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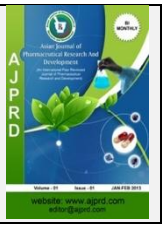

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Review Article

Nutraceuticals: -In Skin Care and Formulations A Review

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A B S T R A C T

The physiologically active ingredients that sustain health advantages are known as nutraceutical.Due to their therapeutic benefits, these products are crucial to human health care.The nutritional advantages, medicinal effects, and safety profile of nutraceuticals have earned them prominence.Nutraceuticals are wellknown throughout the world and are expanding in the sphere of services like illness prevention and health care promotion.For a better knowledge of nutraceuticals, this review has also provided instances and explanations of numerous drugnutraceutical interactions.Numerous nutraceutical patents have been filed in a variety of agricultur al and medical fields.In addition to being used for nutrition, nutraceuticals have been used as a support therapy for the prevention and treatment of a number of illnesses, including to lessen the negative effects of chemotherapy for cancer.Micronized food items a nd other nutraceutical supplements with enhanced health advantages are also produced thanks to nanotechnology.There has also been discussion of the most recent important discoveries (clinical research) on nutraceuticals that demonstrate the therapeutic effe ct of the bioactive compounds in these products on a range of illnesses.Numerous internal and environmental factors, including ho rmone imbalances, UV radiation, and the biological evolution of cells, all contribute to the ongoing aging of the skin.These internal and external factors increase the appearance of aging skin, which is characterized by telangiectasias, wrinkles, roughness, loss of e lasticity, and diminished firmness.Nutraceuticals have been researched all year long to combat and postpone a number of food-related issues.

Keywords: b-Carotene; Fatty acids; Lutein;Lycopene; Minerals; Nutraceuticals;Polyphenols; Vitamin C; Vitamin E;

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INTRODUCTION

Nutraceuticals are often described as a new generation of foods and dietary supplements that go beyond basic nutrition, offering potential health benefits. Many reviews highlight how these products can support skin health in different ways. However, there is still a lack of comprehensive evaluation of the nutraceuticals currently available in the market, especially in terms of whether their claimed benefits are truly backed by clinical evidence.

The skin, being the largest organ of the body, is constantly undergoing the process of aging—both from within (intrinsic aging) and due to external influences (extrinsic aging). Its primary function is to serve as a barrier, shielding the body from harmful agents like pathogens, ultraviolet (UV) radiation, chemical exposures, and even excessive water loss.

Unfortunately, constant exposure to such stressors leads to the generation of free radicals and triggers inflammation. These processes gradually damage collagen and elastic fibers, which are key components for maintaining skin's structure and resilience. Over time, this results in visible signs of aging such as roughness, fine lines, wrinkles, uneven pigmentation, broken capillaries (telangiectasias), reduced elasticity, and loss of firmness.

Structurally, the skin is made up of three main layers:
(a) the epidermis (outer layer),
(b) the dermis (middle supportive layer), and
(c) the hypodermis or subcutaneous tissue (the deeper layer providing cushioning and insulation).

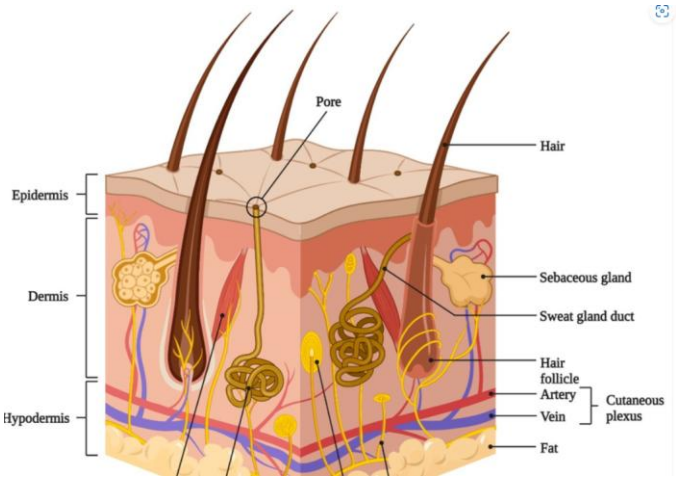

Figure 1: layers of human skin

1. Epidermis

- It is the outermost layer
- It contains keratinocytes (make keratin for strength), melanocytes (produce melanin for skin color), and Langerhans cells (immune defense)
- There are no blood vessels
- It constantly renews itself

2. Dermis

- Middle layer
- Contains collagen and elastin (strength and elasticity)
- Houses hair follicles, sweat glands, sebaceous glands (oil), blood vessels, and nerves

3. Hypodermis (Subcutaneous Layer)

- Deepest layer
- Composed of fat and connective tissue
- Provides insulation, energy storage, and shock absorption

Ultra violet radiation:-

- Exposure to ultraviolet (UV) radiation is one of the major contributors to skin aging and damage, leading to inflammation, breakdown of the extracellular matrix (ECM), degenerative changes, and even skin cancer. UV light is categorized into three types based on wavelength: long-wave UVA (320–400 nm), medium-wave UVB (280–320 nm), and short-wave UVC (100–280 nm). Fortunately, the ozone layer blocks UVC, but both UVA and UVB reach the Earth's surface. Of the two, UVB makes up only about 0.3% of solar radiation that reaches the ground, while UVA penetrates almost completely.

- The skin absorbs UV rays in a wavelength-dependent way—UVB is mostly absorbed by the epidermis (the outer layer), while UVA, with its longer wavelength, can penetrate deeper into the dermis. Solar UV radiation interacts with various molecules across these skin layers, triggering both beneficial and harmful effects. On the positive side, UV radiation helps the skin synthesize vitamin D, which is essential for bone health and immune function. Most people can make enough vitamin D with just brief sun exposure on areas like the hands, forearms, or legs. However, individuals with darker skin tones (such as Africans or African Americans) or those living in regions with low sunlight may not synthesize sufficient vitamin D from limited sun exposure. In such cases, dermatologists recommend obtaining vitamin D through diet or supplements rather than prolonged sun exposure, which increases the risk of damage.

- Skin aging itself is a complex process influenced by two mechanisms: intrinsic (internal) and extrinsic (external). Intrinsic or natural aging is unavoidable and shaped by genetics, cellular metabolism, hormonal changes, and the simple passage of time. Clinically, it presents as thinning skin, increased fragility, and a gradual loss of elasticity. Extrinsic aging, on the other hand, is largely driven by environmental factors like chronic sun exposure. Excessive UV radiation generates reactive oxygen species (ROS), creating a state of oxidative stress. This leads to harmful effects such as lipid and protein oxidation, DNA damage, and loss of mitochondrial function.

- To counteract this, the skin activates its natural defense system by producing antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), and thioredoxin reductase (TrxRs), as well as relying on antioxidant molecules like glutathione (GSH), vitamin E (α-tocopherol), and vitamin C (ascorbic acid). However, these defenses are not always sufficient, especially after excessive sun exposure or in the presence of carcinogenic agents, leaving the skin vulnerable to oxidative injury and accelerated aging.

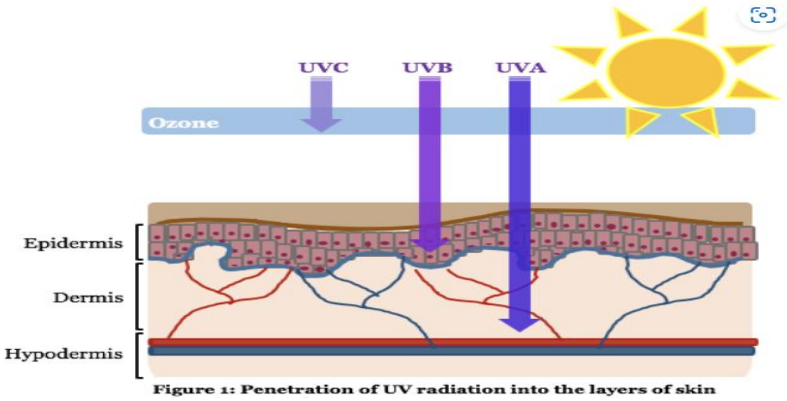

Figure 2: Penetration of the UV Rays in the Human Skin Layers

Skin complexion plays a key role in determining how sensitive a person is to UV radiation and their overall risk of developing skin cancer. To help classify this, Dr. T.B. Fitzpatrick developed the "Fitzpatrick Scale" in the 1970s. This scale categorizes skin into six types (phototypes) based on pigmentation and how the skin reacts to sun exposure.

Another way to measure UV sensitivity is through the Minimal Erythematous Dose (MED). MED refers to the smallest dose of UV radiation—mainly UVB—needed to cause visible sunburn, which typically shows up as redness (erythema) or swelling (oedema) within 24–48 hours after exposure.

People with lower Fitzpatrick skin types (lighter skin tones) generally have lower MED values, meaning their skin burns more easily. This increased sensitivity is closely linked to a higher risk of melanoma and other forms of skin cancer.

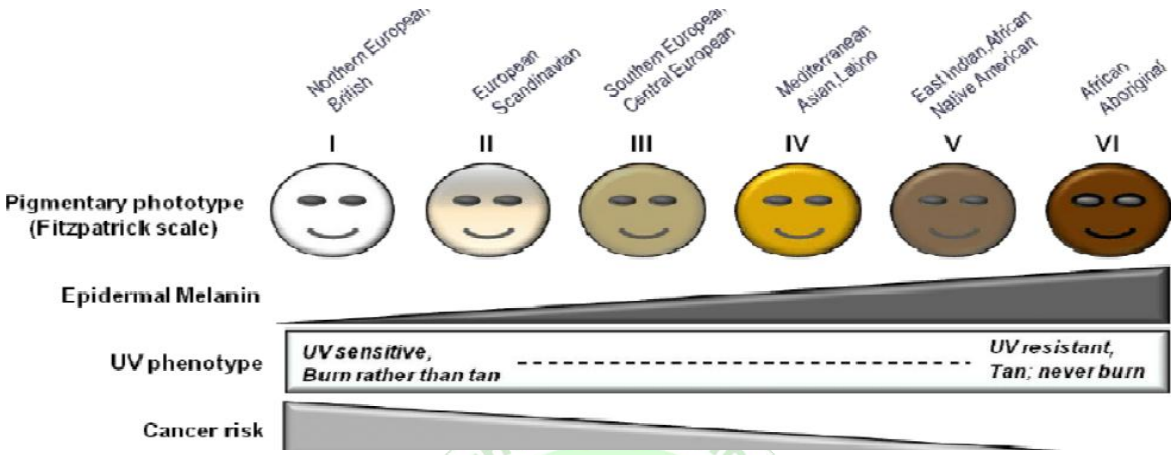

Figure 3: this shows how much pigmentation occurs due to sun's uv rays on the human skin and what can be their cancer risk level depending on the uv radiation

Skin physiology: -

Your skin is much more than just a covering—it's your body's first line of defense. It acts as a protective shield, keeping out harmful things like UV rays, germs, pollutants, and chemicals, while also preventing your body from losing too much water. At the same time, it helps you cope with changes in the environment, whether that's extreme heat, cold, wind, or humidity.One of the skin's most impressive jobs is regulating body temperature. On hot days,it cools you down by releasing sweat that evaporates, while in cold weather, it conserves heat by narrowing blood vessels and causing goosebumps—tiny muscle contractions that help trap warmth.The skin is also constantly renewing itself. Deep in the lower layers, fresh cells are produced. These gradually move upward, harden through a process called keratinization, and eventually die, forming the outermost layer that acts as a tough, protective shield. This ongoing cycle ensures your skin stays strong and able to handle everyday stress.The barrier itself is built like a brick wall: the cells (corneocytes) are the "bricks," and fats like cholesterol, fatty acids, and ceramides act as the "mortar" that holds them together. This structure keeps your skin firm and intact. Natural moisturizing factors inside the skin help lock in water, while oils from sebaceous glands add an extra layer of protection on the surface. On top of that, the skin maintains a slightly acidic pH, which makes it harder for harmful microbes to survive.Beneath all this lies the subcutaneous fat layer, or subcutis. This layer doesn't just cushion your body; it stores energy, keeps you warm, and absorbs shocks to protect deeper tissues. Interestingly, scientists have also discovered that it works like an active organ, producing hormones that affect different processes in the body. As we age, this fat layer shifts or decreases, which is one reason why the shape of our face and body changes over time.

Skin Health: -

Healthy skin plays a big role in how we look and feel. A clear, even complexion and a smooth surface naturally make the face appear more attractive, while overall skin health is often associated with youthfulness. In fact, research shows that women with healthy-looking skin are often perceived as being several years younger than their actual age. Four main qualities define youthful, healthy skin: an even tone, smooth texture, firmness, and a natural glow. Many factors can influence these qualities. External stressors—like harsh temperatures, UV radiation, pollution, chemical or mechanical irritation, and even psychological stress—can all leave lasting effects on the skin. Natural aging also contributes significantly. With time, the skin's supportive proteins, collagen and elastin, gradually weaken, and its ability to retain moisture declines due to reduced hyaluronic acid production. This leads to visible changes such as wrinkles, loss of elasticity, and sagging. On top of this, oxidative stress—caused by an excess of free radicals overwhelming the body's antioxidant defenses—accelerates aging by damaging both the outer (epidermis) and deeper (dermis) layers of the skin. As skin ages, its barrier functions also become less efficient. The "inside-out" barrier, which prevents water loss (measured as trans-epidermal water loss or TEWL), weakens partly because of reduced blood circulation. Meanwhile, the "outside-in" barrier, which blocks harmful substances from entering, also becomes more fragile as the skin thins, especially in the stratum corneum, and as cellular metabolism slows down. This

makes the skin more permeable and more sensitive to irritants. Inflammatory skin conditions at any age can further compromise these barriers, making it harder for the skin to maintain its natural balance and resilience.

To assess improvements in skin health, researchers often use parameters such as:

- Hydration levels
- Trans-epidermal water loss (TEWL)
- Elasticity and firmness
- Wrinkle depth and reduction
- Collagen content and synthesis
- Surface smoothness and roughness
- Dermal thickness and density
- Overall appearance and perceived skin quality
- UV protection and resistance to sun damage
- Inflammation and immune response
- Lipid and ceramide composition
- Pigmentation and melanin content
- Healing and regenerative capacity
- Oxidative stress markers
- Sebum production and surface lipid balance

Nutrition also plays a powerful role in skin health. Deficiencies caused by poor diet or restrictive eating can show up visibly on the skin. On the other hand, research suggests that certain nutrients—including amino acids, carotenoids, flavonoids, and vitamins A, C, D, and E—can support skin structure and function, enhance appearance, and even slow down visible aging.

Search Strategy and Criteria for the Assessment of Nutraceuticals Affecting Skin Health: -

This review organizes nutraceuticals based on their proven benefits for skin health, with the classifications shaped by the strength and quality of available scientific evidence. As highlighted by Kalra EK, the real test of any claimed benefit lies in its scientific validation. Similarly, the European Nutraceuticals Association (ENA) evaluates and presents nutraceuticals according to the level of supporting evidence. For this assessment, an extensive literature search was carried out using PubMed (National Center for Biotechnology Information, National Library of Medicine, Bethesda, MD, USA) and Google Scholar (Google LLC, Mountain View, CA, USA) databases, covering publications up to December 2024. The search included preclinical and clinical studies, systematic reviews, and meta-analyses. Importantly, the studies reviewed generally used dosages that were in line with the recommended intake ranges for the respective products, though some variation was observed.

Amino acids

N-Acetylcysteine: -

- N-acetylcysteine (NAC), chemically known as *(2R)-2-acetamido-3-sulfanylpropanoic acid* ($C_5H_9NO_3S$), is a thiol-containing compound derived from the naturally occurring amino acid L-cysteine.
- It appears as a white crystalline powder, has a slightly sour taste and a faint vinegar-like (acetic) smell, and remains stable under normal room conditions.
- NAC is essentially a prodrug—meaning it gets converted in the body into L-cysteine, which then helps produce glutathione.
- Glutathione is one of the body's most powerful natural antioxidants, helping protect cells from damage caused by oxidative stress.

Pharmacokinetic property	Value
Oral dose	200-800 mg
Bioavailability	5%
Peak plasma concentration	0.35-0.40 mg/L (1-2 h)
Volume of distribution	0.33-0.47 L/kg
Terminal half life	>6 h
Excretion	70% (feces), 30% (urine)

- As we get older, our body's ability to produce glutathione slows down, which can make us more vulnerable to oxidative damage.
- Supplementing with NAC has been shown to boost glutathione levels, and studies have noted a reduction in oxidative stress and markers of cell damage in the blood after its use.
- Although NAC is available in both oral and topical forms, there's currently no official Recommended Dietary Allowance (RDA) set by the U.S. Institute of Medicine's Food and Nutrition Board. More clinical research is needed to figure out the ideal daily dose of NAC—especially for specific goals like improving skin health.

Carotenoids: -

Carotenoids are a diverse group of naturally occurring pigments found in plants, with more than 600 identified compounds. Of these, around 20 are known to be present in human blood and tissues, where they play important biological roles. These pigments are fat-soluble and are best recognized for their ability to act as powerful antioxidants. Specifically, carotenoids are effective scavengers of reactive oxygen species (ROS), the unstable molecules that contribute to oxidative stress and cellular damage. By neutralizing ROS, carotenoids help protect skin and other organs from the harmful effects of oxidative stress, which is closely linked to aging, inflammation, and damage caused by ultraviolet (UV) radiation.

b-Carotene: -

- β-Carotene is one of the most important dietary carotenoids, primarily because it serves as a precursor to vitamin A (retinol). Once metabolized, it contributes to maintaining healthy vision, immune function, and skin integrity.
- Beyond its nutritional role, β-carotene functions as a potent antioxidant. It helps shield cells from oxidative stress by preventing lipid peroxidation caused by free radicals and singlet oxygen.

- This protective effect is particularly relevant for skin, where oxidative damage accelerates aging and increases vulnerability to environmental stressors.
- Another significant property of β-carotene is its photoprotective ability. Regular intake has been shown to increase the minimal erythema dose (MED)—the threshold of UV exposure required to produce skin redness—thereby reducing the risk of sunburn.
- It also plays a role in defending the immune system from UV-induced suppression, further supporting skin health.
- Dietary sources of β-carotene include green leafy vegetables (such as spinach and kale), orange-colored root vegetables (like carrots and sweet potatoes), and yellow to orange fruits (such as mangoes and apricots).
- Since β-carotene converts to vitamin A, its recommended intake is expressed in retinol activity equivalents (RAE). According to the Institute of Medicine, 2 µg of supplemental all-trans-β-carotene equals 1 RAE, whereas 12 µg of dietary β-carotene equals 1 RAE.
- Based on this, the daily recommended intake for men is about 1,800 µg RAE from supplements and 10,800 µg RAE from diet, while for women it is 1,400 µg RAE from supplements and 8,400 µg RAE from food sources.

Lutein and Zeaxanthin: -

- A recent clinical study found that taking 10 mg of lutein daily improved skin hydration, elasticity, and lipid content, highlighting its role in maintaining healthy skin.
- Along with zeaxanthin, lutein acts as a powerful antioxidant that accumulates in the skin, where it helps filter blue light.
- This is important because blue light—from both sunlight and artificial indoor sources—can trigger the formation of free radicals, leading to oxidative stress and potential damage to organs exposed to light, including the eyes and skin.
- Since the human body cannot synthesize lutein or zeaxanthin, they must be obtained through diet.
- They are abundant in green leafy vegetables, while eggs provide a more bioavailable form. Although no official Recommended Dietary Allowance (RDA) has been set, research suggests benefits at 6–10 mg of lutein and 2 mg of zeaxanthin daily.
- The American Optometric Association specifically advises these amounts to support eye health and reduce risks of age-related macular degeneration and cataracts

Lycopene Content of Selected Foods		
Food	Amount	MG
Tomato paste, canned	1 cup	75.4
Tomato juice, canned	1 cup	22
Watermelon, raw	1 wedge (1/16 of a melon that is 15 inches long x 7.5 inches in diameter)	13
Tomatoes, raw	1 cup	4.6
Catsup (ketchup)	1 tablespoon	2.5
Pink grapefruit, raw	½ grapefruit	1.7

Lycopene: -

- Lycopene is a unique carotenoid that, unlike β-carotene, does not convert into vitamin A. Instead, its strength lies in being the most effective quencher of singlet oxygen, making it one of the most powerful antioxidants in its family.
- Research has shown that lycopene-rich foods, particularly tomato paste, can significantly reduce UV-induced skin redness (erythema) and lower the activity of MMP-1, an enzyme responsible for breaking down collagen and contributing to skin aging.
- Higher concentrations of lycopene in the skin have also been linked to smoother skin texture and reduced roughness, further highlighting its protective and anti-aging potential.
- Natural sources of lycopene include tomatoes, pink grapefruit, and watermelon, all of which provide this antioxidant in a readily absorbable form.
- Currently, there is no official Recommended Dietary Allowance (RDA) for lycopene as set by the Institute of Medicine.
- More clinical research is needed to determine the ideal intake levels for maximizing health and skin benefits, while also evaluating potential risks from supplementation.

Minerals

Copper: -

- Copper is an essential trace mineral that occurs naturally in soil and plays a vital role in maintaining healthy skin. It functions as a crucial cofactor for several enzymes, including lysyl oxidase, which is responsible for collagen crosslinking, and tyrosinase, which is involved in skin pigmentation.
- By stimulating the proliferation of keratinocytes and fibroblasts—two key cell types in the skin—it enhances tissue repair and collagen production.
- This activity helps restore damaged skin, improve elasticity, and maintain firmness. Moreover, copper's natural anti-inflammatory and antibacterial properties make it valuable in topical applications, where it has been used to accelerate wound healing and protect against infection.
- Dietary copper is widely available, with the richest sources found in nuts, seeds, shellfish, meats, and whole grains. According to the Food and Nutrition Board of the Institute of Medicine, the recommended dietary allowance (RDA) for copper is 900 µg per day for adults over 19 years. However, while copper's role in overall health is clear, further clinical studies are

needed to identify the optimal daily intake for maximizing skin health and anti-aging benefits.

Curcumin: -

- Curcumin is a polyphenol derived from the turmeric spice. It has a yellow pigment, which is responsible for the characteristic yellow color of curry [34].
- Curcumin serves many biologically active roles, as does EGCG, including the alike anticarcinogenic, anti-inflammatory, and antioxidant roles.
- Curcumin's anti-inflammatory properties are exhibited through its ability to suppress proinflammatory cytokines including chemokines, cyclooxygenase-2, prostaglandin E2, MMPs, interleukins (IL) such as IL-6 and IL-12, and tumor necrosis factor-a. In addition, curcumin serves as an antioxidant by suppressing ROS production, scavenging free oxygen radicals, and inhibiting lipid peroxidation.In 2017, Shailaja et al. studied curcumin's anti-inflammatory properties in albino rats as a potential anti-aging nutraceutical.
- The study compared three dosages of oral daily curcumin supplementation against two different standard rat feed and water diets. They report a statistically significant decrease in the C-reactive protein levels in the curcumin-supplemented group compared with the two control groups.
- The Food and Nutrition Board of the Institute of Medicine's RDA of curcumin has not been established; however, the United States Food and Drug Administration (FDA) has labeled curcumin safe for ingestion and pharmacologic use.
- In 2016, Pal et al reported two studies of safe oral supplementation of curcumin between 2–8 g per kg daily. Further studies are needed to determine the optimal daily allowance while accessing for supplementation health risks.

Vitamins

Vitamin c: -

- Vitamin C, also known as ascorbic acid, is a vital water-soluble nutrient that the human body cannot synthesize on its own. Because we lack the ability to produce it de novo, maintaining adequate levels depends entirely on dietary intake.
- Once consumed, vitamin C undergoes oxidation to form dehydroascorbic acid, which is taken up into cells through glucose transporters. Inside the cell, it is reduced back to ascorbic acid, allowing it to participate in a wide range of biological processes.
- One of vitamin C's most important roles is as a potent antioxidant. It neutralizes harmful free radicals, helping protect lipids, proteins, and DNA from oxidative stress.
- This activity is particularly valuable for skin and connective tissues, where oxidative damage contributes to aging and impaired healing. Beyond its antioxidant capacity, vitamin C also serves as an essential cofactor in collagen biosynthesis. By donating electrons during collagen hydroxylation, it supports the maturation of both intracellular and extracellular collagen fibers—critical for skin strength, elasticity, and wound repair.
- Dietary vitamin C is abundant in many fruits and vegetables. The richest sources include citrus fruits (oranges and grapefruits), kiwifruit, strawberries, red and green peppers, broccoli, and Brussels sprouts.
- Regular intake through these foods has been shown to raise both plasma and skin concentrations, enhancing overall antioxidant defense.
- According to the Food and Nutrition Board of the Institute of Medicine, the recommended dietary allowance (RDA) for vitamin C is 90 mg per day for men and 75 mg per day for women aged 19 years and older. Ensuring adequate intake supports not only general health but also skin resilience and youthful appearance.

Vitamin E: -

- Vitamin E refers to a family of fat-soluble compounds, with alpha-tocopherol (αT) being the most abundant and biologically active form in the human body. Among its key functions, αT acts as a potent antioxidant, neutralizing free radicals, protecting cell membranes, and reducing oxidative damage that can trigger premature cell death.
- It also helps stabilize cellular structures and minimizes the activation of nuclear factor kappa B (NF-κB), a protein complex linked to inflammation.
- One of vitamin E's notable roles is its photoprotective effect. Studies have shown that αT, especially when taken together with vitamin C, can increase the minimal erythema dose (MED), meaning it raises the skin's tolerance to UV radiation and lowers the risk of sunburn.
- However, UV exposure itself depletes the skin's vitamin E reserves, contributing to photoaging. Encouragingly, both oral supplementation and topical application can restore and boost skin levels of αT, strengthening its defense against UV-induced damage.
- The richest natural dietary sources of vitamin E are plant seeds and nuts, including sunflower seeds, almonds, peanuts, walnuts, pecans, pistachios, and sesame seeds. Smaller amounts are also present in various fruits and vegetables.
- Currently, the optimal daily allowance of vitamin E for skin health remains undefined, and further research is needed to establish safe and effective intake levels for maximizing its protective benefits.

CONCLUSIONS:

The purpose of this review was to provide dermatologists with a clearer understanding of the mechanisms, efficacy, and potential dermatologic benefits of some of the most popular nutraceuticals. For most individuals, a balanced and varied diet supplies sufficient amounts of these nutrients to support skin health. However, in cases where diets are lacking in key components, targeted supplementation may offer added benefit. This highlights the importance of physicians and other providers openly discussing nutraceutical use with patients—emphasizing not only the potential benefits but also the risks of overconsumption, as even beneficial compounds can

become harmful when taken in excess. Given the rapid growth of online marketplaces and the frequent promotion of unverified products, it is equally critical that patients are guided toward safe, authentic, and medically certified sources of nutraceuticals.

The evidence gathered in this review suggests that nutraceuticals supported by strong scientific data are generally well tolerated, safe, and effective for practical use in dermatology. Still, it is striking that only 17 out of nearly 50 products evaluated demonstrated meaningful clinical efficacy. This disparity reflects the ongoing gap between marketing claims and the actual body of scientific evidence. On a positive note, some of the most widely used compounds—including vitamins, collagen peptides, omega-3 fatty acids, and hyaluronic acid—are among those with the strongest documentation supporting their effectiveness in improving skin health.

The field of nutraceutical research is rapidly evolving, with the number of clinical studies increasing each year. As new findings emerge, reclassification of individual nutraceuticals may be necessary—upgrading their evidence levels if new trials confirm benefits, or downgrading them if claims fail to hold up under further scrutiny. Future research could also reshape the safety profiles of some products, though based on current knowledge, serious safety concerns remain rare for substances already approved as dietary supplements.

Ultimately, the classification framework proposed in this review may help both healthcare professionals and consumers identify nutraceuticals with the greatest likelihood of real clinical benefit. Nevertheless, it is important to acknowledge that many aspects of nutraceutical efficacy extend beyond the scope of this paper. Readers seeking more detailed evaluations of specific compounds may benefit from exploring the growing body of specialized reviews that continue to expand this important field.

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