Microchemical Journal,* **110**, 731(2013), https://doi.org/10.1016/j.microc.2013.08.012
77. C. Couteau and L. Coiffard, *Cosmetics,* **3(3)**, 27(2016), https://doi.org/10.3390/cosmetics3030027
78. G. Sotiropoulou, E. Zingkou and G. Pampalakis, *Experimental Dermatology,* **30(5)**, 628(2021), https://doi.org/10.1111/exd.14299
79. S. Saharawat and S. Verma, *Current Drug Delivery,* **21(11)**, 1460(2024), https://doi.org/10.2174/0115672018269199231121055548
80. F. L. Smith and F. L. Meyskens, *Molecular Nutrition & Food Research,* **60(6)**, 1264(2016), https://doi.org/10.1002/mnfr.201500822
81. N. Kooltheat, A. Tedasen, K. Yamasaki and M. Chatatikun, *Journal of Evidence-Based Integrative Medicine,* **28**, 1(2023), https://doi.org/10.1177/2515690X231152928
82. A. Ramesh, A. Nandi, S. Devanathan, L. Jayaraman and S. Sivaji, *Journal of Advanced Biotechnology and Experimental Therapeutics,* **6(1)**, 67(2023), https://doi.org/10.5455/jabet.2023.d107
83. H. J. Lee, W. J. Lee, S. E. Chang and G. Y. Lee, *International Journal of Molecular Sciences,* **16(8)**, 18384(2015), https://doi.org/10.3390/ijms160818384
84. J. Li, X. Min, X. Zheng, S. Wang, X. Xu and Peng, *Molecules,* **28(16)**, 5969(2023), https://doi.org/10.3390/molecules28165969
85. H. T. Trung, T. D. Thang, T. H. D. V. Nguyen, D. C. Tuan, N. H., N. X. Ha, T. V. Chen, H. T. Oanh, N. T. T. Giang and P. T. Thuy, *Natural Product Communications,* **18(12)**, 1(2023), https://doi.org/10.1177/1934578X231222383
86. D. D. Handoyo, E. Girsang, A. N. Nasution and I. N. E. A. Lister, *Traditional Medicine Journal,* **26(2)**, 84(2021), https://doi.org/10.22146/mot.56081
87. H. T. Van, T. D. Thang, T. N. Luu and V. D. Doan, *RSC Advances,* **11**, 37767(2021), https://doi.org/10.1039/d1ra07370b
88. W. Rinaldi, I. Machdar, D. Ariefa Luthfiah, F. Azwar, S. S. Fauzal, M. Z. I. Noer and C. N. Azriana, *Materials Today Proceedings,* **63(1)**, 22(2021), https://doi.org/10.1016/j.matpr.2021.12.406
89. S. Fatima, I. Farzeen, A. Ashraf, B. Aslam, M. U. Ijaz, S. Hayat, M. H. Sarfraz, S. Zafar, N. Zafar, J. O. Unuofin, S. L. Lebelo and S. Muzammil, *Molecules,* **28(8)**, 3469(2023), https://doi.org/10.3390/molecules28083469
90. Z. Munanda, Z. Mahyiddin, S. Muhammad, I. Machdar and Z. Ulya, *Journal of Patchouli Essential Oil Products,* **1(2)**, 52(2022), https://doi.org/10.24815/jpeop.v1i2.28817

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