

A Comprehensive Review On Botanical UV Shields and Polyherbal Sunscreen Technology.

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ABSTRACT

Sunscreens play a vital role in protecting the skin from harmful ultraviolet (UV) radiation, which is responsible for erythema, photoaging, hyperpigmentation and skin cancers. This review highlights the classification, mechanism of action, advantages and limitations of conventional as well as polyherbal sunscreens. UV radiation, especially UVA and UVB rays, induces oxidative stress, DNA damage and collagen degradation leading to premature skin aging and carcinogenesis. Polyherbal sunscreens containing natural ingredients such as *Camellia sinensis*, *Curcuma longa*, *Aloe vera*, pomegranate, neem and cucumber provide effective photoprotection through UV absorption, antioxidant and anti-inflammatory activities. These herbal formulations improve skin hydration, enhance SPF and reduce adverse effects associated with synthetic sunscreens. The review also discusses evaluation parameters including SPF determination, viscosity, spreadability, stability and skin irritation studies. Furthermore, advancements in nanotechnology, eco-friendly formulations and multifunctional herbal actives are expected to improve the safety, efficacy and environmental compatibility of future sunscreen products.

Keywords: Polyherbal Sunscreen, Ultraviolet Radiation, Photoprotection, Antioxidant Activity, Skin Cancer

INTRODUCTION:

According to the Drugs and Cosmetics Act of 1940 and the rules set in 1945, the term "cosmetic" describes any product meant to be applied to the human body or any of its parts. This is done for cleansing, beautifying, improving attractiveness or altering appearance. It also includes any formulation used as part of a cosmetic. Human skin is the most exposed area of the body and prior research on skin cells, both in vitro and in vivo, has demonstrated that ultraviolet (UV) radiation can harm the molecules and structures of skin cells. UV radiation is partially reflected by the skin and partially absorbed by different layers of the skin.¹

Malignant melanoma, squamous cell carcinoma and basal cell carcinoma are among the skin cancer types that are more likely to develop as a result of prolonged UV exposure. The UV-C rays that are most detrimental to life are blocked by ozone. Currently UV-B and to a lesser extent UV-A radiation are the main causes of skin cancer.

UV exposure increases oxidative stress in skin cells, which leads to an overabundance of reactive oxygen species (ROS) that may cause and accelerate the development of cancer. Dysplasia and cytological atypia may result from the epidermis's uneven thickening as photoaging advances. Antioxidants, keratolytic, moisturisers and sunscreens can all be used as effective photoprotection strategies.²

IDEAL CHARACTERISTICS OF SUNSCREEN:³

1. It should protect from sunburn
2. It should possess photoaging property
3. It should protect from skin cancer
4. It should not produce phototoxic/ photoallergic reactions
5. It should protect from photosensitivity diseases, like:
 - Polymorphous light eruption (290-365 nm)
 - Solar urticaria (290-515 nm)
 - Chronic actinic dermatitis (290 nm-visible)
 - Persistent light reaction (290-400 nm)

CLASSIFICATION OF SUNSCREEN:

There were 16 authorized sunscreen compounds listed in the most recent FDA sunscreen monograph, which was published in 1999. It suggests replacing the labels "chemical" and "physical" with the categories "organic" and "inorganic" for sunscreens. In the world, sunscreen agents are typically referred to by three names. These include the trade name, US adopted name (USAN), and International Nomenclature Cosmetic Ingredient (INCI) name.³

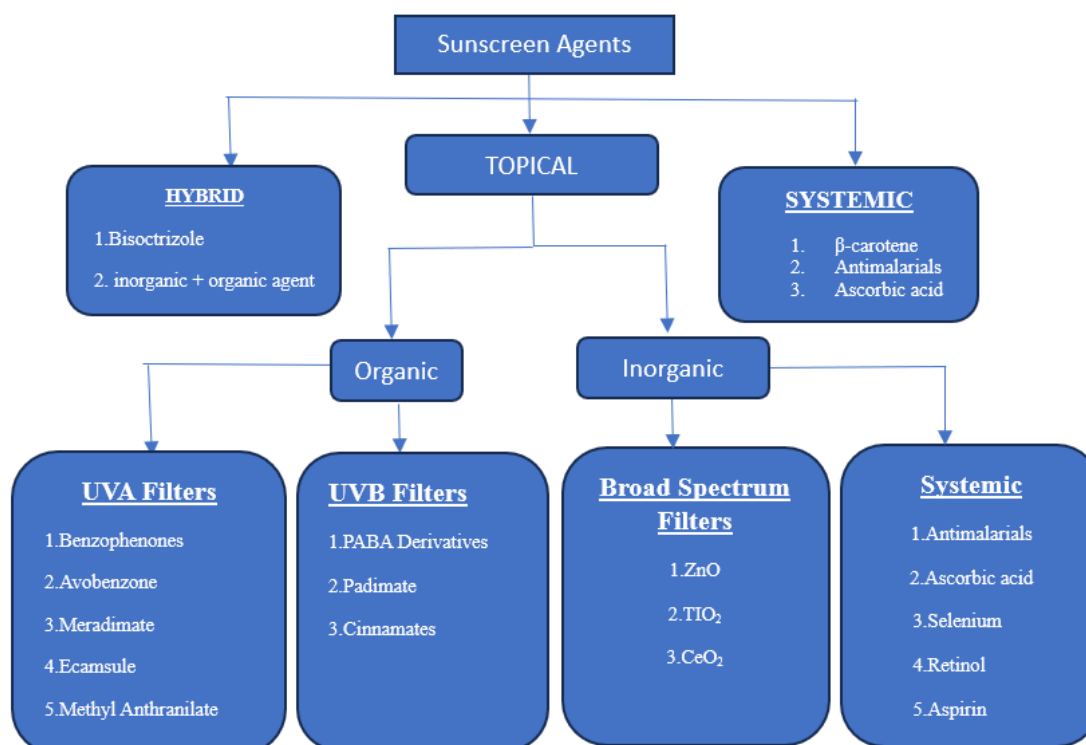


Fig 1. Classification of sunscreen agent.

Sunscreen is classified mainly into 2 types:

1. Physical sunscreen
2. Chemical sunscreen

1. Physical sunscreen:⁴

They contain active ingredient such zinc oxide or titanium oxide, which works by setting on top of the skin to deflect or scatter the damaging UV rays from the skin. They are also known as physical blocker, they almost provide complete protection from the UV rays. They are thick and greasy preparation.

Advantages:

1. Broad spectrum of activity.
2. Protects from sun as soon as applied.
3. Long lasting action.
4. Suitable for all skin types.

Disadvantages:

1. Can be rub-off easily.
2. Leave whitish cast on the skin.
3. It required more friction to rub.

2. Chemical sunscreen:

Oxybenzone, avobenzone, octocrylene, etc are examples of chemical filters, which are aromatic substances that absorb intense UV light and cause stimulation to higher energy levels. The absorbed energy is transformed into lower-energy wavelengths, such infrared radiation (i.e., heat), when these molecules return to their ground states.⁵ they create chemical reaction and work by changing UV rays into heat and then realising that heat from the skin.⁴

Chemical sunscreen falls into two groups. The first group is UVA filters such, as anthranilates, dibenzoylmethanes and benzophenones. The second group is UVB filters such as salicylates, cinnamates, para-aminobenzoic acid (PABA) derivatives and camphor derivative. these blockers help sunscreen absorb UV light and they are safe. Chemical sunscreen stays stable do not irritate skin do not evaporate, do not cause photosensitivity and do not stain skin, they are better. Besides, they are mostly used in combination at levels currently allowed by the FDA to provide broad-spectrum absorption, as well as it increases SPF values.⁶

Advantages:

1. They are thinner and spreads more easily on skin.
2. No need of large application on skin because there is no space between the sunscreen molecules after application.
3. Formula is easier.

Disadvantages:

1. Increases internal skin temperature.
2. It required approx. 20 min to work after application.
3. Higher the SPF value higher the chance of skin irritation.
4. Reapplication is necessary.

PATHOPHYSIOLOGY OF UV INDUCED SKIN DAMAGE:

Many variables, such as wavelength, dose, race and characteristics of the skin tissues, can affect UV-induced damage to the skin. The strong photons emitted from UV light must first penetrate layers of skin and be taken

in by a cellular component (chromophore, photosensitizer) to produce any biological changes. Several biological reactions are triggered.

There are two mechanisms by which UV light can cause damage. These include direct absorption of UV light by cell chromophores, possibly leading to photo-induced reactions.

This is general form of damage that can occur to DNA bases. Photosensitization processes involving the action of either endogenous or exogenous sensitizers are another second indirect mechanism.

The two types of programmed cell death are known, which are either apoptotic cell death or necrosis. The latter is known to be the passive process, in which the external injury, not normal cellular function, is the causative agent of damage, often leading to cytoplasmic swelling.⁷

DNA is the most familiar UVB target. The two major photochemical reactions UVB triggers in DNA are cyclobutane pyrimidine dimers (CPDs) and (6-4) pyrimidine-pyrimidone photoproducts [(6-4) PPs. Most photochemical products result from C→T and CC→TT mutations at dipyrimidine sequences in DNA. Due to their abundance, slow repair, and distinctive mutagenicity, CPDs are considered to be more mutagenic than the rest. The high frequency of p53 mutations in squamous cell carcinomas originates from these photolesions. In reports, it has been mentioned that T-T lesions may lead to the induction of N-Ras mutations in human melanomas and mouse squamous cell carcinomas.⁸

UV RADIATION AND SKIN DAMAGE

1. Low Energy [UVA]

They are used in tanning beds. They cause wrinkles and skin aging. They also give skin a false feeling of protection from the sun and skin color. The ozone layer can be easily penetrated by UVA rays.

Longwave radiation or UVA

- a) 320-400
- b) Erythrogenic effect diffuses into the dermis and is weak.
- c) Responsible for the progression towards a natural-looking skin tone.
- d) The majority of cases of photosensitivity reactions induced by medications occur.
- e) UVA may potentiate the action of UVB⁹

2. High Energy [UVB]

Produces sunburns, cataracts, susceptible system damage and skin cancers. Possibly escalates the incidence of melanoma in persons below the age of 20 years. The utmost UVB rays are absorbed by the ozone layer.

UVB (Middle wave Radiation): Wavelength (290-320 nm)

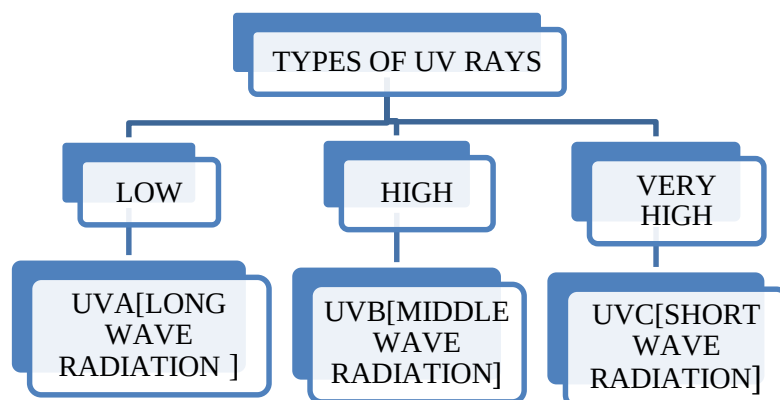
Compared with UVA, a smaller proportion of UVB radiation is comprised within the electromagnetic spectrum, and as a result of the absorbance by skin chromophores, it is more likely to cause erythema. It can reach the epidermal layer of the skin but has less skin penetration compared with UVA.¹⁰

3. Very High Energy (UVC)

These rays have the most damaging effects. Fortunately, it is reflected back by the ozone layer and never reaches the surface of the earth.

UVC: short-wave or germicidal radiation

- a) Wavelength: 100-290nm.
- b) Does not reach to Earth's surface.
- c) Is produced by artificial ultraviolet sources.⁹



EFFECTS OF UV RADIATION ON SKIN

UV light, extending from shorter to longer wavelength, can be categorized into three main bands of UV light according to its spectrums: UVC, UVB and UVA. The ozone level in the stratosphere generally filters out UVC photons, with the shortest wavelength (between 200 and 290 nm) and has the most energy compared to other UV light spectrums. Hence, it does not reach the surface of the earth. Approximately 5% of UV light reaching the surface of a planet is comprised of UVB photons with a wavelength measuring between 290 and 320 nm. The human epidermis has completely absorbed it. The remaining 95% is comprised of UVA photons with a wavelength extending from 320-400 nm. It has two main wavelength ranges spelled as UVAII and UVA I with a wavelength extending from 320-340 and 340-400 nm, respectively. While being less energetic than the UVB rays, UVA rays have a deeper penetration capacity within the dermis.

The exposure of UV light has both beneficial and detrimental effects on the skin of humans. The following are some advantages of UV for the skin:

- Production of Vitamin D
- Release of Beta-endorphins during sun exposure

Manages skin conditions such as psoriasis vulgaris but it may also cause negative effects if the skin is exposed to too much ultraviolet radiation¹¹.

The activation of MMPs has been found to be triggered by UVR, and MMP1 is currently found to be the major enzyme involved in collagen breakdown and skin photoaging. Because UVA has long been known to be highly efficient in its ability to induce ROS and dermal degradative enzymes, it would not be surprising that antioxidants could inhibit this result.¹²

Additionally, UVA exacerbates UVB's harmful effects, such as skin cancer and cataracts, an eye condition.¹⁰

The following are the effects caused in the human skin by ultraviolet radiation:

Acute consequences

A primary sign of inflammation would be erythema. Excessive UVB irradiation can also induce erythema through increased vascular permeability and vasodilation of cutaneous blood vessels. Clinical manifestations of inflammation, such as erythema, pain, and edema, can also be related to erythema. Blistering can also occur as a result of severe erythema.

After being exposed to UVA radiation, there occurs a pigmentation or tanning response, which the happens in the following three distinct phases:

- First transient phase, also known as the immediate pigment darkening reaction or IPD/Immediate Tanning Reaction, occurs from several minutes to a maximum of two hours after UVA irradiation.

- A prolonged phase two, known as persistent pigment darkening (PPD), presents with a tan to brown pigmentation. This reaction occurs in a matter of hours post-exposure to UVA and results in some residual pigmentation that persists for at least 24 hours.

Sunburn: This is an inflammatory response where the keratinocytes are affected by UVB rays beyond a certain intensity, thereby triggering the pathways of apoptosis, or programmed cell death, of the keratinocytes. Peeling or skin rejuvenation of the affected area is among the clinical manifestations. Cell name: These are the keratinocytes.¹³

Long-term consequences

Skin cancers, also recognized as photo carcinogenesis, are frequent in Caucasians and not very common in Asian and Black Africans (30). There exist two variants of skin cancers, which include melanomas and nonmelanomas (squamous cell carcinomas and basal cell carcinomas). The major contributor to skin cancers is UVB rays, which accomplish both DNA damage and immunosuppression.

Long-term UV irradiation triggers a cumulative production of ROS, responsible for triggering photoaging. ROS accumulation triggers the release of transforming growth factor beta (TGF- β) and activator protein 10-1 (AP-1) molecules, which activates the synthesis of matrix metalloproteinases (MMPs). These factors collectively contribute to collagen degradation and the inhibition of production of procollagens I and III.¹¹

Herbal Ingredients Used in Polyherbal Sunscreens

Natural plant extracts are increasingly included in polyherbal sunscreens on account of their sun -protective, anti-oxidative, anti-inflammatory effect and moisturizing and cosmetic functions. These phytochemicals include such compounds as polyphenols, flavonoids, carotenoids, tannins and terpenes that both absorb UV light and neutralize the free radicals created by ultraviolet radiation.¹⁴

Commonly studied herbal ingredients include *camellia sinensis* (green tea), *punica granatum* (pomegranate peel), *curcuma longa* (turmeric), *aloe vera* and also cucumber, carrot seed and neem. Each of these components provides distinct features and benefits to the sunscreen compositions. They are also capable of direct UV protection by sequestering UVA and UVB rays.¹⁵

Below is a summary table of important herbal ingredients used in polyherbal sunscreens and their functions:

Table 2. Herbal Ingredient

Herbal Ingredient	Key Bioactive Components	Primary Functions in Sunscreen
<i>Camellia sinensis</i> (Green tea)	Catechins, polyphenols	Antioxidant; UV-absorbing; reduces UV-induced oxidative stress
<i>Punica granatum</i> (Pomegranate)	Phenolic acids, flavonoids	Antioxidant; photoprotective; anti-inflammatory
<i>Curcuma longa</i> (Turmeric)	Curcumin and related curcuminoids	Antioxidant; anti-inflammatory; may protect against UV-related irritation
<i>Aloe vera</i>	Polysaccharides; phenolics	Soothing; moisturising; supportive antioxidant; enhances skin comfort
<i>Vinca</i> flower extract	Flavonoids, tannins, terpenoids	UV-protective compounds; contribute to SPF when combined

Lavender oil, Almond oil, Honey	Terpenes, flavonoids, antioxidants	Additional antioxidant and soothing effects; may assist skin health
Neem (Azadirachta indica)	Terpenoids and antioxidants	Anti-inflammatory; helps calm skin exposed to UV stress
Beetroot (Beta vulgaris)	Betalains; antioxidants	Antioxidant; may contribute to UV protection and skin health
Cucumber extract	Vitamins; flavonoids	Cooling; hydrating; antioxidant support
Oils (e.g., Coconut, Olive, Almond, Grape seed)	Fatty acids; vitamins A, E	Moisturizing; antioxidant; secondary UV-support
Algae (e.g., seaweed extracts)	Polyphenols, carotenoids	Photoprotective; antioxidant; anti-photoaging potential

Mechanism of Photo protection by Herbal Sunscreens

Herbal sunscreens offer photo protection in a variety of ways, which minimize the adverse effects of ultraviolet (UV) rays on the skin. As opposed to chemical absorption or physical reflection of UV rays by synthetic sunscreens, the mode of action of herbal sunscreens are considered multifactorial, which includes UV absorption, antioxidant activity, anti-inflammatory properties and stimulation for skin repair mechanisms.¹⁶

High number of phytoconstituents (flavonoids, phenolics compounds, tannins, carotenoids and polyphenol) is known for their natural ability to absorb UV. All of these compounds absorb UVA and UVB because of their conjugated aromatic structures, which reduce the penetration of this radiation into deeper skin layers and protect against cellular damage. Formulations containing plant extracts have been found to increase sun protection factor (SPF).¹⁷

Reactive oxygen species (ROS) are major mediators of the UV effects on photo aging, DNA damage and skin cancer. Botanical-based sunscreens have a potent antioxidant activity through direct free radical scavenging and the down-regulation of oxidative stress. Polyphenol and vitamin-rich plant extracts guard against lipid peroxidation, protein oxidation and DNA damage from UV radiation, protecting skin cell functions against the impact of photo damage

Along with antioxidant activity, plant ingredients also have anti-inflammatory activities which diminish UV-induced erythema, oedema and irritation. These effects are attributed to suppression of inflammatory mediators, such as prostaglandin, cytokines and nitric oxide. As such, the herbal sunscreens enhance skin tolerance and decrease any adverse occurrence of long-term exposure to sun.¹⁸

In addition, herbal sunscreens impart skin barrier protection and repair. Some plant extracts are claimed to stimulate collagen biosynthesis, inhibit matrix metalloproteinases and increase skin moisturization and elasticity leading to anti-aging affect. Novel delivery systems like gels, creams and microsponges are enhancing the stability, penetration and sustained action of herbal actives in turn increasing photoprotective efficacy.¹⁹

Formulation Approaches in Polyherbal Sunscreen

1. Selection of Herbal Ingredients

Several plant extracts such as *camellia sinensis*, *punica granatum*, *citrus sinensis*, and *curcuma longa* are widely selected in polyherbal sunscreen formulations because they are rich in polyphenols and flavonoids which have the ability to absorb UV rays and neutralize free radicals. In one reported formulation, when the concentration of polyherbal extract blend in an emulsion base was increased from 6% to 10% (w/w), its photoprotective capacity increased progressively, and the formulation with the highest concentration of the extract exhibited the highest sun protection factor (SPF).

2. Conventional Formulation Approaches

Conventional formulation approaches in polyherbal sunscreen mainly include creams, lotions, gels, ointments, sprays, and foams. Among these, oil-in-water emulsions are a frequently used system in base formulation due to their spreadable, non-greasy nature, and ability to mix well with both hydrophilic and lipophilic herbal actives.¹³

Apart from these emulsions, some other research has looked into other unique combinations of botanical actives. For example, the combination of *vitis vinifera* (grape seed) and *silybum marianum* (milk thistle) with *camellia sinensis* in cream formulation showed significant antioxidant activity as well as photoprotective effect, indicating that combinations of different extracts can exert broad-spectrum photoprotection as effective as some synthetic sunscreen.¹⁸

3. Advanced Formulation Approaches

Advanced formulation approaches include nanoemulsions, liposomes, solid lipid nanoparticles, nanostructured lipid carriers, and phytosomes for improving the delivery and stability of herbal actives.

Similarly, solid lipid nanoparticle systems loaded with bioactive compounds like safranal have been developed to enhance natural photoprotection while exhibiting broad-spectrum sunscreen properties.¹⁹

4. Polyherbal Combination Strategy

The formulation strategies of polyherbal sunscreens emphasize the synergy of natural botanicals and the optimum concentration of extracts to achieve maximum photoprotective efficacy. Different herbal extracts are combined to enhance antioxidant and UV protective activities. For example, the combination of *vitis vinifera* (grape seed), *silybum marianum* (milk thistle), and *camellia sinensis* demonstrated significant antioxidant as well as photoprotective effects, suggesting that combinations of botanical extracts can provide broad-spectrum photoprotection comparable to some synthetic sunscreens.¹⁸

5. Use of Natural Oils and Butter

Natural oils and lipidic substances are commonly incorporated in polyherbal sunscreen formulations to improve skin moisturization, spreadability, and formulation stability. Ingredients such as Olive Oil, Stearyl Alcohol, and Cetyl Alcohol are widely used in oil-in-water emulsion systems as they provide a stable vehicle for herbal extracts and improve the rheological properties of the formulation for topical application.¹³

6. Incorporation of Natural UV Filters

Polyherbal sunscreen formulations incorporate natural UV filters mainly from plant-derived polyphenols, flavonoids, and bioactive compounds which possess UV absorbing and antioxidant properties. Extracts of *camellia sinensis*, *punica granatum*, *citrus sinensis*, and safranal-containing systems have shown the ability to enhance photoprotection and provide broad-spectrum sunscreen activity.¹⁹

7. Stabilization Approaches

Stabilization approaches in polyherbal sunscreen formulations involve the use of emulsifying agents, polymeric carriers, and nanoparticle-based systems to maintain formulation stability and improve the efficacy of herbal actives. Microsponge systems encapsulate polyherbal extracts in a polymeric matrix which stabilizes UV filters and enables controlled release upon topical application. In addition, solid lipid nanoparticles enhance the stability and photoprotective performance of bioactive compounds in sunscreen formulations.

The formulation strategies of polyherbal sunscreens show an increasing emphasis on the synergy of natural botanicals, the optimum concentration of extract, and delivery systems to achieve maximum photoprotective efficacy along with acceptable aesthetic and stability.¹⁹

EVALUATION OF POLYHERBAL SUNSCREEN

The evaluation of the herbal sunscreen formulation took into account several important factors.

Organoleptic properties:

In this we looked closely at how the product appeared, its color, and whether it had a consistent texture throughout. This helped ensure the formulation was both appealing and uniform.

Determination of Viscosity:

To determine the viscosity Brookfield viscometer (RVDV-II+PRO) is used and chose the appropriate spindle for the test. We measured out 50 ml of the sample and placed it in a beaker. The spindle is inserted into the sample and the rotation speed (rpm) is adjusted as needed. We specifically measured the viscosity of the herbal sunscreen formulation. It is measured at 5, 10, 20, 50 and 100 rpm. The viscosity is computed using the factor obtained from the reading.⁹

Determination of pH:

The pH of herbal sunscreens is determined using a digital pH meter. The pH is measured after 1 g of the formulation is dissolved in 100 ml of freshly prepared distilled water for 2 hours. The purpose of this study is to guarantee that the pH of the produced herbal sunscreens is similar to the pH of the skin after 24 hours of use. The results are triple-checked and S.D. is recorded.

Spreadability:

The spreadability of herbal sunscreens determined their therapeutic efficiency. The appropriate amount of herbal sunscreen is applied between two slides and under specified load directions, the two sides are timed in seconds to slide off. Spreadability is defined as the time it took to separate two slides.

The formula for calculating it is:

$$S = \frac{M \times L}{t}$$

Where,

M = weight tied to the upper slide

L = length of glass slide

T = time taken to separate the slides

Extrudability Study

The extrudability of the herbal sunscreens is measured in this study by calculating the percentage of the formulation extruded from the collapsible tube based on the weight in grams necessary to extrude at least 0.5 cm of the gel ribbon in 10 seconds. After that, the extrudability is estimated using the formula.

$$\text{Extrudability} = \frac{\text{Applied weight to extrude gel from tube (gm)}}{\text{Area(cm}^2\text{)}}$$

Thermal Stability:

The oil separation of herbal sunscreens is studied in a humidity chamber at $37 \pm 1^\circ\text{C}$ and 60-70 % RH. 20 mm wide and herbal sunscreens is spread onto inner wall of chamber (100 ml capacity, the whole height) one after the other. The beaker is placed in a humidity chamber for 8 hrs at $37 \pm 1^\circ\text{C}$ and 60-70 % RH. There should be no oils separation and that the herbal sunscreen passed the test.²⁰

SPF Determination:

A UV Visible spectrophotometer is employed to analyze the in-vitro efficacy of herbal sunscreens. A 0.10 percent solution (w/v) of herbal sunscreen lotions in ethanol is prepared by dissolving 0.050 g of herbal sunscreen lotions in 50.0 ml of ethanol. Between 290 and 320 nm, the samples of each herbal sunscreen are scanned at 5 nm intervals. SPF is calculated using the equation below. Three times each sample ss analysed.

$$\text{SPF} = \text{CF} \sum \text{EE}(\lambda) \times \text{I}(\lambda) \times \text{A}(\lambda)$$

Where,

CF= Correction factor

EE= Erythemogenic effect

I= Intensity of solar light of wavelength

A= Absorbance

Antioxidant Activity Determination:

The sunscreens antioxidant activity is evaluated using the DPPH system.

Anti-radical activity is calculated as follows:²⁰

$$\text{Anti-radical activity} = \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} \times 100$$

In-vitro Occlusion Studies:

Skin occlusion can be defined as the complete coverage of the skin's surface. The following formula can be used to calculate the occlusivity of herbal sunscreens:

$$\text{Occlusion factor (F)} = \frac{(A - B)}{A} \times 100$$

Were,

A= water loss without sample,

B = water loss with the sample.

This method uses a filter paper-covered water-filled beaker. The occlusion factor varies from zero to one hundred, with zero indicating no occlusion effect and one hundred indicating complete surface covered by topical application. 50 to 200 mg of each herbal sunscreen is evenly placed on the filter paper surface to create a solid film with an 8.5 mg/cm² concentration. A beaker covered with filter paper is used as a reference control, with no samples applied. For 48 hours, the samples are maintained at 32°C and 50-55% RH. At the same time, the water flow or evaporation rate through the filter paper is determined by weighing the samples after 6, 24 and 48 hours. Each experiment is repeated thrice.²¹

Homogeneity:

Test for homogeneity A small amount of the sunscreen lotion is placed on a glass slide. The lotion is carefully spread into a thin, even layer on the slide. A cover glass is placed on top. The slide is then observed under a microscope. The lotion is visually examined for any visible particles, clumps or uneven distribution. If the lotion appears uniform with no visible coarse particles, it's considered homogeneous.²²

Washability:

The washability test is performed by applying a small amount of cream on the dorsal surface of the hand and spreading it uniformly. The area is washed with running tap water without soap. The ease of removal is observed visually and recorded as easily washable, moderately washable or poorly washable.²³

Microbial test:

Agar media is prepared then the formulated cream is inoculated on the plate's agar media by streak plate method and a controlled is prepared by omitting the cream. The plates are placed in the incubator and it incubated at 37°C for 24 hours. After the incubation period, the plates are taken out and the microbial growth are checked and compared with the control.²⁴

Drug content:

The drug content of the herbal sunscreen is determined by dissolving an accurately weighed quantity of cream (about 500 mg) in about 50 ml of ethanol. These solutions are transferred quantitatively to volumetric flasks and dilutions are made with the same solvent. The resulting mixture is then filtered through Whatman filter paper before subjecting the solutions to spectrophotometric analysis. The linear regression equation derived from the calibration data is used to calculate drug content.²⁵

Skin Irritation Study:

The in-vivo acute dermal irritation study for herbal sunscreen is performed according to OECD guideline 404 using healthy Wistar rats. The animals are housed under standard laboratory conditions with free access to food and water. The dorsal surface of each rat is shaved carefully 24 hours before the experiment without damaging the skin. A measured quantity of the cream (about 0.5-1 g) is applied uniformly over a marked area of approximately 2-3 cm² on the shaved skin. The treated site is left in contact with the formulation for 24 hours. After the exposure period, the site was observed at 24, 48 and 72 hours for signs of erythema (redness) and edema (swelling). The severity of skin reactions is scored according to the Draize scoring method and the formulation is considered non-irritant if no significant skin reactions are observed.²⁶

In Vitro Drug Release Studies:

In-vitro release study of the formulated is carried out by using diffusion cell through egg membrane as a biological membrane. Diffusion cell with inner diameter 1.4 cm was used for the study. The formulation 1 ml are placed in donor compartment and freshly prepared 100 ml pH 6.8 phosphate buffer in receptor compartment. Egg membranes are mounted in between donor and receptor compartment. The position of the donor compartment is adjusted so that egg membrane just touches the diffusion medium. The whole assembly is placed on the thermostatically controlled magnetic stirrer. The temperature of the medium is maintained at $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$. The entire assembly is placed in the magnetic stirrer to preset the rpm at 50 and stir the solution continuously with the aid of a magnetic bead. 1 ml of sample is withdrawn from receiver compartment after every 1 hours then analyzed by UV-Visible Spectrophotometer.²⁷

Stability Testing:

1. Centrifugation test:

Centrifugation and the freeze-thaw process are employed to check the stability of each herbal sunscreen. The centrifugation process is carried out for 10 minutes at 10000 rpm with intervals of 500 rpm and phase separation is observed. The herbal sunscreens are stored at 20°C and 40°C in freeze-thaw research and phase separation is observed. Each of the tests is conducted three times.²⁰

2. Chemical degradation test:

Stability testing of herbal sunscreen is done to assess the drug and formulation stability. The stability studies are done according to ICH guidelines. The stability studies are carried out as per ICH guidelines. The cream filled in bottle and kept in humidity chamber maintained at $30 \pm 2^{\circ}\text{C} / 65 \pm 5\% \text{ RH}$ and $40 \pm 2^{\circ}\text{C} / 75 \pm 5\% \text{ RH}$ for two months. At the end of studies, samples are analyzed for the physical properties and viscosity.²⁸

Advantages of herbal Sunscreen^{29,30}

1. Protection against UV radiation
2. Prevention of sunburn (erythema).
3. Reduction in risk of skin cancer
4. Prevention of premature skin aging (photoaging)
5. Protection in photosensitive condition.
6. Adjunct in dermatological therapy
7. Availability in various formulations

Disadvantages of herbal Sunscreen^{31,32,33}

1. Skin irritation and allergic reactions.
2. Incomplete protection.
3. Photoinstability of some agents.
4. Systemic absorption concerns.
5. Environmental impact.
6. Cosmetic drawbacks.

Future Perspectives of Sunscreens

1. Development of Safer and More Photostable UV Filters

Future sunscreen research is focused on creating new UV filters that offer broad-spectrum protection with enhanced photostability to maintain effectiveness during prolonged sun exposure. These filters are designed to remain primarily within the stratum corneum, minimizing systemic absorption and reducing potential long-term health risks associated with some chemical filters. Advances in molecular design and computational chemistry support the creation of filters with optimized UV absorption, stability and safety profiles.³⁴

2. Nanotechnology-Based Sunscreen Formulations

Nanotechnology is poised to significantly advance next-generation sunscreens by improving their performance and user experience. Incorporating UV filters into carriers such as solid lipid nanoparticles, nanostructured lipid carriers, liposomes and polymeric nanoparticles enhances the stability of active ingredients, ensuring prolonged and consistent protection. Additionally, nano-sized inorganic filters like Zinc oxide and Titanium dioxide provide effective broad-spectrum UV protection³⁵

3. Eco-Friendly and Reef-Safe Sunscreens

Rising environmental awareness has driven the development of reef-safe and biodegradable sunscreens that minimize harm to marine ecosystems. Future sunscreens increasingly focus on using natural and bio-inspired photoprotective compounds, such as mycosporine-like amino acids (MAAs) derived from marine organisms and plant-based polyphenols, which offer effective UV protection while being environmentally sustainable.³⁶

4. Incorporation of Antioxidants and Multifunctional Actives

Future sunscreen formulations are evolving into multifunctional products that offer more than just UV protection. The incorporation of antioxidants such as vitamins C and E, flavonoids and polyphenols help neutralize reactive oxygen species generated by UV exposure.³⁷

5. Personalized and Smart Sunscreen Systems

Advancements in digital health and wearable technology are paving the way for personalized photoprotection through smart sunscreen systems. These innovations integrate sunscreens with UV sensors and mobile applications to monitor real-time ultraviolet exposure.³⁸

6. Regulatory and Clinical Evaluation Advancements

Future developments in sunscreen technology will be supported by stricter regulatory guidelines and the implementation of standardized testing methods to ensure product safety, efficacy and environmental compatibility.³⁹

Conclusion:

Sunscreens are essential in preventing UV-induced skin damage, including erythema, photoaging, hyperpigmentation and skin cancers caused mainly by UVA and UVB radiation. The article highlights that polyherbal sunscreens have emerged as a promising alternative to conventional synthetic formulations due to their multifunctional properties. Herbal ingredients such as *Camellia sinensis*, *Curcuma longa*, *Aloe vera*, *Punica granatum* and neem possess natural UV-absorbing, antioxidant and anti-inflammatory activities that help reduce oxidative stress, DNA damage and collagen degradation induced by ultraviolet exposure. The review also emphasizes that combining multiple herbal extracts enhances SPF, skin hydration, photostability and overall skin compatibility while minimizing irritation and environmental toxicity associated with chemical sunscreens. Furthermore, proper evaluation parameters such as SPF determination, viscosity, spreadability, stability and skin irritation studies are necessary to ensure product quality and efficacy. Future advancements in nanotechnology and eco-friendly formulations may further improve the safety, effectiveness and acceptability of polyherbal sunscreen products.

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