EJPMR, 2025, 12(11), 295-299 Review Article Impact Factor 7.065

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

ISSN (O): 2394-3211
ISSN (P): 3051-2573
Coden USA: EJPMAG

EMERGING TRENDS IN SUNSCREEN FORMULATION TECHNOLOGY

Kuldeep Jangid, Vipin Mathur*

Lachoo Memorial College of Science and Technology (Autonomous), Sector – A, Shastri Nagar, Jodhpur.

***Corresponding Author: Dr. Vipin Mathur**

Lachoo Memorial College of Science and Technology (Autonomous), Sector - A, Shastri Nagar, Jodhpur.

DOI: https://doi.org/10.5281/zenodo.17539806

How to cite this Article: Kuldeep Jangid, Vipin Mathur* (2025). Emerging trends in sunscreen formulation technology. European Journal of Biomedical and Pharmaceutical Sciences, 12(11), 295–299.

This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 11/10/2025 **Article Revised on 01/11/2025** **Article Published on 01/11/2025**

ABSTRACT

Sunscreens have emerged as pharmacologically and commercially significant dermatological formulations, driven by rapid advancements in cosmetic science and pharmaceutical innovation. This systematic review examines the pharmacological mechanisms, formulation strategies, and market relevance of sunscreens, emphasizing the evolution and significance of the Sun Protection Factor (SPF). Both chemical (organic) agents - such as avobenzone and oxybenzone - and physical (inorganic) filters like titanium dioxide and zinc oxide are reviewed for their photoprotective mechanisms, safety, and formulation challenges. The study systematically evaluates published literature on formulation design, pharmacokinetics, efficacy assessment, and consumer perception of SPF-based products. It also explores the relationship between SPF labelling, therapeutic performance, and consumer behavior. Pharmacologically, sunscreens function as essential agents against ultraviolet-induced oxidative damage, photoaging, and carcinogenesis. Ongoing research continues to enhance their efficacy, photostability, and safety. Integrating pharmacological advances with formulation science and public awareness will enable the development of safer, more effective, and sustainable sunscreen products.

KEYWORDS: Sunscreen, pharmacological mechanisms, formulation science, market relevance, Sun Protection Factor (SPF).

1. INTRODUCTION

Sunscreen is a topical formulation developed to safeguard the skin from the harmful effects of ultraviolet (UV) radiation emitted by the sun.[1] It serves a vital role in dermatological care by preventing sunburn, minimizing the risk of skin cancer, and reducing premature aging induced by prolonged sun exposure.[2] Depending on its formulation, sunscreen acts by absorbing, reflecting, or scattering UV rays to mitigate their damaging impact on the skin.

Ultraviolet radiation consists primarily of two types - UVA and UVB rays - that exert distinct effects on the skin. UVA rays penetrate deeper into the dermal layers and are largely responsible for photoaging manifestations such as wrinkles, pigmentation, and loss of elasticity. In contrast, UVB rays primarily affect the epidermis and are associated with acute damage, including erythema and sunburn. An effective sunscreen formulation provides *broad-spectrum protection*, offering defense against both UVA and UVB radiation to ensure comprehensive skin coverage.

Modern sunscreens are available in diverse dosage forms such as lotions, creams, sprays, gels, and sticks, catering to different consumer preferences and skin types.[3] The efficacy of a sunscreen is determined by its Sun Protection Factor (SPF), which quantifies its ability to protect the skin against UVB-induced damage. For routine daily application, dermatologists recommend a broad-spectrum sunscreen with an SPF of 30 or higher.[4]

Proper application technique is equally important for optimal protection. Sunscreen should be applied generously and reapplied at regular intervals—particularly after swimming, sweating, or towel drying. Consistent use of sunscreen, combined with additional photoprotective measures such as wearing protective clothing, wide-brimmed hats, and seeking shade during peak sunlight hours, plays a critical role in maintaining skin health.

Regular and informed use of sunscreen is not merely a cosmetic practice but a pharmacologically significant preventive strategy. Its consistent application supports long-term dermatological well-being, reduces the incidence of UV-induced skin disorders, and contributes to overall public health protection.[5]

2. BENEFITS AND LIMITATIONS OF SUNSCREENS

Sunscreens confer multiple pharmacological and dermatological benefits:

- Photoprotection: Shields the skin from harmful UVA and UVB radiation, thereby reducing the risk of sunburn, photoaging, and skin cancer.
- Prevention of Pigmentation Disorders: Helps minimize hyperpigmentation, melasma, and sun-induced dark spots.
- Maintenance of Skin Integrity: Protects collagen and elastin fibers, preserving skin elasticity and overall dermal health.
- Adjunct to Dermatological Therapies: Beneficial in managing conditions such as photosensitivity and post-procedural care after chemical peels or laser treatments.[6,9]

Despite their protective benefits, sunscreens may present certain limitations:

- Skin Reactions: Some chemical filters may cause allergic reactions, irritation, or contact dermatitis in sensitive individuals.
- Environmental Impact: Certain sunscreen ingredients, such as oxybenzone and octinoxate, have been associated with coral reef damage and aquatic toxicity.
- Comedogenic Potential: Frequent or improper use of heavy formulations can clog pores and contribute to acne formation.
- Limited Duration of Protection: Requires regular reapplication for sustained efficacy, especially after swimming or perspiration.[7,10]

3. FORMULATION OF SUNSCREEN PREPARATIONS

The formulation of sunscreen preparations requires a precise balance between efficacy, safety, and cosmetic acceptability. The protective performance of a sunscreen depends on the judicious selection, concentration, and combination of both active and inactive components to ensure broad-spectrum coverage, photostability, and user compliance.[1]

3.1 Active Ingredients

Active ingredients serve as the primary UV filters and are categorized into chemical and physical types. Chemical filters, such as avobenzone, octocrylene, octinoxate, oxybenzone, homosalate, Tinosorb M, and Tinosorb S, absorb ultraviolet radiation and convert it into less harmful energy forms, thereby minimizing skin damage.[8] In contrast, physical filters such as titanium dioxide and zinc oxide act by reflecting and scattering UV rays, providing broad-spectrum protection while being particularly suitable for sensitive skin formulations.[2]

3.2 Inactive Ingredients

Inactive ingredients play essential roles in ensuring formulation stability, skin compatibility, and aesthetic quality. Emollients and moisturizers (e.g., dimethicone, glycerin, squalene) enhance hydration and improve the sensory attributes of the product. Emulsifiers such as polysorbates and cetyl alcohol facilitate the stable blending of oil and water phases. Thickeners and stabilizers including carbomer and xanthan gum provide desirable viscosity and prevent phase separation. Preservatives such as phenoxyethanol and ethylhexylglycerin maintain microbiological integrity, while fragrances and colorants may be included in minimal amounts, particularly in formulations designed for sensitive skin. Solvents and carriers, typically water and alcohol, act as dispersion media to optimize the delivery and uniformity of active ingredients.[3]

3.3 Method for the Preparation of SPF 50 Sunscreens

The preparation of SPF 50 sunscreen formulations involves a series of controlled steps to achieve product uniformity and stability. The process begins with the separate preparation of the oil phase—comprising emollients and chemical sunscreens—and the water phase, which includes humectants and preservatives. Both phases are heated independently to 70–80°C, followed by gradual incorporation of the water phase into the oil phase under continuous stirring to form a stable emulsion. The mixture is then cooled to approximately 40°C, after which temperature-sensitive components such as antioxidants and fragrances are incorporated. The final formulation undergoes homogenization and testing to assess uniformity, stability, SPF value, and potential irritation.[7]

3.4 Formulation Considerations

An effective sunscreen formulation must ensure broad-spectrum UV protection, achieved through a synergistic blend of chemical and physical filters. The inclusion of emollients improves skin hydration and tactile feel, while stabilizers enhance photostability and extend product shelf life. Furthermore, water-resistant agents strengthen film formation, enhancing performance during perspiration or aquatic exposure. These considerations collectively contribute to a stable, efficacious, and cosmetically acceptable sunscreen preparation.[4,8]

4. PHARMACOLOGICAL ASPECT

Sunscreens are pharmacologically designed to protect the skin from the harmful effects of ultraviolet (UV) radiation, a major contributor to skin damage, photoaging, and carcinogenesis. Their effectiveness depends on active ingredients that either absorb, reflect, or scatter UV radiation, thereby mitigating harmful biological effects.[5]

4.1 Classification of Sunscreen formulations

Sunscreen formulations can be broadly classified into chemical and physical (mineral) types. Chemical sunscreens contain organic compounds that absorb UV radiation and convert it into heat. Common agents include Avobenzone (broad-spectrum UVA protection), Octocrylene (absorbs UVB and some UVA while stabilizing other ingredients), Octinoxate (targets UVB rays), Oxybenzone (absorbs UVB and partial UVA), and Homosalate (primarily UVB protection). Physical or mineral sunscreens contain inorganic compounds that block and scatter UV rays. Notable examples are Titanium Dioxide, which provides broad-spectrum UVB and partial UVA protection, and Zinc Oxide, which protects against both UVA and UVB radiation.[6,9]

The pharmacological effects of sunscreens are clinically significant. By absorbing or blocking UVB radiation, they prevent sunburn and erythema. Chronic UV exposure can lead to photoaging and increased risk of skin malignancies, which sunscreens help mitigate by reducing DNA damage in epidermal cells. Sunscreens also help prevent hyperpigmentation and uneven skin tone caused or worsened by UV exposure.

4.2 Sun Protection Factor (SPF)

A key parameter in sunscreen efficacy is the Sun Protection Factor (SPF), which quantifies protection against UVB-induced erythema. SPF is calculated using the formula:

$$SPF = \frac{MED_{protected}}{MED_{unprotected}}$$

MED (Minimal Erythemal Dose) is the smallest dose of UV radiation that causes a minimal, perceptible redness or sunburn on the skin (protected: sunscreen is applied; unprotected: sunscreen is not applied) within a few hours after exposure.

An SPF of 30 theoretically allows 30 times longer sun exposure without erythema. While higher SPF values provide extended protection, the benefits plateau at very high levels (SPF 30 blocks ~97% of UVB, SPF 50 blocks ~98%).

Sunscreens should be reapplied every two hours or after swimming, sweating, or towel drying, as SPF does not account for product durability. Broad-spectrum formulations are essential because SPF only measures UVB protection, while UVA rays also contribute to photoaging and carcinogenesis. Adequate SPF selection and proper use reduce acute sunburn, long-term photodamage, hyperpigmentation, and the risk of skin cancer, making sunscreens a critical pharmacological intervention in photoprotection.[8]

4.3 Importance and Comparison of SPF 30 and SPF 50

The Sun Protection Factor (SPF) is a critical measure of a sunscreen’s ability to protect the skin from UVB-induced erythema and long-term damage. SPF 30 is widely recommended for general daily exposure and blocks approximately 97% of UVB radiation. It provides effective protection for most individuals, reducing the risk of sunburn and cumulative photodamage during regular outdoor activities.

SPF 50, on the other hand, blocks about 98% of UVB radiation. While the numerical difference in UVB absorption may seem small, SPF 50 offers an additional safety margin, making it particularly useful for individuals with fair or sensitive skin, or for those who are exposed to intense sunlight for prolonged periods. It helps lower the cumulative UVB dose reaching the skin, further minimizing the risk of acute sunburn and long-term photodamage.

It is important to note that the effectiveness of both SPF 30 and SPF 50 depends not only on the SPF rating but also on correct application. Sunscreen should be applied generously, and reapplied every two hours or after swimming, sweating, or towel drying. Choosing between SPF 30 and SPF 50 should consider individual skin type, sun exposure duration, and environmental intensity, ensuring optimal photoprotection.[9]

4.4 Influence of SPF on Skin Health

The SPF (Sun Protection Factor) of a sunscreen has a significant impact on overall skin health, as it determines the level of protection against harmful UVB rays that cause sunburn, DNA damage, and skin cancer. Using an adequate SPF helps prevent photoaging, hyperpigmentation, and loss of skin elasticity by minimizing cumulative sun damage.

Regular use of SPF 30 or higher reduces the risk of developing actinic keratosis and melanoma, two serious UV-induced skin conditions. Higher SPF formulations (SPF 50 or above) offer better defence for people with fair or sensitive skin, or those prone to conditions like rosacea or melasma, by reducing inflammation and pigment formation caused by UV exposure.

On the other hand, improper use of SPF can indirectly harm skin health. Overreliance on high-SPF products may lead individuals to extend sun exposure without reapplication, resulting in hidden UV damage. Moreover, some high-SPF products with heavy or chemical filters can clog pores or irritate sensitive skin.

Therefore, while higher SPF values enhance protection, maintaining balanced use, including broad-spectrum coverage (UVA + UVB), reapplication, and complementary measures like wearing protective clothing, is essential for preserving long-term skin health.[10]

5. SWOT ANALYSIS OF SUNSCREENS

- Strengths: Proven pharmacological efficacy in preventing UV-induced skin damage and reducing risks of photoaging and skin cancer; wide availability in multiple formulations suited to various skin types; growing consumer awareness of sun protection and preventive skincare.[8]
- Weaknesses: Limited photostability of certain chemical filters; potential for irritation or allergic responses; requirement for frequent reapplication; some formulations may cause pore blockage or cosmetic discomfort.[6]
- Opportunities: Development of novel, photostable broad-spectrum agents; use of natural and antioxidant-based ingredients; application of nanocarrier systems to enhance efficacy; increasing global demand for multifunctional and eco-friendly products.[4,10]
- Threats: Environmental toxicity concerns, particularly coral reef damage; competitive and saturated market; evolving regulatory restrictions on certain UV filters; consumer scepticism regarding safety and SPF authenticity.[7]

6. MARKETING PERSPECTIVE OF SUNSCREEN

The global sunscreen market has evolved into a dynamic and rapidly expanding sector within the skincare and cosmetic industry. Valued at approximately USD 13-15 billion in 2024, it is projected to reach nearly USD 20–22 billion by the early 2030s, growing at a compound annual growth rate (CAGR) of around 4–6%. This growth is primarily driven by the increasing awareness of the harmful effects of ultraviolet (UV) radiation, rising concerns about premature skin aging, and a growing emphasis on preventive skincare among consumers.

From a market perspective, sunscreen has shifted from being viewed solely as a protective healthcare product to becoming an essential part of daily skincare and cosmetic routines. The modern consumer demands multifunctional products that combine UV protection with additional benefits such as moisturizing, anti-aging, and skin-brightening properties. This trend has encouraged manufacturers to develop innovative formulations, including tinted sunscreens, lightweight gels, and hybrid skincare–suncare products, to cater to varied skin types and preferences.

In recent years, the mineral sunscreen segment—based on physical UV filters such as zinc oxide and titanium dioxide—has gained significant attention due to increasing demand for “clean,” “natural,” and “reef-safe” formulations. Environmental sustainability and ingredient safety have become major marketing and regulatory focuses, influencing product development and consumer choice alike.

The Indian sunscreen market mirrors this global trend, showing even stronger growth momentum. It is expected to reach about USD 800 million by 2030, with a projected CAGR of nearly 9%. Factors such as growing urbanization, rising disposable income, increased dermatological awareness, and the influence of social media have greatly contributed to this expansion. The Indian market also shows a strong inclination toward affordable, non-greasy, and broad-spectrum formulations suitable for the country’s humid climate and diverse skin tones.[10]

However, the market faces certain challenges that influence its trajectory. These include misconceptions regarding SPF levels and reapplication, regulatory scrutiny over certain chemical UV filters, and the need for better consumer education regarding the proper use of sunscreens. Additionally, the pressure to develop sustainable packaging and environmentally safe ingredients adds to production costs, impacting pricing and accessibility in emerging markets.

Despite these challenges, the sunscreen market continues to present significant opportunities. The growing demand for high-SPF, broad-spectrum, and skin-type–specific products, along with the rise of e-commerce and digital marketing platforms, is expected to strengthen market expansion in the coming years. The integration of dermatological science with cosmetic appeal and the adoption of innovative technologies in formulation and packaging are shaping the future of this sector.

In conclusion, the market perspective of sunscreen reflects a balanced interplay between consumer awareness, technological innovation, and environmental responsibility. As sunscreen transitions from a seasonal necessity to a daily skincare essential, its market outlook remains positive, with continued potential for growth, diversification, and sustainable innovation in the global and Indian contexts.[3]

7. CONCLUSION

Sunscreens have emerged as indispensable agents in dermatological care, offering comprehensive protection against ultraviolet-induced skin damage, photoaging, and carcinogenesis. Their efficacy relies on the synergistic integration of chemical and physical UV filters, optimized formulation techniques, and consistent consumer use. Beyond their pharmacological significance, modern sunscreens represent a convergence of healthcare and cosmetic innovation, evolving toward formulations that are photostable, non-irritant, and environmentally responsible. The market trajectory underscores a growing consumer shift toward daily, multifunctional, and sustainable products that align with global awareness of skin health and environmental impact. However, challenges persist in maintaining photostability, minimizing adverse reactions, and ensuring public education on correct application. Future developments must focus on nanocarrier-based systems, natural UV filters, and eco-safe formulations to achieve the dual goals of efficacy and sustainability. Thus, sunscreens continue to bridge scientific advancement with preventive dermatology, reaffirming their critical role in global skin health management.[4,7]

REFERENCES

1. Singhal M, Khanna S, Nasa A. Cosmeceuticals for the skin: an overview. Asian J Pharm Clin Res., 2011; 4-16.
2. Wells FV, Lubowe II. Cosmetics and the skin. Reinhold Book Corporation, London, 1969; 8.
3. Harry RJ. Harry's Cosmetology. 7th edn, Chapter 23, 397. London: Longmans, 1982.
4. Pier Francesco M, Chen HD, Xing-Hua G, Gazzaniga G, Morganite G. Natural Ingredient for advanced nutricosmetics. Personal Care Europe., 2013; 6(2): 19-24.
5. Clark A, Hessler JL. Skin Care. Facial Plast Surg Clin North Am., 2015; 23(3): 285-95.
6. Draelos ZD. New developments in cosmetics and skin care products. Adv Dermatol, 1997; 12: 3-17.
7. Joshi LS, Pawar HA. Herbal Cosmetics and Cosmeceuticals: An Overview. Nat Prod Chem Res., 2015; 3: 170.
8. Jou PC, Feldman RJ, Tomecki KJ. UV protection and sunscreens: what to tell patients. Cleve Clin J Med., 2012; 79(6): 427-36.
9. Kaimal S, Abraham A. Sunscreens. Indian J Dermatol Venereol Leprol, 2011; 77(2): 238-43.
10. Marionnet C, Tricaud C, Bernerd F. Exposure to non-extreme solar UV daylight: spectral characterization, effects on skin and photoprotection. Int J Mol Sci., 2014; 16(1): 68-90.