

A Review on Lycopene Derived from Watermelon Based Herbal Sunscreens

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Abstract- *The evolution of sun protection has increasingly shifted from synthetic chemical filters—often associated with environmental toxicity and adverse health effects—toward natural, plant-based alternatives. This review explores the photoprotective potential of lycopene derived from watermelon (Citrullus lanatus), a potent carotenoid with superior antioxidant properties. Unlike traditional UV filters that physically block radiation, lycopene functions as an internal biological shield, quenching singlet oxygen and neutralizing reactive oxygen species (ROS) generated by UV exposure. This paper highlights the distinct advantages of watermelon-derived lycopene, specifically its high bioavailability due to the prevalence of the cis-isomeric form, compared to other sources like tomatoes. Furthermore, the study examines the synergistic efficacy of lycopene when combined with mineral blockers such as zinc oxide and titanium dioxide, offering broad-spectrum protection while mitigating photoaging and inflammation. Despite formulation challenges regarding lipophilicity and stability, advanced delivery systems such as nano-emulsions show promise in enhancing efficacy. Conclusively, watermelon-derived lycopene represents a sustainable, reef-safe, and effective bioactive ingredient for the next generation of herbal cosmeceuticals.*

INTRODUCTION

The quest for effective sun protection has driven a continuous evolution in sunscreen technology. Historically, early forms of sunscreens were rudimentary, often concoctions of natural oils and zinc oxide used to create a physical barrier against the sun's rays. The 20th century saw the rise of chemical sunscreens, which absorb ultraviolet (UV) radiation. While highly effective, these synthetic compounds have raised concerns about potential health and environmental impacts. This has fueled a renewed interest in natural and herbal alternatives, leading to the exploration of plant-derived compounds that can offer photoprotection with a more favorable safety profile. One such compound gaining significant attention is **lycopene**, a powerful carotenoid found abundantly in watermelon.

Lycopene is a naturally occurring pigment responsible for the red color in many fruits and vegetables.

Beyond its role as a colorant, it is a potent antioxidant that can neutralize harmful free radicals generated by UV exposure. This antioxidant activity helps to mitigate the cellular damage that leads to photoaging and skin cancer. Unlike many synthetic sunscreens, which primarily act as UV filters, lycopene-based sunscreens work by providing an internal shield against oxidative stress. This dual-action approach—filtering UV rays and repairing cellular damage—is a key advantage.

Ideal sunscreen characteristics include broad-spectrum protection (against both UVA and UVB rays), water resistance, photostability, and non-irritating properties. While lycopene itself does not offer a high sun protection factor (SPF) alone, it significantly boosts the efficacy of other natural UV filters like zinc oxide and titanium dioxide. This synergistic effect allows formulators to create sunscreens with excellent protection without relying on high concentrations of chemical filters.

Advantages of Lycopene Derived- Watermelon in Sunscreens:

Strong Antioxidant Protection – Lycopene neutralizes singlet oxygen and reduces oxidative damage in skin cells.
Natural and Safe – Being plant-derived, it avoids risks associated with synthetic chemicals (endocrine disruption, allergic reactions).
Eco-Friendly – Unlike oxybenzone and octinoxate, lycopene does not harm marine life or coral reefs.
Synergistic Action – Works well with other botanicals (green tea polyphenols, aloe vera, vitamin E) to provide holistic skin protection.
Anti-Aging Effects – Prevents collagen breakdown and reduces wrinkle formation, adding cosmetic appeal.

Disadvantages of Lycopene Derived Watermelon in Sunscreens:

The disadvantages of herbal sunscreens, in general, can include a lower SPF compared to their synthetic counterparts, a thicker or chalkier consistency, and a less pleasant feel on the skin. However, ongoing research and advanced formulation techniques are addressing these issues, making herbal sunscreens more elegant and user-friendly. The

use of watermelon-derived lycopene also adds a unique advantage: it's a sustainable and widely available resource.

LIMITATIONS AND CHALLENGES

Despite its potential, watermelon-derived lycopene faces formulation challenges:

- **Low Water Solubility** – Being lipophilic, lycopene requires specialized delivery systems.
 - Photo- and Heat-Sensitivity – Degrades upon prolonged exposure to oxygen, light, and high temperature.
- **Limited UV Absorption** – Unlike zinc oxide or titanium dioxide, lycopene does not physically block UV radiation. Thus, it acts more as a complementary antioxidant rather than a primary UV filter.
- ❖ **Ideal Characteristics of Herbal Sunscreens with Lycopene**
 - An ideal lycopene-based herbal sunscreen should meet the following requirements:
 - Broad-spectrum protection against both UV-A and UV-B rays.
 - Strong antioxidant and anti-inflammatory potential.
 - Photostability and resistance to degradation.
 - Safe, hypoallergenic, and suitable for all skin types.
 - Non-greasy and cosmetically acceptable formulation.
 - Environmentally sustainable and reef-safe.

To overcome lycopene's limitations, advanced delivery systems such as nano-emulsions, solid lipid nanoparticles, liposomes, and biodegradable polymeric carriers have been developed, significantly improving its stability, skin penetration, and efficacy

Background and Historical Perspective

Human beings have always been exposed to solar radiation, and protection from its harmful effects has been a necessity since antiquity. The earliest evidence of sun-protective practices can be traced back to the ancient Egyptians, who used extracts of rice bran, jasmine, and lupine seeds to reduce tanning and protect the skin. In ancient Greece, olive oil was widely used for moisturizing and providing limited protection against sunlight, while Ayurvedic and Chinese medicine recommended turmeric, sandalwood, and various herbal pastes for maintaining skin health under sun exposure.

The scientific concept of ultraviolet (UV) radiation as a health hazard gained momentum only in the 19th and 20th centuries, leading to the development of chemical sunscreens such as para-aminobenzoic acid (PABA) and cinnamates. While effective, these synthetic agents were soon criticized for their adverse effects, including skin irritation, hormonal disruption, photo-instability, and environmental toxicity, particularly coral reef bleaching. Consequently, attention shifted toward natural bioactive compounds capable of delivering skin protection without adverse ecological and health concerns.

THE WORLD HEALTH ORGANIZATION (WHO):

The World Health Organization (WHO) strongly recommends the consistent use of broad-spectrum sunscreen with a minimum SPF of 15 or higher during any outdoor activity to protect the skin from the harmful effects of ultraviolet (UV) radiation. Continuous exposure to UVA and UVB rays can lead to a wide range of adverse outcomes, including sunburn, premature skin aging (photoaging), pigmentation disorders, DNA damage, and a significantly increased risk of skin cancers, particularly melanoma, basal cell carcinoma, and squamous cell carcinoma. This recommendation is especially important for individuals who participate in outdoor sports, swimming, or physical exercise, as these activities often involve prolonged sun exposure and heavy perspiration that can reduce sunscreen effectiveness. To ensure adequate protection, WHO advises reapplying sunscreen every two hours, or even more frequently in cases of swimming, sweating, or towel drying, as these actions can remove or dilute the protective layer.

Additionally, WHO highlights the importance of using the correct quantity—approximately 2 mg of sunscreen per cm² of skin, which equals about one teaspoon for the face and neck and two tablespoons for the entire body—along with adopting complementary measures such as wearing protective clothing, wide-brimmed hats, and UV-blocking sunglasses, and seeking shade during peak sunlight hours (10 a.m. to 4 p.m.).

In recent years, public awareness has grown regarding the negative effects of certain synthetic UV filters, such as oxybenzone, octinoxate, and avobenzone, which have been associated with skin irritation, hormonal disruption, and environmental damage, particularly to marine ecosystems and coral reefs.

When incorporated into sunscreen formulations, Lycopene works synergistically with mineral UV filters like zinc oxide and titanium dioxide, as well as other natural antioxidants such as vitamin E, green tea polyphenols, and

aloe vera extracts, to enhance the skin's defense against UV damage. It also offers the advantage of being non-toxic, biodegradable, and environmentally safe, making it an ideal choice for eco-conscious skincare. Furthermore, Lycopene's lipophilic nature allows it to integrate easily into skin cells, supporting long-term protection and repair. The growing inclusion of Lycopene and other natural bioactive ingredients in modern sunscreen products reflects a global shift toward safer, sustainable, and more effective sun protection solutions.

PLANT PROFILE (WATERMELON)

Botanical Classification:

- Kingdom:** Plantae
- Division:** Angiosperms
- Class:** Eudicots
- Order:** Cucurbitales
- Family:** Cucurbitaceae
- Genus:** Citrullus
- Species:** Citrullus lanatus

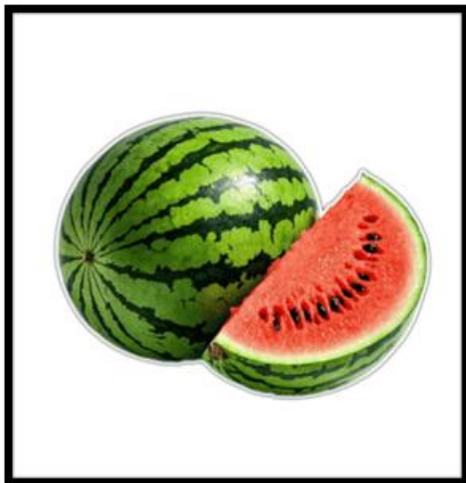


Fig.1 Watermelon

Common Names:

- English:** Watermelon
- Hindi:** तरबूज (Tarbooj)
- Marathi:** कलिंगा (Kalingad)

Geographical Distribution:

- Native to Africa, widely cultivated in tropical and subtropical regions worldwide, including India, China, and the USA.

Morphology:

- Plant Type:** Creeping vine with tendrils.
- Leaves:** Large, lobed and green.
- Flowers:** Yellow, unisexual flowers.
- Fruits:** Large, round to oblong berries with a thick rind (green with dark stripes) and juicy red or yellow flesh containing seeds.

WHAT IS LYCOPENE?

Lycopene is a naturally occurring carotenoid pigment responsible for the red to pink coloration in fruits such as watermelon, tomato, pink guava, red grapefruit, and papaya. Chemically, it is an acyclic isomer of β -carotene with the molecular formula $C_{40}H_{56}$. Unlike some other carotenoids, lycopene lacks provitamin A activity but is known for its exceptional antioxidant properties.

Structurally, lycopene consists of a long chain of conjugated double bonds (11 in total), which are responsible for its strong singlet oxygen-quenching ability and free radical-scavenging activity. It is highly lipophilic and is typically stored in cell membranes and lipophilic compartments of the body.

Watermelon (*Citrullus lanatus*) is considered one of the best natural sources of lycopene, especially in its cis-isomeric form, which is more bioavailable compared to the all-trans form found in raw tomatoes.

Lycopene: A Potent Natural Antioxidant:

Among naturally occurring phytochemicals, lycopene, a carotenoid responsible for the red color of fruits like watermelon, tomato, and pink guava, stands out as one of the most powerful singlet oxygen quenchers. Its antioxidant activity has been reported to be twice as high as β -carotene and ten times more effective than α -tocopherol in neutralizing free radicals [3]. Reactive oxygen species (ROS) generated by UV exposure can cause oxidative stress, lipid peroxidation, DNA damage, and collagen degradation, accelerating skin aging and increasing the risk of skin cancer [4]. Lycopene's ability to scavenge ROS, inhibit inflammatory pathways, and stabilize cellular membranes positions it as a natural candidate for photoprotection.

Phytochemical Constituents:

- Lycopene:** A potent carotenoid with antioxidant and photoprotective properties.
- Vitamin C (Ascorbic Acid):** Enhances collagen synthesis and provides antioxidant

benefits.

- **Flavonoids:** Aid in free radical scavenging.
- **Aminoacids (Citrulline):** Supports skin hydration and anti-aging.
- **Phenolic Compounds:** Contribute to UV protection and anti-inflammatory effects.

Medicinal & Cosmetic Uses:

- Acts as a natural sunscreen due to lycopene's ability to absorb UV radiation.
- Provides anti oxidant protection against free radicals and oxidative stress.
- Helps in skin hydration and brightening due to vitamin C content.

Lycopene present in various Herbal Plants

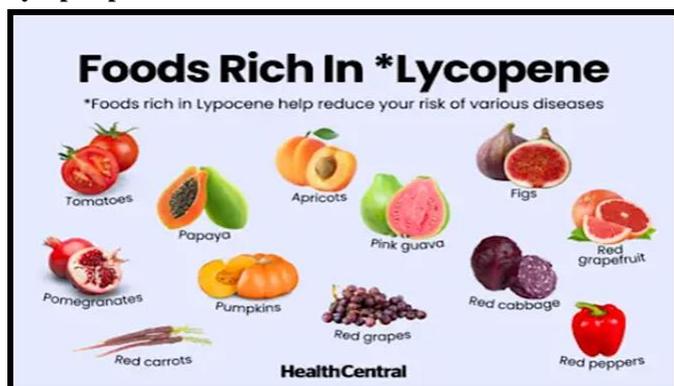


Fig 2 : Foods Rich in Lycopene

WATERMELON AS A SOURCE OF LYCOPENE:

While tomatoes are traditionally considered the richest source of lycopene, watermelon (*Citrullus lanatus*) offers distinct advantages. Research has shown that the lycopene in watermelon is highly bioavailable because it predominantly exists in the cis-isomeric form, which is more easily absorbed by the human body compared to the all-trans form prevalent in tomatoes. Moreover, watermelon cultivation is sustainable, widely practiced, and cost-effective, making it a scalable source of lycopene for industrial applications. Perkins-Veazie and Collins reported that watermelon contains 40% more bioavailable lycopene than raw tomatoes, while additional studies highlight its stability when processed under controlled conditions. Thus, watermelon-derived lycopene is not only a dietary antioxidant but also an emerging candidate for dermatological formulations, especially herbal sunscreens.

Aloe Vera:

The leaves of *Aloe vera* and *A. barbadensis* are the source of aloe vera gel. Aloe vera gel is widely used in cosmetics and toiletries for its moisturizing and revitalizing action. It blocks both UVA and UVB rays and

maintain skin's natural moisture balance. The enzyme bradykinase in aloe stops the sunburns and stimulates immune system intervention. Acemannan which is D-isomer mucopolysaccharides speeds up the repair phase and the increased production of fibroblasts and collagen. Aloe extracts and aloin from the plant have spectrophotometric peaks at about 297 nm and hence can act as a sunscreen for skin as well as hair.

The study was carried out to determine the photo protective activity of Aloe vera juice on Asian hair namely Black, grey which are chemically colored. Tryptophan content of hair treated with aloe vera juice before and after exposure to UV radiation. The tryptophan content measurements revealed that hair which was untreated and exposed showed higher degree of chemical damage while treated with Aloe vera juice offered protection from UV damage



Figure 3 : Aloe Vera

Pomegranate:

Pomegranate (*Punica granatum*) is having principle antioxidant polyphenols in its juice include the ellagitannins and anthocyanins. Weerakkody P et al explained the effect of applying sunscreen treatments to pomegranate fruit on the degree of sunburn damage and the effect of maturity and sunburn on the internal antioxidant concentration of the juice.



Figure 4 : Pomegranate

They evaluated effectiveness of three commercial sunscreen treatments Parasol1 (Crop Care, Australia), Surround1 (Ag NovaTech., Australia) and Anti-stress-5001 (EnviroShield Products Co., USA) For preventing sunburn damage of pomegranate, fruit was grown in Condobolin, New South Wales, Australia. The results showed that there was a significant effect of the sunscreen treatments ($p = 0.05$) for the severely sunburn damaged fruit category. Fruit treated with Surround1 (14.7%) and Parasol1 (12.8%) had significantly lower numbers of fruit with severe damage compared to the control fruit (25.8%); the effect using the anti-stress 5501 (19%) was not significant.

Tomato:

Tomato (*Lycopersicon esculentum*) fruit is the major source of lycopene and studied for its antioxidant activity in cosmetic and pharmaceutical field. Tomato is rich in lycopene, a widely studied powerful antioxidant and anti-carcinogenic carotenoid with strong reducing ability. Lycopene is a carotenoid, which gives red color to the tomatoes. It is not merely a pigment but a

powerful antioxidant, neutralizes free radicals especially those derived from oxygen, present under the lipid membrane and skin cover. Lycopene scavenges lipid radicals, reduces lipid peroxidation, and prevents erythema caused by UV radiation on the skin. Lycopene may reduce the damaging effect which UV light can have on the skin and can boost protection against both

the short term (sunburn) and cumulative effects of sun exposure (cancer).



Figure 5 : Tomato

Almond:

Almond is commercially known as almonds. Seeds are rich in polyphenolic compounds especially flavonoids and phenolic acids. The UVB protective property of this plant's skin extract was tested.



Figure 6 : Almond

Soybean Oil:

Soybeans (*Glycine Max*) are a nutritious and cost-effective addition to sunscreen. Soybeans originally come from China and are a rich source of essential fatty acids, protein, lecithin, iron and calcium in the diet. When used topically on the skin, soybean oil is a cost-effective moisturizer compared to other oils and has a natural SPF of 10



Figure 7 : Soybean

Saffron

Golmohammadzadeh SH et al evaluated saffron for its anti-solar activity. The pollens of the saffron (*Crocus sativus*) were dried and powdered in a grinder. The experimental formulations included a homosalate (8%) lotion reference, lotions with 2, 4 and 8% of grinded saffron, and the control lotion base without saffron. The lotions containing saffron were prepared like homosalate lotion reference according to FDA. The sun protection factors (SPFs) of the formulations were determined by an in vitro spectrophotometry method. The results of this study indicated that saffron can be used as a natural UV absorbin gagent.

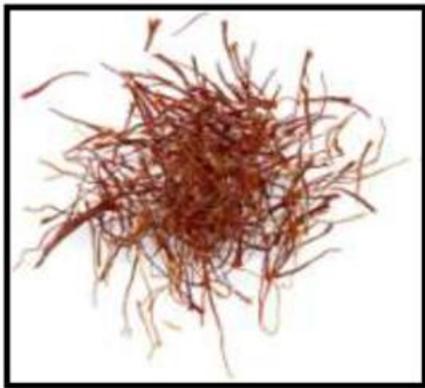


Fig 8 : Saffron

Key Properties of Lycopene

- Molecular Weight: 536.89 g/mol
- Solubility: Lipid-soluble, insoluble in water
- Stability: Sensitive to heat, light, and oxygen
- Color: Deep red

- Antioxidant Potential: Strong singlet oxygen quencher (more effective than β -carotene or vitamin E)

PHARMACOLOGICAL USES OF LYCOPENE

1. Skin Care and Sunscreens

Lycopene is increasingly used in dermatological formulations for its ability to protect against oxidative stress caused by UV radiation. It helps reduce photoaging, erythema (sunburn), and inflammation. In herbal sunscreens, it acts as an antioxidant shield to support the efficacy of physical or mineral UV filters.

2. Antioxidant Therapy

As a potent antioxidant, lycopene neutralizes free radicals, reducing cellular damage and oxidative stress. It is used in nutraceuticals and dietary supplements to support cardiovascular, skin, and prostate health.

3. Anti-inflammatory and Anti-aging Agent

Lycopene reduces the expression of pro-inflammatory cytokines and matrix metalloproteinases (MMPs), contributing to healthier skin and reduced signs of aging. It also helps in maintaining skin elasticity and hydration.

4. Functional Foods and Beverages

Lycopene is used as a functional ingredient in juices, fortified foods, and health drinks, especially for cardiovascular and prostate health due to its lipid-lowering and anti-inflammatory effects.

5. Cancer Chemoprevention

Several in vitro and epidemiological studies have suggested lycopene's role in reducing the risk of certain cancers (e.g., prostate, lung, and skin cancers), attributed to its anti-proliferative and anti-mutagenic properties.

6. Pharmaceutical and Nutraceutical Formulations

Lycopene is incorporated into capsules, soft gels, and topical ointments aimed at preventing oxidative cell damage, improving immune response, and supporting tissue regeneration.

NATURAL SUNSCREEN

The use of sunscreen as photo protecting agents for UV protection is becoming very popular. sunscreen preparation is defined as a formulation which, when applied topically, protects the treated area from sunburn. Sunscreens are used to aid the body's natural defense mechanisms to protect against harmful UV radiation from the sun. Its function is based on its ability to absorb, reflect or scatter the sun's rays. The Sun protection factor (SPF) of a sunscreen is calculated by comparing the amount of time needed to produce sunburn on sunscreen protected skin to the amount of time needed to cause sunburn on unprotected skin [1]. Efficacy of sunscreens depends on ability to protect against UV-induced sunburns, and their chemo preventive activity.

To overcome the effects caused by the UV exposure, sunscreen products are used which protects the skin from those harmful effects. The main function of sunscreen product is protecting the skin from solar UV radiation's damaging effects. The active ingredients in the sunscreen mainly scatter, reflect or absorb the UV radiation, before it is penetrated into the skin and prevents the components of skin from damage. A sunscreen product is more or less like an umbrella which protects from the harmful effects of rain. The sunscreen protects the skin from the harmful effects of UVR. The coating of sunscreen formulation on the skin should be uniform. The layer of sunscreen applied should be very thin.

The thickness should be less than 0.001 inches. Klein K (1997) reviewed on the Sunscreen products: formulation and regulatory considerations. He explained that formulation of the sunscreen is mainly based on the ingredient's polarity. The ingredients used can be separated according to its polarity. With the combination of viscosity and polarity of the ingredients, many types of sunscreen formulation can be prepared. Range of sunscreen product formulation types by overall formula polarity and product viscosity is shown in figure 4. This selection of formulation is mainly done for the uniform coating of sunscreen formulation in both valley and peaks of the skin. Sunscreen product applied to the skin surface with poor film formation and ideal film formation on the skin

TYPES OF SUNSCREENS

Sunscreens can be broadly classified into three main types based on their mechanism of action: physical, chemical, and herbal/natural. This classification is a useful way to understand the various approaches to sun protection. Here is a simplified representation:

Sunscreens

- **Physical (Mineral) Sunscreens**
 - Work by creating a physical barrier to reflect UV radiation.
 - Examples: Zinc Oxide, Titanium Dioxide.
- **Chemical Sunscreens**
 - Work by absorbing UV radiation and converting it into heat, which is then released from the skin.
 - Examples: Oxybenzone, Avobenzone, Octinoxate.
- **Herbal (Natural) Sunscreens**
 - Utilize plant-based ingredients for UV protection and antioxidant benefits.
 - Examples:
 - **UV Filters:** Red raspberry seed oil, carrot seed oil.
 - **Antioxidants:** Lycopene (from watermelon), Green Tea Extract, Vitamin E.
 - **Physical Filters:** Zinc Oxide, Titanium Dioxide (often used in combination with herbal extracts).

Herbal sunscreens, particularly those incorporating lycopene, are gaining popularity due to their perceived safety and nourishing properties. Unlike traditional chemical filters that can be irritating or cause allergic reactions, natural ingredients often offer additional benefits like moisturization and anti-inflammatory effects. Lycopene, in particular, is an excellent example of a natural active ingredient that provides more than just UV protection; it actively works to improve skin health.

EFFECTS CAUSED BY ULTRAVIOLET RADIATION (UVR) AND THE ROLE OF WATERMELON-DERIVED LYCOPENE

Ultraviolet radiation (UVR) is one of the most prominent environmental aggressors responsible for various forms of skin damage, including photoaging, inflammation, immunosuppression, and carcinogenesis. The skin, being the outermost organ, is constantly exposed to UVA (320–400 nm) and UVB (280–320 nm) rays, which together contribute to more than 90% of visible skin damage caused by solar radiation. While synthetic sunscreens often target the direct absorption or reflection of UV rays, they fail to address the oxidative and inflammatory aftermath of UV exposure. This is where natural antioxidants, particularly lycopene derived from watermelon (*Citrullus lanatus*), become highly valuable. Lycopene, a lipophilic carotenoid, plays a pivotal role in neutralizing the harmful effects caused by UVR. When extracted from watermelon, lycopene demonstrates high bioavailability and antioxidant capacity due to its naturally occurring cis-isomeric configuration. The integration of

watermelon-derived lycopene into herbal sunscreen formulations not only complements physical or chemical UV filters but also enhances skin resilience through its protective biochemical properties.

Below is an in-depth correlation between UVR-induced skin effects and the mitigating actions of watermelon-derived lycopene:

1. Oxidative Stress and Free Radical Generation

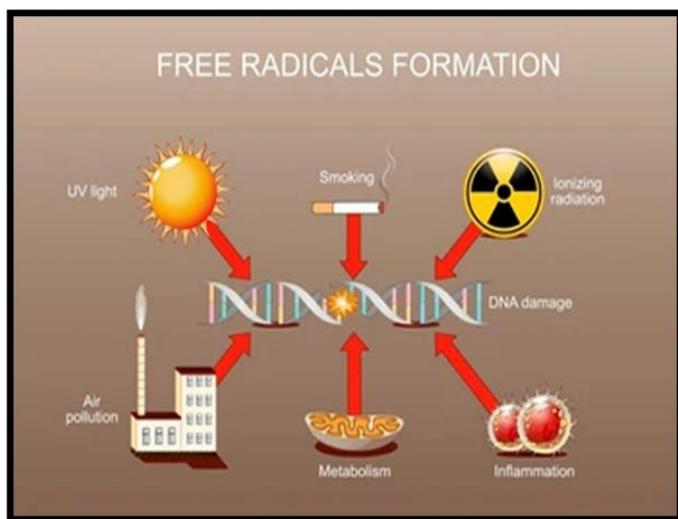


Fig 9 : Oxidative Stress and Free Radical Generation

- UVR, particularly UVA, stimulates the formation of reactive oxygen species (ROS) like singlet oxygen (1O_2), hydroxyl radicals, and superoxide anions. These species initiate lipid peroxidation, degrade cellular structures, and accelerate skin aging.
- Watermelon-derived lycopene acts as a powerful antioxidant, effectively quenching singlet oxygen and scavenging ROS. Studies indicate that lycopene is up to 10 times more effective than α -tocopherol and 2 times more effective than β -carotene in this regard. When topically applied or included in sunscreen formulations, it helps reduce oxidative damage to skin cells.

2. DNA Damage and Mutagenesis

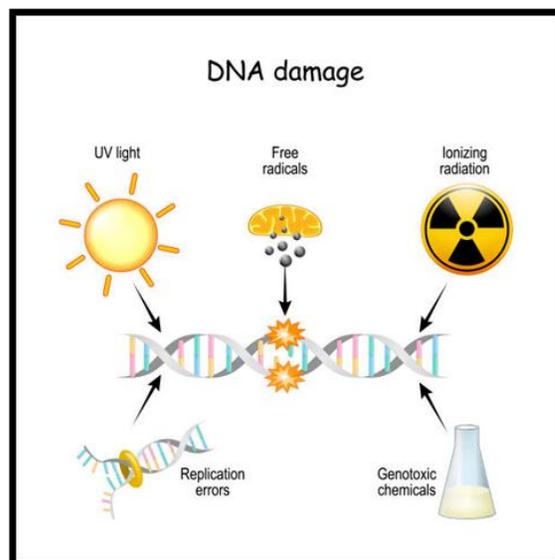


Fig 10 : DNA Damage and Mutagenesis

- UVB radiation directly damages DNA by inducing cyclobutane pyrimidine dimers (CPDs) and oxidative base modifications such as 8-oxo-deoxyguanosine. Unrepaired lesions may initiate mutations and carcinogenesis.
- Lycopene from watermelon can inhibit UV-induced DNA damage by reducing oxidative stress and enhancing the activity of DNA repair enzymes. Its ROS-scavenging action minimizes indirect DNA damage, thereby lowering mutation risk.

3. Photoaging (Premature Aging)

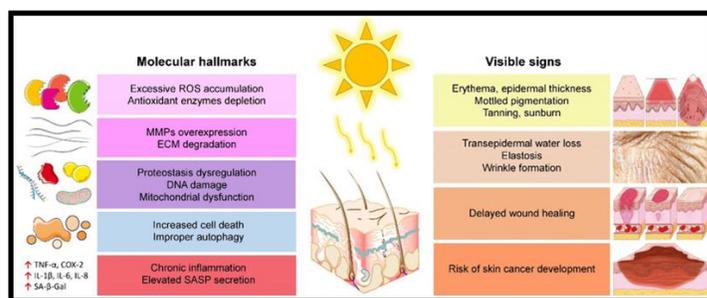


Fig 11 : Photoaging (Premature Aging)

- Chronic UV exposure upregulates matrix metalloproteinases (MMPs), particularly MMP-1, which degrade collagen and elastin fibers in the dermis. This results in wrinkles, sagging, and uneven skin tone. Watermelon lycopene inhibits MMP expression and supports collagen preservation. It also helps improve dermal thickness and elasticity when included in antioxidant-rich cosmetic formulations. This makes lycopene an ideal anti-aging agent in herbal sunscreens.

4. Inflammatory Response and Erythema

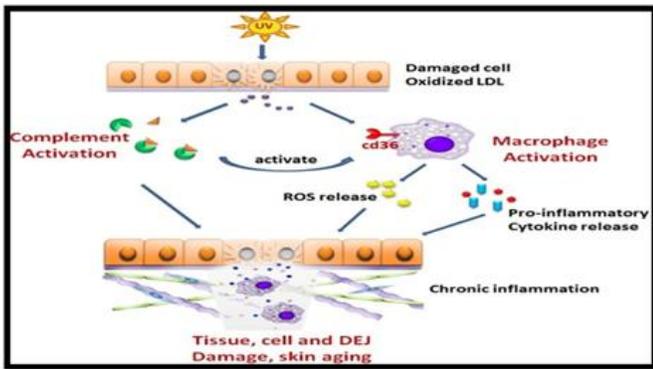


Fig 12 : Inflammatory Response and Erythema

- UVR activates pro-inflammatory pathways such as NF-κB and increases the production of cytokines like IL-6, IL-1β, and TNF-α. This leads to erythema (sunburn), edema, and discomfort.
- Topical or systemic use of watermelon-derived lycopene has been shown to reduce levels of inflammatory markers and suppress prostaglandin synthesis. Its incorporation into herbal sunscreens can thus reduce redness, burning sensations, and irritation post-UV exposure.

○
5. Immune Suppression

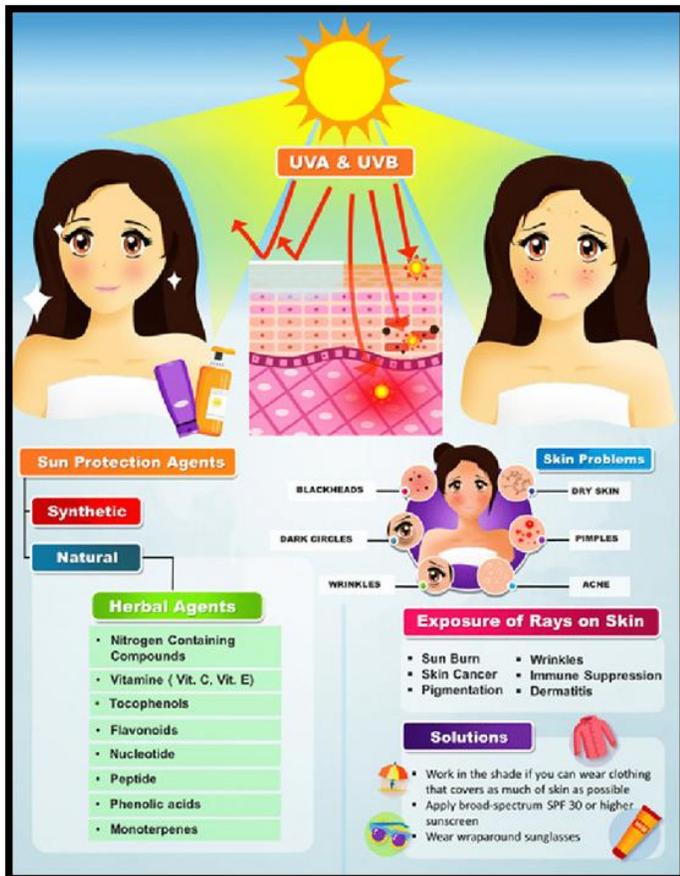


Fig 13 : Immune Suppression

- UV-induced immunosuppression reduces the skin's ability to detect and destroy abnormal or precancerous cells. This is mediated through the downregulation of Langerhans cells and increased IL-10 production.
- Lycopene helps maintain immune competence in the skin by regulating cytokine levels and preventing excessive ROS-mediated damage to immune cells. When used regularly, watermelon lycopene supports immunological surveillance and protects against photo immunosuppression.

6. Hyperpigmentation and Melanogenesis

- UVA radiation stimulates melanogenesis by upregulating tyrosinase activity in melanocytes, resulting in hyperpigmentation, melasma, and uneven skin tone.
- Watermelon lycopene exhibits tyrosinase-inhibiting activity and can reduce melanin synthesis, contributing to a more even complexion. It can serve as a natural skin-brightening agent when formulated in herbal sunscreens.

7. Risk of Skin Cancer

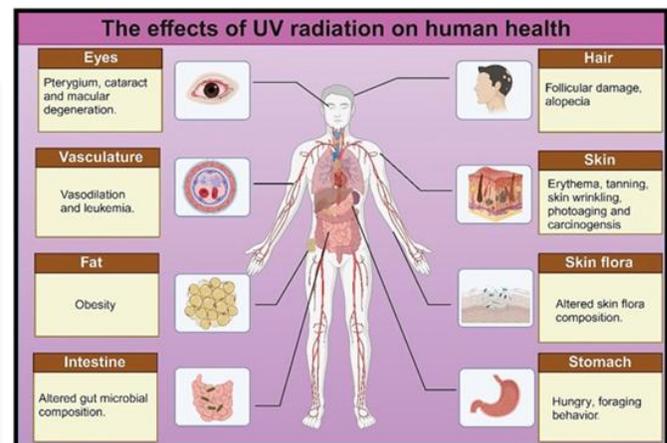


Fig 14 : Risk of Skin Cancer

- Persistent DNA damage and immunosuppression from chronic UV exposure increase the risk of non-melanoma skin cancers such as basal cell carcinoma and squamous cell carcinoma.
- Lycopene has demonstrated chemo preventive properties through anti-mutagenic, anti-proliferative, and apoptosis-inducing effects. Regular use of lycopene-enriched topical products may reduce cumulative DNA damage and skin cancer risk.

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