
Exploring The Potential Of Herbal Plants As Natural Sunscreen Agents: Literature Review

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Abstract

Indonesia, as a tropical country, experiences high ultraviolet (UV) exposure, increasing the risk of skin damage and highlighting the importance of sunscreen use; However, chemical sunscreens may cause adverse effects, making natural ingredients promising alternatives. This study aims to evaluate the potential of herbal plants as natural sunscreens based on Sun Protection Factor (SPF) values using a Systematic Literature Review (SLR) of SINTA-indexed journals published between 2021 and 2026, including experimental studies reporting in vitro and/or in vivo SPF values. The results indicate that herbal plants contain secondary metabolites such as flavonoids, phenolics, tannins, and terpenoids that contribute to photoprotective activity, with SPF values ranging from minimal to ultra protection depending on plant type, extract concentration, and formulation; higher concentrations generally increase SPF, and advanced systems such as nanoemulsions improve effectiveness, although certain interactions may reduce SPF. In conclusion, herbal plants show strong potential as natural sunscreen agents; however, further formulation optimization and comprehensive safety and efficacy studies are required.

Keywords: Flavonoids, Herbal Sunscreen, Photoprotection, Sun Protection Factor, Ultraviolet Radiation.

INTRODUCTION

Indonesia is one of thirteen countries located on the equator and has a tropical climate. Indonesia's location on the equator makes it one of the countries with high sun exposure (Tahar et al., 2019). Humans can benefit from UV radiation in several ways, such as obtaining vitamin D, producing more white blood cells, which help protect the body, and improving sleep quality by promoting the production of the hormone melatonin, which regulates sleep cycles. However, despite these benefits, prolonged exposure to UV radiation can be harmful to humans. Exposure to UV rays, which have the ability to penetrate the skin's dermis and damage its cells, results in decreased skin elasticity, which increases the risk of premature aging, photoaging, dry and rough skin, uneven pigmentation, wrinkles, and benign skin tumors (actinic keratosis). Sunburn, a type of skin irritation caused by exposure to UVB rays, can result in signs of redness. Itching of the reddened skin usually accompanies these symptoms (Sofia et al., 2021).

According to the World Health Organization (2018), prolonged sun exposure can cause skin damage. There are two types of skin damage: acute (quick) and chronic (long-term). Sunburn and tanning are examples of acute skin damage. Sunburn is a skin condition characterized by pain and warmth, while tanning is another condition caused by exposure to UV radiation that causes skin darkening. Therefore, appropriate efforts are needed to prevent these adverse effects on the skin, one of which is by using sunscreen (Avianka et al., 2022).

Sunscreen is a skincare cosmetic that can protect the skin from sun exposure (Minerva, 2019). Sunscreen has the ability to protect the skin by delaying erythema, which is expressed as the Sun Protection Factor (SPF) (Avianka et al., 2022). SPF (Sun Protection Factor) or Sun Protection Factor (FPM) is a number that refers to the level of protection against sunlight. The higher the SPF value, the greater the level of protection. The SPF number also indicates how long the skin can stay in the sun without experiencing sunburn (Gabros et al., 2023).

Chemical sunscreens are generally allergenic, causing photoirritation, photosensitivity, and contact dermatitis (Tahar et al., 2019). Sunscreens containing active ingredients from natural ingredients can be an alternative for consumers with skin sensitivity to the use of chemical sunscreens (Wulanningtyas et al., 2023). Several studies have shown that several phytochemical compounds found in plants can

be extracted and have potential as sunscreens because of their photoprotective properties (Tahar et al., 2019). Some phytochemical compounds known to have the ability to protect the skin from UV rays include cinnamates, flavonoids, tannins, and quinones, all of which have the ability to protect the skin from UV rays (Wulanningtyas et al., 2023). This literature review aims to identify natural ingredients that have potential as sunscreens based on their SPF values.

RESEARCH METHODS

This study used the Systematic Literature Review (SLR) method, a research approach carried out by systematically identifying, evaluating, and synthesizing relevant scientific articles based on predetermined research questions (Karim & Hambali, 2024). This method was chosen because it can provide a comprehensive overview of the development of natural extract-based sunscreen formulations and the effectiveness of the resulting Sun Protection Factor (SPF) values. Data were obtained from national journal articles accredited by the Science and Technology Index (SINTA) 1–6 through Google Scholar. The search was conducted using the following keywords: "sunscreen formulation," "plant extract," "SPF," "sunscreen," "UV protection," and "cosmetic preparations."

The article selection process was carried out systematically by referring to a number of criteria that had been established since the beginning of the research. Inclusion criteria included: articles published between 2021 and 2026; indexed in SINTA-accredited national journals; discussing the formulation of plant extract-based sunscreen preparations in various dosage forms, such as creams, gels, lotions, or serums; being experimental laboratory research with primary data; and including the results of in vitro and/or in vivo Sun Protection Factor (SPF) value testing along with their numerical values. The exclusion criteria included: articles that did not include numerical SPF value data, articles in the form of literature reviews (reviews) without experimental data, articles that only tested pure isolates without a formulation process, and articles that were not fully accessible (full text).

The results collected from each article included the author's name, year of publication, the sunscreen dosage form used, the type and concentration of plant extract used, the SPF test method, and the SPF values obtained. The collected data were then processed using a descriptive-comparative analysis approach. The goal was to directly observe and compare the effectiveness of the SPF values of various formulations, extract types, and dosage forms. As a reference for categorizing SPF levels, this review adhered to standards established by the Food and Drug Monitoring Agency (BPOM) and the Food and Drug Administration (FDA). In the final stage, all findings from the various literature were synthesized, conclusions were drawn, and compiled into a systematic narrative to produce a complete and comprehensive discussion.

RESULTS AND DISCUSSION

Name	Title	Secondary Metabolites	Results	Method
Princess, 2024	Formulation Development and Evaluation of Sunscreen Spray Preparations Using Ethanol Extract of Galangal Rhizome (<i>Kaempferia galanga</i>) as a Moisturizer	Ethyl para methoxycinnamate	Ethanol extract of galangal rhizome (<i>Kaempferia galanga</i>) showed potential as a sunscreen spray with an SPF value of 2.237 at F2 (2 g) and 3.185 at F3 (3 g), which is included in the minimal	Using a UV-Vis spectrophotometer with a wavelength of 290–320 nm, but only using a non-specific standard method.

			protection category.	
Rohmani et al., 2024	Formulation and Activity of Sunscreen Cream from Ethanol Extract of Calendula officinalis L Flowers	Flavonoid	The SPF value of the ethanol extract increased with increasing extract concentration. In the in vitro test, F0 (0%) showed no protection, F1 (5%) minimal protection, F2 (7%) SPF 6.03 (extra protection), and F3 (10%) SPF 11.55 (maximum protection). In the in vivo test, F1 (5%) minimal protection, F2 (7%) moderate protection, and F3 (10%) extra protection, with the positive control showing extra protection approaching F3. This increase in the SPF value is in line with the increasing content of flavonoids as the main secondary metabolite.	This was conducted using an in vitro method using a UV-Vis spectrophotometer at a wavelength of 290–320 nm using the Mansur method. Furthermore, an in vivo method was used using the MED (Minimal Erythema Dose) method using Wistar rats.
Sari & Susiloningrum, 2022	DETERMINATION OF SPF VALUE OF SUN SCREEN CREAM CONTAINING MANGGO EXTRACT (Curcuma mangga Valeton & Zijp) AND TITANIUM DIOXIDE	Flavonoid	Results: Mango ginger extract in cream concentrations of 1–5% produced very low SPF (0.288; 0.778; and 0.907) and thus did not provide protection. The pure extract showed a high SPF (24.478; ultra protection). Meanwhile, the combination of 5% extract + 5% TiO ₂ increased the SPF to 2.799 (minimal protection), indicating a synergistic effect but not optimal.	The SPF test was conducted in vitro using UV-Vis spectrophotometry using the Mansur method at a wavelength of 290–320 nm (5 nm interval) to measure the absorbance capacity against UVB.
Novitasari & Amboro, 2021	Green Tea Leaf Extract	Polyphenols (catechins)	Green tea leaf extract in gel	Determination of SPF was carried

	(Camelia Sinensis) Sunscreen Gel Formulation and Determination of Sun Protection Factor (SPF) Value		preparations showed an increase in SPF values with increasing concentration. The formula without extract (0%) had an SPF of 1.16, thus providing no protection. At concentrations of 8–12%, SPF values of 9.6–14.5 were obtained, which is considered maximum protection. While at a concentration of 14%, SPF values of 15.4 are considered ultra protection, indicating increasingly optimal photoprotective activity with increasing extract concentration.	out in vitro using UV-Vis spectrophotometry using the Mansur method with absorbance measurements at a wavelength of 290–320 nm to evaluate the preparation's ability to absorb UVB radiation.
Rahayu et al., 2023	Determination of Sun Protection Factor (SPF) and Antioxidants of Green Algae Extract (<i>Ulva reticulata</i>) as Sunscreen with UV-Vis Spectrophotometer	Flavonoids and phenols	The ethyl acetate extract had the best activity with an SPF of 11.74 (maximum protection). All extracts exhibited antioxidant activity with an IC50 of approximately 0.375–0.46 mg/mL. The highest levels of phenols and flavonoids support sunscreen activity.	Experimental: extraction (n-hexane, ethyl acetate, ethanol), SPF test using Mansur method (UV-Vis), antioxidant test using DPPH method, total phenol & flavonoid test
Yanuarti et al., 2021	Antioxidant Activity and Physical Evaluation of Sunscreen Cream Preparations from <i>Turbinaria conoides</i> and <i>Moringa oleifera</i>	Flavonoids and phenolics	The best combination cream (S = 1:1) has strong antioxidant activity (IC50 50–100 µg/mL), is physically stable, O/W emulsion type, and meets the cream evaluation parameters.	Experimental: cream formulation, DPPH antioxidant test, stability test (centrifugal), emulsion type, globule diameter, and organoleptic
(Sagala & Juniasti, 2021	Test for Determination of Total Phenolic Content	Flavonoids, alkaloids and tannins	The results of the SPF test on moringa leaf extract extracted	In vitro and the absorbance was measured using

	and SPF (Sun Protection Factor) Value of Ethanol Extract of Moringa Leaves (<i>Moringa Oleifera</i> L.).		with 96% ethanol solvent showed that the lowest SPF value was found at a concentration of 200 ppm, namely 7.31 and the highest SPF value was found at a concentration of 1000 ppm, namely 36.71.	UV-Vis spectrophotometry
(Taupik et al., 2022)	Evaluation of the Sunscreen Ability of Corn (<i>Zea mays</i>) Seed Extract In Vitro Using the UV-Vis Spectrophotometry Method	Flavonoids, anthocyanins, condensed tannins, alkaloids and triterpenes	From the test, the results obtained were that the best activity was shown by a concentration of 600 ppm for both ethyl acetate and 70% ethanol extracts with an average SPF value of $24.1724.18 \pm 0.0852$ (ultra protection) and 10.23 ± 0.021 (maximum protection), respectively.	In vitro using the UV-Vis spectrophotometry method
Suswidianoro, V. et al., 2025	Sunscreen Cream Formulation Combination of Moringa Leaf Extract (<i>Moringa oleifera</i>) and Sweet Orange Peel (<i>Citrus x aurantium</i>)	Flavonoids, alkaloids, tannins, saponins	The highest SPF 48.8 (ultra protection) in formula 1 (the best combination of moringa & orange extracts)	In vitro and the absorbance was measured using UV-Vis spectrophotometry
Adriana et al., 2024	Formulation and Physical Evaluation of Sunscreen Cream Preparations with Lime Leaf Extract (<i>Citrus Aurantifolia</i>) as Facial Treatment	Flavonoids (quercetin)	Lime leaf extract in cream preparations showed an increase in SPF value with increasing concentration, where Formula 1 (3%) produced an average SPF value of 6.3261, which is included in the moderate protection category. Formula 2 (6%) showed an average SPF value of 71.9893, which is classified as ultra protection. Meanwhile, Formula 0 did not provide any protection, and	The SPF test was conducted in vitro using UV-Vis spectrophotometry, with absorbance measurements at a wavelength of 290–320 nm after the cream sample was diluted in ethanol, to evaluate the UVB absorption capacity.

			Formula 3 produced an SPF value that exceeded the range of SPF values considered good.	
Arianto et al., 2022	The Use of Carrot Seed Oil (<i>Daucus carota</i> L.) to Formulate Nanoemulgels as an Effective Natural Sunscreen and Skin Anti-Aging	Carotene, fatty acids, β -carotene,	Nanoemulgel 4% carrot seed oil produces SPF 20.28 ± 0.22 , higher than the regular emulgel 13.94 ± 0.27 .	In vitro using UV spectrophotometry.
El-Otmani et al., 2024	Formulation of Biological Sunscreen from <i>Calendula arvensis</i> Capitula Extracts	Phenolic, flavonoid, tannin	The sonicated hydroethanol extract showed an SPF of 193.65 ± 0.02 , higher than zinc oxide 11.88 ± 0.03 .	In vitro using UV spectrophotometry, Mansur method.
Tania et al., 2022	Sunscreen Cream Formulation of Noni Leaf Extract (<i>Morinda citrifolia</i> L.) with Emulsifier Combination of Tween 80 and Lecithin	Flavonoids, alkaloids, tannins, triterpenoids, saponins, coumarins, anthraquinones, carotenoids	Noni leaf extract was tested at concentrations of 5%, 10%, and 20%; the formulation study used the 10% extract. The specific SPF value of the cream preparation was not visible in the initial summary.	In vitro using UV-Vis spectrophotometry at a wavelength of 290–320 nm with the Mansur method.
Hidayati et al., 2025	Formulation and Activity Testing of Sunscreen Nanoemulsion Cream Derived from 96% Ethanol Extract of Kersen Leaves (<i>Muntingia calabura</i> L.)	Flavonoids, phenolics, saponins, tannins	F0 0.72 no potential; F1 2% 12.15 maximum protection; F2 4% 17.34 ultra protection; F3 6% 30.56 ultra protection.	In vitro using a UV-Vis spectrophotometer.
Tran et al., 2024	Potential Use of Polyphenol-Enriched Extract from <i>Moringa oleifera</i> Leaves as an Active Ingredient in Sunscreen	Polyphenols, flavonoids such as quercetin, kaempferol, myricetin	The cream containing 2% moringa extract + 2% oxybenzone showed good in vitro SPF values, but the specific SPF number was not visible in the initial summary read.	In vitro, by measuring the SPF value of the cream formulation.

Maharai et al., 2020	The effect of the combination of Aristoflex® AVC and Glycerin on the formula of basil leaf extract gel	Flavonoids, essential oils	SPF values range from 3.18 to 5.47 (low protection category). The highest SPF is in Formula III (5.47).	UV-Vis spectrophotometry Mansur method
Endriyatno et al., 2024	Determination of the SPF value of torch ginger flower extract (<i>Etilingera elatior</i>) in vitro	Flavonoids, terpenoids, saponins, tannins	The highest SPF value was found in 70% ethanol extract at a concentration of 1%, which was 106.8 ± 1.25 (very high category). 1% methanol extract: 80.12 ± 1.54 , 1% n-hexane: 67.97 ± 2.06	UV-Vis spectrophotometry Mansur method (290 - 320 nm)
Suradnyana et al., 2023	Formulation and testing of antioxidant and sunscreen activity of avocado seed acetone extract cream	Flavonoids, alkaloids, tannins, saponins, phenolics	SPF extract: 39.636 (high protection). SPF cream: F1 = 1.859, F2 = 2.941, F3 = 3.629 (low protection category)	UV-Vis spectrophotometry + DPPH test
Dipahayu, 2020	Sunscreen emulgel formulation of purple sweet potato leaf extract (<i>Ipomoea batatas</i> (L.)) Antin-3 variety	Flavonoids, anthocyanins	Emulgel SPF value: 6.50 (moderate protection), base: 1.17	UV-Vis spectrophotometry Mansur method
Ramlah et al., 2025	Formulation and SPF Value Test of <i>Centella Asiatica</i> L. Leaf Extract Gel Preparation	Flavonoids, alkaloids, terpenoids, saponins, tannins UV-Vis spectrophotometry Mansur method	SPF values: F1 (3%) = 4.7, F2 (5%) = 7.6, F3 (7%) = 11.7. SPF increases with concentration, with moderate to maximum categories.	UV-Vis spectrophotometry Mansur method

Discussion

Overview of SPF results

The assessment of sunscreen effectiveness is generally based on the Sun Protection Factor (SPF) value, which is classified according to the standards of the Food and Drug Monitoring Agency (BPOM) and the Food and Drug Administration (FDA). This classification is used to describe the level of a preparation's ability to protect the skin from exposure to ultraviolet radiation, especially UV-B. In general, SPF values are divided into several categories: SPF less than 4 which provides no protection, SPF 4–6 which is included in the minimal protection category, SPF 6–10 which indicates moderate protection, SPF 10–15 which is included in the maximum protection, and SPF above 15 which is categorized as ultra protection. The higher the SPF value produced, the greater the preparation's ability to protect the skin from the harmful effects of sun exposure. Therefore, this classification is an important reference in evaluating and comparing the potential of various natural ingredients and sunscreen formulations that have been developed.

The influence of secondary metabolites

In general, most of the plants studied are known to contain various secondary metabolites, such as flavonoids, phenolic compounds, tannins, and terpenoids, which play an important role in providing

photoprotective activity. These compounds have the ability to absorb ultraviolet radiation, especially in the UV-B spectrum, thereby reducing the negative impact of sun exposure on the skin. Furthermore, their antioxidant activity also contributes to neutralizing free radicals formed due to UV radiation exposure, thereby preventing further skin cell damage (Abdat, AU 2026).

The role of these secondary metabolites can be seen in several studies showing high SPF values in certain plant extracts. For example, torch ginger flower extract has been reported to have a very high SPF value, reaching over 100, while extracts from the Calendula genus have shown even higher SPF values. These high SPF values indicate that the active compounds, particularly flavonoids and phenolics, contribute significantly to the natural ingredients' ability to absorb and inhibit UV radiation (Abdat, AU 2026).

Furthermore, the photoprotective properties of these compounds depend not only on their presence but also on the concentration and composition of the active compounds in the extract. This suggests that plants with high phenolic and flavonoid content have the potential to be more effective as active ingredients in natural sunscreens. Exploring natural sources rich in these compounds is a crucial step in developing safer, more naturally based sunscreen products (Ashari et al. 2021).

Effect of concentration

In addition to the type of secondary metabolite compound, extract concentration also plays a significant role in determining the resulting SPF value. Most studies show a tendency for SPF values to increase with increasing extract concentration. In other words, there is a positive relationship between the amount of extract used and its protective ability against ultraviolet radiation (Ashari et al. 2021).

This phenomenon can be observed in gotu kola leaf extract, where increasing the concentration from 3% to 7% was followed by an increase in the SPF value from 4.7 to 11.7. A similar trend was also reported in green tea and cherry leaf extracts, which showed an increase in SPF values, reaching the maximum and even ultra protection categories at higher concentrations. These results indicate that increasing the extract concentration contributes to an increase in the number of active compounds that act as photoprotective agents (Ashari, et al. 2021).

Mechanistically, the higher the active compound content in a preparation, the greater the system's ability to absorb or block UV radiation from reaching the skin's surface. However, increasing the concentration also needs to be optimized, as excessively high concentrations can potentially affect the preparation's stability, physical properties, and comfort of use. Therefore, determining the optimum concentration is a crucial aspect in natural-based sunscreen formulations to achieve a balance between effectiveness and product stability.

Influence of dosage form

In addition to composition and concentration, dosage form also plays a crucial role in determining the effectiveness of a sunscreen's SPF value. Various studies have shown that different delivery systems can produce varying levels of protection. Nano-based preparations, such as nanoemulgels, have been reported to provide higher SPF values than conventional preparations such as creams or emulgels. For example, carrot seed oil nanoemulgels demonstrated higher SPF values than conventional emulgels, indicating increased photoprotective effectiveness (Arianto, et al. 2022).

This improvement is related to the characteristics of the smaller particle size of the nanosystem, resulting in a larger surface area. This condition allows for a more even distribution of the active ingredient and enhances the interaction between the active compound and the skin surface. Furthermore, the smaller particle size can also increase the penetration and stability of the active ingredient, thus optimizing its ability to absorb UV radiation. Not all formulation processes produce beneficial results. Several studies have shown that formulations in certain dosage forms can actually reduce the SPF value compared to the pure extract. This is seen in avocado seed and mango ginger extracts, where the initially high SPF value decreased after being formulated into a cream. This decrease is thought to be caused by interactions between the active compound and other components in the formulation, such as the base, emulsifier, or other additives, which can affect stability and UV absorption capacity. (Arianto, et al. 2022).

The selection of the preparation type and formulation system is crucial in the development of natural-based sunscreens. The right formulation approach aims not only to improve stability and comfort of use, but also to maintain and even enhance the effectiveness of the SPF value of the active ingredients used.

Comparison between plants

Comparisons between different plant species show significant variations in their potential activity as natural sunscreens. Some plants, such as moringa, torch ginger, and Calendula species, are reported to have high SPF values, reaching the ultra-protection category. Conversely, other plants, such as basil and galangal, tend to only produce low to minimal SPF values, thus their effectiveness as photoprotective agents is relatively limited (Ashari et al. 2021).

These differences in potency are inseparable from the variations in the types and levels of secondary metabolites contained in each plant. High levels of phenolic and flavonoid compounds are known to contribute significantly to the ability to absorb UV radiation, so plants with a higher concentration of these compounds generally exhibit better photoprotective activity. Furthermore, the presence of other compounds, such as tannins and terpenoids, may also contribute through protective mechanisms against oxidative damage caused by sun exposure. It can be concluded that a plant's effectiveness as an active sunscreen ingredient is determined not only by the presence of specific compounds, but also by the composition and relative concentration of its secondary metabolites. This underscores the importance of selecting the right natural ingredients and standardizing extracts in the development of herbal-based sunscreen products (Ashari et al. 2021).

Comparison of extracts and formulations

A comparison of the sunscreen activity of pure extracts with formulated preparations shows a significant difference in effectiveness. In general, several studies report that the SPF value of pure extracts tends to be higher than after being formulated into dosage forms such as creams, gels, or emulgels. This is seen in avocado seed extract, which has an SPF value of 39.636 (high category), but after being formulated into a cream, it experiences a drastic decrease to between 1.859–3.629, which is in the low protection category. A similar phenomenon also occurs with mango ginger extract, where the pure extract shows a high SPF (24.478), but in cream form only produces an SPF below 1, thus not providing optimal protection.

The decrease in SPF in this formulation is thought to be caused by interactions between the active compound and additional ingredients (excipients) such as emulsifiers, cream bases, and solvents, which can affect the compound's stability and UV absorption capacity. Furthermore, the formulation process can cause degradation of the active compound or changes in its distribution within the formulation matrix, thus reducing its effectiveness.

However, not all formulations show a decrease in activity. Some studies have shown that the right formulation can increase or maintain SPF values. For example, carrot seed oil nanoemulgel has a higher SPF value than standard emulgels, and a combination of moringa leaf extract and sweet orange peel produces a high SPF value of up to 48.8. This suggests that selecting the right preparation base and formulation technology, such as the use of nanosystems or a combination of active ingredients, can increase the stability and effectiveness of photoprotective compounds.

Furthermore, combining the extract with other ingredients, such as titanium dioxide, can also provide a synergistic effect in increasing SPF values, although in some cases the increase is not optimal. Based on these results, it can be concluded that formulation plays a crucial role in determining the ultimate effectiveness of a natural-based sunscreen preparation. A high-potency extract may not necessarily produce a preparation with the same effectiveness without proper formulation optimization.

Validity of the SPF test method

Most of the studies analyzed used UV-Vis spectrophotometry in the 290–320 nm wavelength range. This range primarily describes the ability of a material or preparation to absorb UV-B radiation, the radiation most associated with erythema or redness of the skin. The Mansur method is widely used in in vitro SPF testing because it is simple, rapid, and can provide an initial picture of the

photoprotective potential of a sunscreen extract or preparation. However, this method does not fully describe the effectiveness of protection on human skin because it does not consider biological factors such as penetration, distribution of active ingredients in the skin, application thickness, and interaction with skin components (Chavda et al., 2023).

Furthermore, the SPF value essentially reflects protection against UV-B, not full protection against the entire ultraviolet spectrum. Ideal sunscreen protection should encompass both UV-B and UV-A, as UV-A has a wavelength of 320–400 nm and penetrates deeper into the skin, contributing to photoaging, collagen damage, and free radical formation. Based on these results, extracts with high in vitro SPF values cannot necessarily be categorized as broad-spectrum sunscreens unless tested for UV-A protection. The FDA also states that broad-spectrum products must demonstrate protection against both UV-B and UV-A, with a critical wavelength of at least 370 nm (Verma et al., 2024).

Research limitations

Most of the studies analyzed in this review used UV-Vis spectrophotometry with the Mansur method to determine SPF values in vitro. This method is widely chosen because it is relatively simple, fast, and efficient in evaluating a material's ability to absorb UV radiation, particularly in the UV-B wavelength range. However, the in vitro approach has fundamental limitations, as it cannot fully reflect the biological conditions of human skin, such as penetration factors, distribution of active ingredients, and interactions with skin components.

Furthermore, the limited research involving in vivo testing is a weakness in the development of natural-based sunscreens. In vivo testing is needed to provide a more accurate picture of the effectiveness of protection against erythema and safety of use on the skin. The lack of in vivo data means that the existing research results are still preliminary and require further validation.

In addition to limitations in testing methods, differences in results between studies are also influenced by variations in extraction procedures, the type of solvent used, and the composition of the formulation. These differences can affect the amount and stability of the active compounds obtained, thus directly impacting the resulting SPF value. Furthermore, the lack of uniform method standardization presents a challenge in comprehensively comparing and interpreting results between studies.

Development direction

Based on the analysis, it can be concluded that herbal plants show promising potential for development as active ingredients in natural sunscreen formulations. This potential is supported by the presence of secondary metabolites that can provide photoprotective effects and antioxidant activity. However, the use of these natural ingredients still requires further development, particularly in terms of formulation optimization and determining the appropriate concentration to achieve maximum protective effectiveness.

Furthermore, the application of modern delivery technologies, such as nanoformulation systems, is one approach that has the potential to improve the stability and performance of active compounds in absorbing UV radiation. Furthermore, more comprehensive follow-up research, particularly through in vivo testing, is needed to ensure safety, effectiveness, and suitability for use in real-world conditions on human skin. Efforts to standardize methods, including extraction, formulation, and SPF testing, are also crucial for generating more consistent and comparable data across studies. With these factors, the development of natural-based sunscreens is expected to be not only effective but also safe and widely applicable in the long term.

Safety of natural ingredients as sunscreen

The use of natural ingredients as sunscreen is often considered safer than synthetic chemicals. However, the safety of natural ingredients still needs to be evaluated because some active plant compounds can cause irritation, allergies, photosensitivity, or phototoxicity, especially when used topically and exposed to sunlight. Therefore, the development of plant extract-based sunscreens requires more than just assessing the SPF value; it also requires safety testing, such as skin irritation testing, phototoxicity testing, light stability testing, and skin compatibility testing (Verma et al., 2024).

A high SPF value does not always guarantee that a product is safe for long-term use. An ideal herbal sunscreen product should strike a balance between photoprotective effectiveness, product stability, and safety. Safety evaluation is crucial because some additional ingredients in the formulation, such as preservatives, fragrances, emulsifiers, or bases, can also affect the potential for irritation and comfort on the skin (Resende et al., 2022).

CONCLUSION

Based on the results of the Systematic Literature Review that has been conducted, it can be concluded that herbal plants have the potential to be developed as active ingredients in natural sunscreens because they contain secondary metabolites, such as flavonoids, phenolics, tannins, and terpenoids, which play a role in photoprotective and antioxidant activities. The Sun Protection Factor (SPF) values obtained show variations from minimal to ultra protection categories, which are influenced by the type of plant, active compound content, extract concentration, and the formulation system used. In general, increasing the extract concentration and the application of nano-based formulation technology are known to be able to increase the effectiveness of protection against ultraviolet radiation by improving the stability and distribution of active substances in the preparation.

However, the effectiveness of natural-based sunscreens is still influenced by formulation factors, as interactions between active compounds and certain excipients can cause a decrease in SPF values. Furthermore, the majority of analyzed studies are still limited to in vitro testing using UV-Vis spectrophotometry methods, thus not fully representing the effectiveness of protection on the biological conditions of human skin. Therefore, further research is needed that includes in vivo testing, safety evaluation, photostability, and standardization of extraction and formulation methods to produce herbal sunscreen preparations that are effective, safe, and stable, and have the potential for further development in the cosmetic and pharmaceutical fields.

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