A Detailed Review of Sunscreen and Sun Protection Factor (SPF)

Arvind Kumar Maurya[1], Sachin Kumar[2]
[1,2]Instiitute Of Technology and Management, GIDA, Gorakhpur

***Abstract*—The crucial role that sunscreen lotions play in protecting your skin from ultraviolet (UV) radiation's harmful effects—which can be classified as either UVA or UVB—is examined in this study. These rays, which are known to cause sunburn, skin aging, and even carcinogenesis, are blocked by sunscreens. Sunscreen has emerged as a crucial product in reducing the hazards associated with sun-induced phototoxic damage, which includes the negative consequences of prolonged exposure to ultraviolet light.**

According to the review, adding herbal ingredients to sunscreen formulas is a safe and efficient way to increase protection as showed by the (SPF). The article goes into additional detail about how UVA and UVB radiation work, highlighting how they affect skin differently. There includes a thorough discussion of important evaluation criteria like SPF, broad-spectrum protection, and ingredient safety. The assessment also looks at developments in sunscreen technology, include the creation of skin-friendly, lightweight formulas. The article concludes by giving readers a thorough explanation of how sunscreens shield the skin from phototoxic damage and by offering advice on how to choose the right sunscreen products for different skin types. It also emphasizes how crucial regular application is for the best protection.

***Index Terms*—Sunscreen, Herbal, UVA and UVB, SPF, Sunscreen Cream**

I. INTRODUCTION

The skin is constantly exposed to the damaging effects of ultraviolet (UV) energy emitted by sunlight since it is located at the point of contact amidst the The body of a person and its surroundings. The most active component of solar light, UVB (280–320 nm), is known as "the burning rays" and accounts for 4%–5% of UV light [1]. Sunscreen decreases the quantity of (UV) rays that affects your skin, protecting it from the sun's damaging rays. By forming a chemical layer that deflects and/or collects ultraviolet radiation from your skin, sunscreen filters UV radiation rather than blocking it. There isn't a sunscreen that completely blocks UV rays. There will always be some UV rays that penetrate the skin and harm the cells underneath. This harm accumulates over time and might raise the risk of skin cancer. UV radiation has a limited wavelength range, beginning at about 200–400 nm, makes up a tiny portion of the electromagnetic spectrum. UVB (290-320 nm), UVA (320-400), and UVC (200-290 nm) are further divisions of the UV spectrum. UVA photons make up 90% of the UV-light that reaches the planet. It has a very wide range (320–400 nm) and that are not affected by the ozone barrier. Sun tanning is caused by UVA light, which enters the skin the deepest. UVA is linked to rapid skin aging and has a tendency to impair immunological activity UVB photons are mostly taken in by the protective ozone barrier and that have a medium range (290–320 nm). It doesn't penetrate deep inside the skin as UVA rays and that are the main cause of sunburned. Additionally, they are in charge of photoaging and photo carcinogenesis. [2]

Ultra-violet radiations and human skin:
It comes under electromagnetic radiation that has a wavelength in between 200 and 400 nm that lies between visible light and X-rays. According to this, this UV radiation falls into three categories:

UV-A Radiation:
This radiation has a 320–400 nm range. It is primarily to blame for the skin's instant tanning or darkening. Relatively long-wavelength UVA radiation makes up around 95% of the UV rays that reaches to earth. It is instantly accountable for the skin browning effect and has the the capacity to penetrates the skin's deepest layers. Furthermore, wrinkles and skin aging also have

a role. For a long period, UVA was believed to cause no long-term harm. According to recent research, there may also be improvements in the development of skin malignancies.[3] In contrast to UVB, erythema is less effective than both browning and color darkening, both instantaneous and delayed. UVA has significant negative consequences, such as skin cancer, eye damage, photography, and immunological suppression. Since 7-dihydrocholesterol irradiation increases vitamin D3, UVA rays are beneficial. the tanning-promoting darkening of preformed melanin pigments.[4]

UV-B Radiation:
This radiation has a wavelength range of 280–320 nm. It is 1000 times inclined to produce sunburned than UV-A. Latitude, altitude, season, daytime, cloudiness, and the ozone layer all affect how much UV-B and UV-A radiation from the sun to the outermost layer of the Earth. Higher altitudes and the equator experience the highest radiance. The UVA-UVB ratio on the surface of the Earth is 20:1. On summer days, the atmosphere contains 96.5% of UV radiation that penetrates to earth surface and 3.5% of UVB rays.[5,6] Sunburn and erythema are the main conditions linked to UVB. Both immunological suppression and photo carcinogenesis may result from it. Although UVB rays are very long in length, they are unable to get through the outermost barriers of the skin. While adding these sudden consequences, it accelerates the premature aging of the skin and encourages the growth of skin cancer. Most solar UVBs are filtered by the atmosphere.[7]

UV-C Radiation:
The short wavelength spans from 200 to 280 nm. The most harmful type of UV radiation falls within this band. However, the atmospheric ozone layers completely filter it, making it less dangerous and effective. [8] Since UVC is well filtered by the layer, it is not regarded as a factor in group exposure and has little physiological importance, even though it has the most energy and the greatest chance for biological harm.[9]

Table 1. Types of ultraviolet radiation

	UV-A	UB-B
Wavelengths (nanometers)	Extended wavelength 320–400 nm • Two varieties: UVA II (320–340 nm) is more powerful than UVA I (340–400 nm).	medium-length wavelength 290–320 nm
Exposure	That is responsible of 95% UV radiation that gets exposed to earth. Able to pass through windows and clouds.	Accounts about 5% of the ultraviolet rays that goes to earth. Ozone barrier blocks most Exposure might varies by season, location, and time of day; during the summer it peaks around ten in the morning and four in the afternoon. Approx 80% of UV-B radiation do reflected at high elevations and on materials like snow and ice, causing them to strike the skin twice.
Effect on skin	More deeply reaches the skin than UVB rays, causing damage to skin cells in the lowermost layer of the epidermis and extending into the dermis. This causes hyperpigmentation, photoaging, and tanning. Contributes to skin cancer Impairs the immunological system of the skin	Depending on the skin type, 5 to 30 minutes of UVB exposure every day aids in the production of vitamin D3, which builds bone. Because excessive UVB rays harm the skin's top epidermal layers, they are also the primary cause of sunburn and skin reddening. May result in skin cancer and hyperpigmentation. Impairs the immunological system of the skin.

UV index

The Ultraviolet Index (UVI) is a rating system that displays the percentage of UV radiation which harms skin that reaches the surface of the Earth throughout daylight hours. The numbers range from 1 to 11.

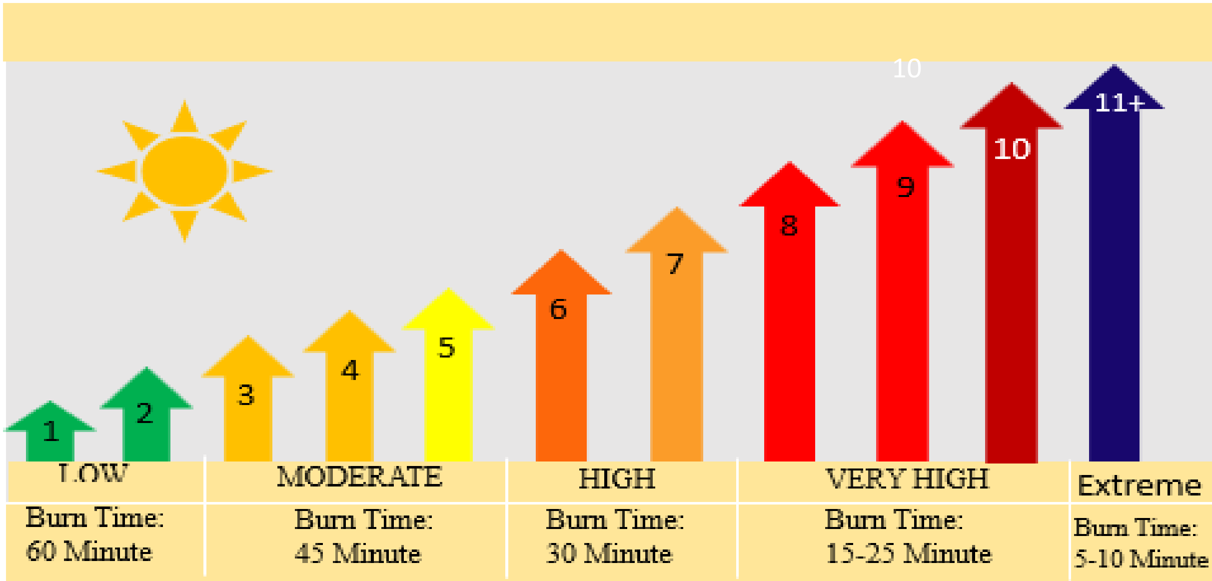

Fig 1: different levels of UV range

The UVI determines how much UV reaches your zone when the sun is regularly at its greatest height in the sky in the early afternoon. The UV photons you are exposed to will be more extraordinary the higher the UVI score. On their UV Index page, the Environmental Protection Agency (EPA) provides UVI conjectures by ZIP code. To determine the degree of UV openness for a given area on the guide, many UVI outlines use a set of tones. A commonly used shade scheme that corresponds to UVI levels has been created by the World Health Organization (WHO). [10]

"Erythema, edema, and pigment darkening are among the acute consequences of exposure to UVB rays on human skin; Long-term effects include delayed the tanning process, growth of the epidermis and the outermost layer sunlight-induced vitamin D production, immunosuppression, and photoaging. UVB-induced erythema can last for weeks in older and fair-skinned people. Four hours after exposure, it begins to appear, peaks between eight and twenty-four hours later, and then disappears over the course of a day or so. Longer wavelengths of UV quickly reduce their capacity to induce erythema; approximately 1000 times the dosage of UVA is needed to elicit the same erythemal reaction as UVB" UVA-induced browning and erythema have biphasic temporal histories. While erythema and UV-induced tanning have nearly identical action spectrums, UVA rays are more effective at browning, whilst erythema is more effectively induced by UVB. Following the conclusion of the irradiation cycle, erythema is always visible right away. It then decreases over a few hours, and then there is a delayed erythema that starts at six hours and peaks at twenty-four hours. [11]

II. EFFECT OF UV ON SKIN

Basal cell carcinoma

Basal cell carcinomas are seen very easily seen as a type of skin cancer in all cancers. An uncontrolled growth or sore in the basal cells of the skin, that is the topmost layer of the epidermis, the thickest part of the skin, is what sets it apart. It always shows up as a somewhat translucent bulge, however it can take many different forms. Generally speaking, light-exposed skin is where basal cell cancer develops. UV radiation exposure raises the danger and growth of basal cell cancer.[12]

Squamous cell carcinoma

The next that is most prevalent kind of skin cancer is called squamous-cell carcinoma. It is differentiated by the uncontrolled growth of atypical cells derived from the squamous cells of the epidermis, which comprise the outer barrier of the skin. It can also show up as open sores, warts, or brought up growths that are reddish in color and have a depression in the center. Squamous cell carcinoma typically occurs in areas that are exposed to light, but it can occur elsewhere on the body. The majority of cases of squamous cell carcinoma are brought on by lifetime exposure to ultraviolet (UV) radiation. [13]

Melanoma

It is most severe type of skin cancer is melanoma, has a strong propensity to spread if treatment is not received. The pigment that gives skin its color is made by melanin-producing cells. Melanomas can be pink, purple, red, blue, white, or skin-colored, although they usually show up as brown or black growths. UV rays from the sun and tanning beds have been demonstrated to significantly raise your risk.[14]

SUN PROTECTION

Sunscreen is the most popular and widely used kind of sun protection, however wearing protective clothes, sunglasses, hats, umbrellas, shade, and maybe Preventing the sun can also
help prevent sunburn.

Sun protective clothing:

Sun protective apparel is usually assessed using a UV protection factor (UPF), that's the proportion of the mean functional UV radiation irradiation transmitted and estimated through air to the average effective UV radiation irradiance transmitted and estimated via cloth. With the exception of the fact that fabric, not sunscreen, is utilized to protect the skin during testing, fabric UPF is equivalent to sunscreen SPF. The maximum amount of time a person can spend in the sun while wearing apparel that covers their skin is determined by these indices using erythema as an endpoint. The following grades are used to represent the results:

TABLE 2: GRADES OF SUN PROTECTION

GRADE	UPF
Adequate defence	15 to 24
Very good protection	25 to 39
Excellent protection	40 to 50+

A. Sun protective sunglasses:

The sole purpose of sun protection eyewear is to shield vulnerable eyes from the adverse effects of solar radiation. Luminous transmittance, or the amount of light that goes through the glasses lens, is commonly used to evaluate how well they protect.

Table 3: Transmission of Light from Sunglasses With Category And Class

Luminous transmittance	Category	Class
80-100%	0	Fashion glasses don't reduce sunglare, but they do offer some or no protection from UV rays.
60-80%	1	Fashion glasses have poor sunglare reduction and UV protection, making them unsuitable for nighttime driving.
35-60%	2	General-purpose sunglasses that offer moderate defense against UV rays and sunglare
10-35%	3	Sunglasses reduce sunglare and offer good protection from UV rays.
3-10%	4	Sunglasses decrease sunglare and offer a high level of UV protection, however they should not be worn while driving.

B. Sunscreen

SUNSCREENS

Definition: "A material that protects the skin from the sun's harmful rays. Through their ability to reflect, absorb, and scatter UVA and UVB rays, sunscreens provide protection against these damaging light types. Using lotions, creams, or gels that contain sunblock can help protect the skin from harm that can lead to signs of aging and carcinoma of the skin.

Benefits of sunscreen

I. Sunscreen reduces skin damage from UV rays.
II. Using sunscreen every day makes skin smoother.
III. Using sunscreen helps stop wrinkles and sagging skin for a short time.
IV. There is less discoloration.
V. Melanoma and the carcinoma of squamous cells are two forms of skin cancer that it can help prevent.

Limitations of sunscreen

1.Some people have an allergic reaction to sunscreen.
2. Long-term sunscreen use may result in a vitamin-D deficit.

TYPES OF SUNSCREENS [15]

There are two varieties based on the ingredients used to prepare sunscreen:

1. PHYSICL SUNSCREENS:

The two most widely used physical sunscreen types are titanium dioxide and zinc oxide. They show defense against UV-A and UV-B radiation. They are suitable for daily use, keeping in mind for kids and those with sensitive skin, because they rarely irritate the skin. However, when applied to the skin, they also result in the so-called "whitening" phenomenon due to the dispersion effect, which adversely affects the appearance and effectiveness of sunblock lotions. [16,17]

2. CHEMICAL SUNSCREEN:

Most materials block just a small part of the UV spectrum. Because of this, the majority of chemical sunblocks are composed of many substances, each of which protects against a different UV radiation spectrum. The UVB spectrum is where sunscreen chemicals are most active. [18] Only a few substances restrict the UVA region. The ideal sunscreen is one that combines physical and chemical active components. Dermatologists frequently recommend sunscreens that contain avobenzone (Parsol®1789) or a physical blocking agent in combination with other ingredients. However, the United States of America prohibits the combination of avobenzone and physical sunscreen. Avobenzone was said to be unstable when it was included in the formula.[19]

III. CLASSIFICATION OF SUNSCREENS ON THE BASIS OF MODE OF APPLICATION

A. TOPICAL SUNSCREEN:

It is applied to the skin's surface to protect it. Based on their nature, it is further separated into three categories:

Organic Sunscreens: According their chemical makeup, these active substances absorb UV light within a specific wavelength range. The UV filter transitions from a low-energy ground state to a high-energy excited state after absorbing radiation. Any of the filters can process the energy it has absorbed from this stimulated state.

Photo stable filter: After dissipating its acquired energy as heat energy into the surrounding environment, After returning to its ground state, this filter can once again receive energy in its full capacity.

Photo unstable filter: After absorbing UV light, the chemical structure of this filter changes, or it degrades. It cannot re-absorb ultraviolet light.

Photo reactive filter: When the filter is stimulated, it interacts with molecules in the environment, such as oxygen, other sunscreen chemicals, and proteins and lipids in the skin. Rective spacies are produced as a result, which could have undesirable biological implications.

a) Newer generation broad spectrum (UVA+ UVB) filters:
b) "Bemotrizional (Tinosorb S), Bisoctrizole (Tinosorb M), Ecamsule (Mexoryl SX), and Silatriazole (Mexoryl XL). Tinosorb M is the first of a new type of UV filters that combines the characteristics of both organic and inorganic UV traditional filters; it scatters, reflects, and absorbs UV light. Ecampule is predominantly a UVA filter." Other than Ecamsule, these filters are in use in the EU and Canada but have not yet received FDA approval in the US.
c) UV rays are reflected, scattered, or absorbed by inorganic sunscreen. The inherent drawbacks of their opaqueness and "whitening effect" can be lessened by utilizing micronized or ultrafine

particles. Calcium carbonate, magnesium oxide, zinc oxide (ZnO), talc, kaolin, and titanium dioxide (TiO2) are a few examples.

d) "Polyphones (tannins, flavonoids), lycopene, fixed oils, and volatile oils are components of natural chemical sunscreens that scavenge reactive oxygen species to shield skin from UV-induced free radical damage."

B. ORAL/ SYSTEMIC SUNSCREEN:

- When taken orally, these sunscreens have antioxidant properties that provide photoprotection. For instance, certain compounds that resemble vitamins, flavonoids, tannins, and phenolics.

SUNSCREEN ACTIVE INGRIDIENTS:

By moisturizers and other inert chemicals, sunscreens have one and may be many of the aforementioned chemical components, which can be mineral or organic in nature and are frequently aromatic compounds conjugated with carbonyl groups. Because of its overall structure. The molecule's ability to absorb extremely energetic UV light and release it as lower-energy photons helps shield the skin from UV damage. Most of the components, with the notable exception of avobenzone, do not undergo substantial chemical changes when exposed to ultraviolet (UV) rays, which enables them to retain their UV-absorption effectiveness without suffering from significant photodegradation. Some active substances and their concentrations are shown in Table 4 below:

TABLE 4: ACTIVE INGRIDIENTS OF SUNSCREEN AND THEIR CONCENTRATION.

ACTIVE INGRIDIENTS	MAXIMUM CONCENTRATION	PROTECTION AGAINST	
		UV A	UV B
Oxybenzone	6%(US) 10%(AUS, EU) 5% (IP)	YES	YES
Methyl anthranilate	5%	YES	NO
Octyl methoxycinnamate	7.5%(US) 10%(AUS,EU) 20%(IP)	NO	YES
Sulisobenzone	5%(US) 10%(AUS,EU, IP)	YES	YES
Titanium dioxide	25% (US) No limits (IP)	YES	YES
Zinc oxide	25% (US)	YES	YES
Avobenzone	3%(US), 5%(EU, AUS) 10%(IP)	YES	NO

Sunscreens made of minerals
(titanium dioxide and zinc oxide) are typically recommended in these areas. For precise information and the most recent data, consult your local regulations.

SUN PROTECTION FACTOR (SPF):

An indicator of how long a sunscreen will protect you from ultraviolet (UV) rays is called sun protection factor, or SPF for short. The upper layer of skin, the epidermis, is the main target of UVB radiation. They are caused by certain surface-level skin malignancies and sunburns. Additionally, the sun emits UVA radiation that can reach the dermis, the lowermost layer of the skin. UVA photons are frequently linked to "tanning." On the other hand, the darker skin tone indicates dermal cell injury. SPF ratings typically only cover UVB rays, however some sunscreens can also block UVA rays.

How much sunburn protection a sunscreen lotion offers is indicated by its SPF rating. For every sunscreen, the amount of UV radiation exposure needed to produce a sunburn is measured and compared to the amount of UV exposure needed to produce a sunburn when wearing sunscreen. The item's label is then printed with the correct SPF rating. Higher SPF values provide greater defense from sunburn (up to 50). Since SPF ratings are derived by a test that assesses mitigation of sunburn produced by UVB radiation, they are the only way to figure out a sunscreen's UV protection. Sunscreens that pass the broad-spectrum test will also be shown to give UVA protection starting of June 2011. Therefore, in compliance with the label rules, sunscreen labeled 'Broad Spectrum SPF [value]' will show protection from both UVA and UVB radiation.

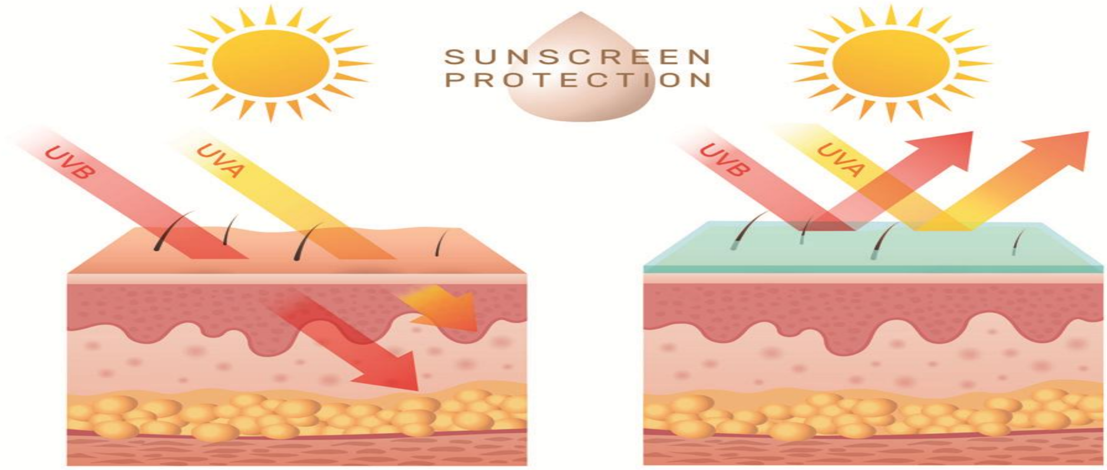

Fig: Sunscreen Protection

SPF is directly correlated with the quantity of sun exposure rather than the length of that exposure, hence this is incorrect. Compared to the early hours of the morning and early evening, the sun shines brighter in the middle of the day. This suggests that midday is when sunburn danger is highest. Geographical location also affects solar intensity, with more solar intensity found at lower latitudes.

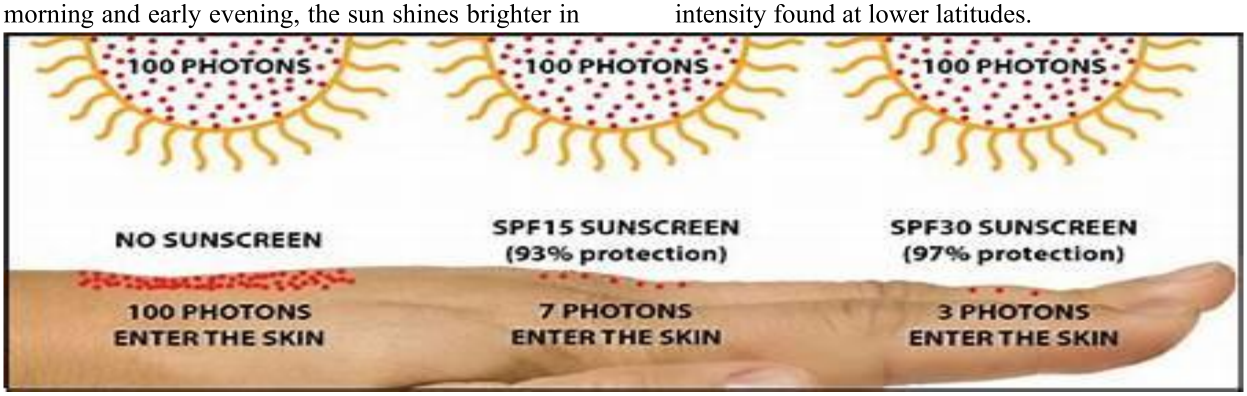

Fig: Understanding SPF

Mansur equation

The following conditions were developed by Mansur et al. (1986) as a simple, fast, and practical numerical condition for the in vitro assurance of SPF using UV spectrophotometry. where CF is the correction factor (=10), Abs is the sunscreen product's absorbance, EE (I) is the erythemal impact range, and I is the solar intensity spectrum. EE × I estimations are constant. Table 1: Standardized item work used for SPF calculation The goal of the current test was to use a UV spectrophotometer to ensure the sun security factor in vitro. [30]

$$SPF = CF \times \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$

Assessment of Formulations for Herbal Sunscreen

Physical Parameters

Color, uniformity, and appearance were assessed.

Calculating Viscosity

"The viscosity was measured using a Brookfield viscometer (RVDV-II+PRO) with the required number of spindles. 50 g of preparation was held in a 50 mL beaker until the spindle groove was dipped and the rpm was set. The viscosity of the herbal sunscreen was measured at 5, 10, 20, 50, and 100 rpm. The factor obtained from the reading was used to compute the coefficient of viscosity".

Assessing pH

The pH of the herbal sunscreen formulations was determined using a digital pH meter and normal cosmetic product analysis protocols. To create the sample, 1 gram of sunscreen was precisely weighed and mixed with 100 milliliters of newly prepared distilled water. The liquid was agitated with a magnetic stirrer for uniform dispersion and let to stand for two hours to guarantee complete solubilization. Prior to measurement, the pH meter was calibrated using standard buffer solutions (pH 4.0, 7.0, and 9.0). The electrode was then immersed in the sample solution, and the pH was measured once a stable reading was achieved. To assure accuracy, each measurement was repeated three times, and the standard deviation (S.D.) was calculated.

This process was used to ensure that the pH of the formulated herbal sunscreens stayed within the skin-friendly range (4.5-6.5) even after extended usage, maintaining compatibility with human skin and reducing irritation risk.

Extrudability Study

The amount or percentage of formulation extruded from the tube, as well as the weight in grams required to extrude at least 0.5 cm of gel ribbon in 10 seconds [20], are used to assess the extrudability of herbal sunscreens. The formula below was used to estimate the extrudability:

$Extrudability = Applied\ weight\ to\ extrude\ gel\ from\ tube\ (gm)\ Area\ (cm2)$ (1)

Spreadability

The spreadability of herbal sunscreen is tested to see how easily it can be applied to the skin. To test this, a predetermined amount of sunscreen is applied between two glass slides. A known weight is then placed on the top slide to create pressure. As the weight moves the upper slide, the time it takes for the slides to separate is recorded. Additionally, the distance traveled by the upper slide prior to separation is measured. The spreadability is determined using the formula S = (M × L) / T, where M is the applied weight in grams, L is the distance moved in centimeters, and T is the time required in seconds. A greater spreadability number means that the sunscreen spreads more easily, making it more suited for smooth application. In contrast, a lower spreadability number indicates that the sunscreen is overly thick, which may impair its uniform distribution on the skin. This evaluation aids in determining the efficacy and usefulness of herbal sunscreens in skincare compositions.

$S = M \times L / t$ (2)

Where,

M = weight tied to upper slide

L = length of glass slide

T = time taken to separate the slides

Thermal Stability

Oil separation from herbal sunscreens was tested in a humidity chamber set to 37±1°C and 60-70% relative humidity. The interior wall of a 100 ml capacity chamber was covered with a 20 mm wide and 5 mm thick stripe of herbal sunscreen. The beaker was placed in a humidity chamber for eight hours at 37°C and 60-70% relative humidity. The herbal sunscreen must pass the test without any oil separation. [21].

Skin Irritation Study

A controlled skin irritation investigation was carried out with three groups of healthy rats (n = 6 per group, both sexes). The animals were housed in typical laboratory settings, with free access to water and a nutritionally appropriate meal. To guarantee consistent exposure, each rat's dorsal fur was shaved on a specific study day, leaving a 5 cm² region on each side of the midline. One side acted as the untreated control, whereas the other was exposed to the test chemical. [22].

Determination of SPF

A UV-visible spectrophotometer was used to test the efficiency of herbal sunscreens in vitro. Fifty grams of herbal sunblock creams were submerged in fifty milliliters of ethanol to yield a 0.10 percent (w/v) solution. Aliquots of each herbal sunblock were imaged at 5-nm intervals from 290 to 320 nm. The subsequent formula was used to calculate SPF. All samples have been assessed three times [23].

$$SPF = CF \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times A(\lambda)$$

Whereas, CF= Correction factor;

EE= Erythemogenic effect;

I= Intensity of solar light of wavelength;

A= Absorbance

The DPPH method is used to determine antioxidant activity in vitro.

"Ascorbic acid was used as a reference, and 1 mL of herbal sunscreens at varying quantities were taken in separate vials. After adding 5 mL of DPPH methanolic solution and shaking well, it was incubated at 370C for 20 minutes. Methanol was used as a blank to measure absorbance at 516 nm. As a control, DPPH absorbance was used.[24]. The percentage of antiradical activity was calculated using the formula below: % *Anti*

$-radimul\ absrrbivs\ -Samlees\ asrrruccces$ $Control\ absorbance$ Occlusion Studies in Vitro (4) × 100 When the entire surface of the skin is covered, this is known as skin occlusion. The occlusivity of herbal sunscreens can be calculated using the following formula: When A is the water loss without the sample and B is the water loss with the sample, we get (F) = $(A - \boldsymbol{N})\ A$. (5) × 100 This approach involves filling a beaker with water and covering it with filter paper." [25,26,27]

A value of 100 indicates that the entire surface has been covered by topical treatment, whereas a value of zero indicates no occlusion effect. On the surface of the filter paper, 50–200 mg of each herbal sunscreen were equally distributed to create a solid layer with a concentration of 8.5 mg/cm2. As a reference control, no samples were added to a beaker coated with filter paper. Maintain the samples at 320°C and 50–55% relative humidity for 48 hours. Weighing the samples after 6, 24, and 48 hours allowed us to determine how much water flowed or evaporated through the filter paper. Three duplicates of each experiment were conducted [24]. Testing for Stability To assess each herbal sunscreen's stability, centrifugation and the freeze-thaw procedure were employed.

Phase separation occurred after centrifugation and freeze-thaw tests. A mutagenicity assay using Salmonella TA 100 confirmed safety with controls and reference mutagens. After dissolving the materials in DMSO, the test strain was preincubated in phosphate buffer at 37°C for 20 minutes. After adding the test samples (herbal sunscreens), the plates were incubated for 48 hours at 37°C. A triplicate assay was used to evaluate each sample's mutagenic reactions to sunscreen ingredients. [28,29,30]

REFERENCES

[1] Arora S., Sharma N., Mahajan A., Kaur J., Singh S.: Development, physicochemical characterization and in-vitro evaluation of herbal sunscreen lotion, Journal of Pharmaceutical Technology, Research and Management., 2015, 3(2), 113–125.

[2] Chauhan R., Bhatt B., Kaushik S.: A review on natural photoprotactants for sunscreen, World Journal of Pharmaceutical Research., 2021, 10(10), 501-522.

[3] Azevedo, Jacqueline S., Nilton S. Viana Jr, and Cristina D. Vianna Soares. "UVA/UVB sunscreen determination by second-order derivative ultraviolet spectrophotometry." IL Farmaco, 1999; 54(9): 573-578.

[4] Young, Richard W. "Sunlight and age-related eye disease." Journal of the National Medical Association, 1992; 84(4): 353.

[5] Sliney, David H. "Photoprotection of the eye–UV radiation and sunglasses." Journal of Photochemistry and Photobiology B: Biology, 2001; 64: 2-3, 166-175.

[6] Schaefer H, Moyal D. and Fourtanier, "A. Recent advances in sun protection. Protection of the Skin against Ultraviolet Radiations." Paris: John Libbey Eurotext, 1998; 119-129.

[7] Bhatia, Saurabh, et al. "Broad-spectrum sun-protective action of Porphyra-334 derived from Porphyra vietnamensis." Pharmacognosy Research, 2010; 2(1): 45.

[8] Fioletov, Vitali, James B. Kerr, and Angus Fergusson. "The UV index: definition, distribution and factors affecting it." Canadian journal of public health, 2010; 101(4): I5-I9.

[9] Rubin, Adam I., Elbert H. Chen, and Désirée Ratner. "Basal-cell carcinoma." New England Journal of Medicine, 2005; 353(21): 2262-2269.

[10] Alam, Murad, and Désirée Ratner. "Cutaneous squamous-cell carcinoma." New England Journal of Medicine, 2001; 344(13): 975-983.

[11] Sander, C. S., et al. "Oxidative stress in malignant melanoma and non-melanoma skin cancer." British Journal of Dermatology, 2003; 148(5): 913-922.

[12] Donglikar M. M., Deore L. S.: Sunscreens: A review, Pharmacognosy. J., 2016, 8(3), 171-179.

[13] Sánchez, G., Nova, J., Rodriguez-Hernandez, A. E., Medina, R. D., Solorzano-Restrepo, C., Gonzalez, J., & Arevalo-Rodriguez, I. (2016). Sun protection for preventing basal cell and squamous cell skin cancers. Cochrane Database of Systematic Reviews, (7).

[14] Schlossman, D. "Sunscreen Technologies for Foundations and Lipsticks. Nice (France): Kobo Products.", 2001; 1-8.

[15] Freund, Robert M. A More Beautiful You: Reverse Aging Through Skin Care, Plastic Surgery, And Lifestyle Solutions. Sterling Publishing Company, Inc, 2010.

[16] Shao, Yun, and David Schlossman. "Effect of particle size on performance of physical sunscreen formulas." PCIA Conference. PRC, Shanghai, 1999.

[17] Nguyen, Uyen, and David Schlossman. "Stability study of avobenzone with inorganic sunscreens." Kobo Products Poster Presentation, SSC New York Conference, 2001.

[18] Hodge A.A, Hopkins F.E, Saha M. and Jha A.N. “Ecotoxicological effects of sunscreen derived organic and inorganic UV filters on marine organisms: A critical review” Marine Pollution Bulletin, 2025; 213: 117627.

[19] Jo Ah-R, Kwon B.R, Lee I, Min J, Choi S, Park N.Y. et al.: “A novel approach for unveiling co-occurrence patterns of UV filter mixtures in sunscreens: Prioritization for hazard and risk assessment” Ecotoxicology and Environmental Safety, 2025; 290: 117527.

[20] Geoffrey K, Mwangi A.N, and Maru S.M. “Sunscreen products: Rationale for use, formulation development and regulatory considerations” Saudi Pharmaceutical Journal, 2019; 27: 1009–1018.

[21] Salsabil E, Wulandari F, and Rohana E. “Formulation and SPF Value Evaluation of Sunscreen Spray Gel Containing Lime Peel Extract (Citrus aurantifolia)” Jurnal Farmasi dan Ilmu Kefarmasian Indonesia, 2024; 11(1): 42-52.

[22] Lergenmuller S, Rueegg C.S, Ghiasvand R and Veierød M.B “Sunscreen Use and Cutaneous Squamous Cell Carcinoma Risk: A Review of the Evidence” Advances in Dermetology and venereology, 2024; 105: 42550.

[23] Shabrina A.M, Azzahra R.S, Permata I.N, Dewi H.P, Safitri R.A, Maya I. et al: “Potential of Natural-Based Sun Protection Factor (SPF): ASystematic Review of Curcumin as Sunscreen” Cosmetics, 2025; 12(10): 1-24.

[24] R- Lezman J, Riskin S. “Sunscreen Safety and Efficacy for the Prevention of Cutaneous Neoplasm” Cerues, 2024; 16(3): 56369.

[25] Rajasekar M, Mary J, Meenambigai Sivakumarb and Selvamb M. “Recent developments in sunscreens based on chromophore compounds and nanoparticles” RSC Advances, 2024;14: 2529.

[26] Singh T.P, Khalid M, Singh S.P, Gupta M and Dr. Kumar M. “Ultimate Sun Protection: Glow Shield Sunscreen” International Research Journal of Pharmacy and Medical Sciences, 2025; 8(2): 11-15.

[27] Brzozowska and Gotlib “Social Media Potential and Impact on Changing Behaviors and Actions in Skin Health Promotion: Systematic Review” Journal of Medical Internet Research, 2025; 27: 1-17.

[28] M. de Araújo, Andressa C, Mariana S, Samuel V, Freitas M, Flávia C et. al.: “NLC-Based Sunscreen Formulations with Optimized Proportion of Encapsulated and Free Filters Exhibit Enhanced UVA and UVB Photoprotection” Pharmaceutics, 2024; 16: 427.

[29] Siswanto, Qulub F and Ofelia V. “Nanoparticle formulation of ZnO: TiO2 as sunscreen cream for Cutaneous Lupus Erythematosus (CLE) patients” Journal of Physics, 2025; 2945: 012019.

[30] Kwon J, Kim M, Kim Y.-J, Yi G.-R and Lee H. “Titania-Cored Janus Multipods as UV-Protective Pickering Emulsifiers for Sunscreens” Small, 2025; 21: 2402577.