

SEASIDE SUNCREEN: TAPPING INTO THE POWER OF MARINE COMPOUND FOR ENHANCED UV SHIELDING

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Biotechnology

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **Meenambigai. S (40230026), Jennita Mary (40230016)** who carried out the project entitled **"SEASIDE SUNSCREEN: TAPPING INTO THE POWER OF MARINE COMPOUND FOR ENHANCED UV SHIELDING"** under our supervision from September 2023 to April 2024.

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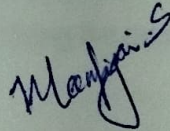
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DECLARATION

We, **Meenambigai. S (40230026)**, **Jennita Mary (40230016)** hereby declare that the Project Report entitled "**Seaside Sunscreen: Tapping into the Power of Marine Compound for Enhanced UV Shielding**" done by us under the guidance of **Ms. S. Haritha** (Internal), **Assistant Professor** and **Dr. M. Rajasekar** (External), **Scientist – C** at Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India, is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biotechnology.

DATE: 05/04/2024

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ABSTRACT

Plants and animals have evolved strong defenses against the harmful effects of oxidative stress and ultraviolet radiation (UV) because of natural selection and evolution. The purpose of this study is to determine how well herbal sunscreen formulations work to block ultraviolet (UV) radiation, lower the risk of sunburn, and prevent skin damage. According to earlier research, natural ingredients regulate UV-induced skin inflammation, barrier degradation, and aging in addition to improving skin elasticity, moisture, texture, and wrinkles. These antioxidant actions also contribute to the photoprotective properties of natural components. The development of sunscreen products, the choice of herbal extracts recognized for their photoprotective qualities, and laboratory testing for UV protection factor (SPF) and antioxidant activity were the methods used. The study measured the sunscreens' capacity to absorb UV radiation using spectrophotometric analysis and then assessed the sunscreens' photostability by simulating sunlight. The research results imply that herbal sunscreens are promised as natural sun protection options because of their promising antioxidant and UV protection properties. The significance of investigating herbal skincare remedies for reducing the negative effects of UV light is highlighted by these outcomes. To improve herbal sunscreen formulations and evaluate their long-term impacts on skin health, more study is necessary. This paper covers all essential aspects of the potential of the plant selected and its prospects.

Keywords: *Herbal sunscreen, UV protection, Antioxidant activity, Salt marsh*

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LIST OF ABBREVIATIONS

ACRONYM	ABBREVIATION
DPPH	2,2-Diphenyl-1-Picrylhydrazyl
UV	Ultraviolet Visible
SPF	Sun Protection Factor
GC-MS	Gas Chromatography-Mass Spectrometry
FT-IR	Fourier Transform Infrared
NMR	Nuclear Magnetic Resonance
TLC	Thin Layer Chromatography
R _f	Retention Factor
CF	Correction Factor
EE(λ)	Erythema Effect
I(λ)	Intensity of Solar Rays
Abs	Absorbance
MTT	3-[4, 5-dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide
nm	Nanometer
CO ₂	Carbon dioxide
DMSO	Dulbecco's Modified Eagle Medium
μ g/ml	Microgram per millilitre
μ l	Microlitre
3T3	Mouse embryonic kidney cell line

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CHAPTER - 1

INTRODUCTION

Sun exposure during the early stages of life has a more significant impact on the likelihood of developing skin cancer during adulthood, compared to sun exposure in later years. Skin cancer is relatively less common in India compared to some Western countries, but its prevalence is increasing due to factors such as changing lifestyles, increased sun exposure, and environmental factors over the past few decades (Nakamura *et al* 2022). Ninety percent of melanomas are caused by UV exposure and are, therefore, easily preventable. There is thus a pressing need to promote the prevention of harmful ultraviolet exposure through good habits sowed early in life, which are further sustained throughout adulthood for optimal risk reduction. For skin cancer and many other skin conditions influenced by the environment, ultraviolet light is the most significant modifiable risk factor. Everyone has to be protected against UV rays. UVA ($\lambda = 320\text{-}400\text{ nm}$), UVB ($\lambda = 280\text{-}320\text{ nm}$), and UVC ($\lambda = 100\text{-}280\text{ nm}$) are the three components that make up UV radiation (Bhattacharjee *et al* 2021). Continuous protection from UV radiation with minimal adverse effects is essential due to its potential to cause sunburns, wrinkles, premature aging, and skin cancer.

Nowadays, all people must use sunscreen products because of protection against ultraviolet (UV) radiation. Compared to other UV rays, UVB is primarily associated with erythema and sunburn which are in the range between 290-320 nm. In contrast to UVB, UVA rays are more efficient in inducing immediate and delayed pigment darkening and delayed tanning than in producing erythema. The use of sunscreen is widely recommended as a primary preventive measure to protect the skin from these harmful effects Fig.1.1. However, concerns have been raised regarding the safety and environmental impact of conventional synthetic sunscreens, prompting the search for natural alternatives

Herbal sunscreens, often natural sunscreens, offer excellent protection against harmful UV rays. Unlike chemical sunscreens, which contain synthetic filters, herbal sunscreens use natural ingredients and plant extracts to shield your skin and offer several potential advantages over

conventional sunscreens. The use of natural ingredients in skincare products has become a trend in recent days. Many herbal ingredients possess additional skincare benefits, such as antioxidant, anti-inflammatory, and moisturizing properties, which may contribute to overall skin health. Herbal sunscreen has become the most essential part of the daily skincare routine for most of the population as it protects the skin from UV radiation (Tiwari *et al* 2022).

The utilization of personal skincare products, which particularly contain safeguarding ultraviolet substances, has observed an unparalleled surge worldwide in safeguarding the human epidermis against diverse health-related hazards arising from the escalating alterations in the climate. Nevertheless, the ecological and environmental repercussions of employing these substances are frequently disregarded, potentially giving rise to detrimental perils to the ecosystem, specifically aquatic life. Many herbal ingredients have not been systematically studied for their photoprotective properties, and their potential for broad-spectrum UV protection remains to be elucidated. Furthermore, the variability in plant composition and extraction methods presents challenges in standardizing herbal sunscreen formulations. The study aims to assess the photoprotective properties of herbal extracts, their compatibility with different skin types, and their potential for broad-spectrum UV protection.

Sesuvium portulacastrum also known as 'sea purslane', is a sprawling perennial herb that mostly grows in coastal saline soils, inland habitats, and mangrove areas worldwide. The extract of this plant is said to have antibacterial and antifungal properties. This plant tolerates abiotic constraints such as salinity, drought, and toxic metals. It is also used as a vegetable, fodder for domestic animals, and as an ornamental plant. Physiological and biochemical studies evidence the tolerance potential of the plant to abiotic stresses and reveal molecular mechanisms of stress tolerance. The primary agents responsible for damaging skin are oxygenated molecules, commonly referred to as "free radicals." In current research, Effective botanical antioxidant compounds are widely used in traditional medicine and include tocopherols, flavonoids, phenolic acids, nitrogen-containing compounds, and

more. It has been discovered by researchers that certain plant oils have inherent sunscreen properties. Sesame oil, for instance, blocks out 30% of UV radiation, while coconut, peanut, and olive oils only block out 20%. Mineral-based oil does not block UV rays, but it does shield skin by dissolving sebum generated by oil glands and promoting skin evaporation.

There are still a ton of undiscovered active molecules in addition to the ones that have already been found. Herbal sunscreen is a botanical-based topical formulation designed to mitigate the harmful effects of ultraviolet (UV) radiation from the sun, thereby minimizing the occurrence of sunburn and associated skin damage, with the ultimate goal of diminishing the risk of skin cancer through the utilization of herbal ingredients. The significance of this research lies in its potential to contribute to the development of safer, more sustainable, and effective sun protection products. By exploring the efficacy of herbal sunscreens, we aim to provide consumers with natural alternatives that offer superior sun protection while minimizing the risks associated with synthetic chemicals. The latest trend is intended to keep perpetually cool while exposed to sunlight. Products that allow users to spend more time in the sun are what customers desire.

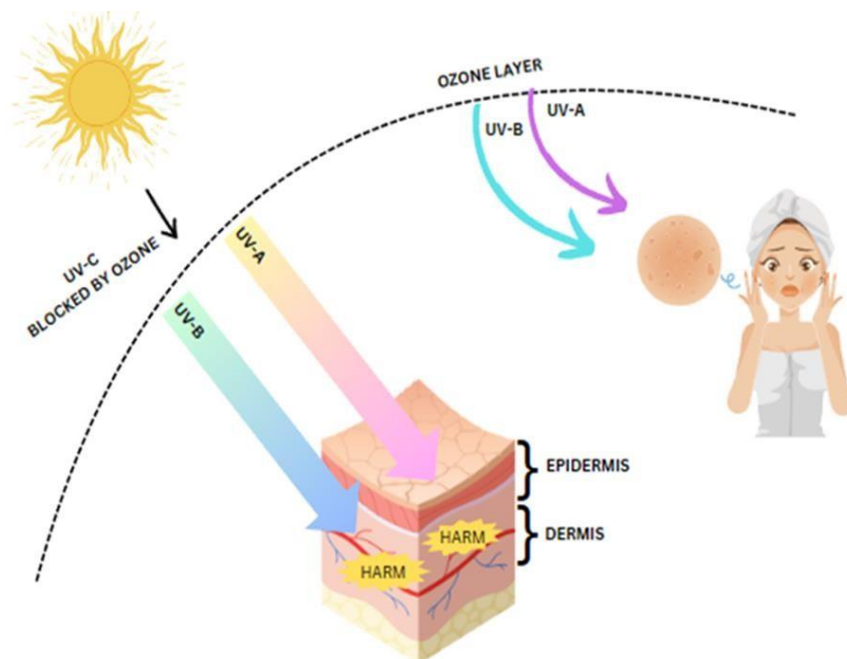


Fig:1.1: Harmful UV rays affecting the epidermal layer of the human

CHAPTER - 2

LITERATURE SURVEY

2.1 INTRODUCTION TO SUNSCREEN

Investigating the world of natural sunscreens reveals a wealth of advantages that support environmental sustainability in addition to providing skin protection. These sunscreens, which are made from minerals like titanium dioxide and zinc oxide as well as plant-derived components, provide broad-spectrum protection without the harsh chemicals seen in other brands (Rasheed *et al* 2012). Vegan- friendly composition supports moral decisions and cruelty-free methods, making them appealing to a wide variety of customers. Significantly, their formulation is safe for reefs, protecting fragile marine environments, and their reduced environmental effect emphasises their dedication to eco-friendly skincare. The selection procedure for a plant-based sunscreen is guided by variables including water resistance, SPF rating, and environmental impact, which ensures low ecological impact and effective protection. Well-liked choices are Thinksport Safe Sunscreen and Babo Botanicals Clear Zinc Sunscreen Lotion (Patel *et al* 2023).

Sunscreen agents are essential for safeguarding our skin against the damaging effects of ultraviolet (UV) radiation, which can lead to sunburn, premature aging, and an increased risk of skin cancer. UV radiation is categorized into three wavelengths: UV-A, UV-B, and UV-C, with UV-B being primarily responsible for sunburn and affecting the epidermal layer of the skin (Kadawla *et al* 2022).

Synthetic sunscreens, the most commonly used, are classified into two main categories: organic filters (chemical) and inorganic filters (mineral). Organic filters encompass compounds such as Benzophenone and PABA derivatives. While effective, some organic filters have been associated with adverse effects, prompting concerns among consumers (Kadawla *et al* 2022). In response to these concerns, natural sunscreens have emerged as an alternative option. These products typically feature ingredients sourced from nature, such as zinc oxide and titanium dioxide, which provide broad-spectrum protection against UV radiation without the potential drawbacks

associated with some synthetic compounds. Natural sunscreens are often favored by those seeking gentler formulations or those with sensitive skin or environmental concerns. Ultimately, choosing the right sunscreen involves considering factors such as skin type, desired level of protection, and personal preferences regarding ingredients. Whether opting for synthetic or natural formulations, regular and proper application of sunscreen remains crucial for maintaining healthy skin and reducing the risk of sun-related damage (Mahajan *et al* 2008).

2.2 FORMULATIONS OF HERBAL SUNSCREEN

The formulation and evaluation of herbal sunscreens represent a promising avenue in the realm of skincare, offering a natural and effective alternative to traditional sun protection products. By harnessing the power of botanical extracts such as *Terminalia arjuna*, *Tinospora cordifolia*, *Glycyrrhiza glabra*, these sunscreens provide not only protection against UV radiation but also potential additional benefits for the skin. The incorporation of key herbal ingredients like turmeric, coconut oil, aloe vera, and lemon further enhances the protective properties of these formulations, combining their respective qualities to create a holistic approach to sun protection. Through rigorous evaluation encompassing various parameters including SPF value, physicochemical characteristics, antioxidant activity, and safety assessments, these herbal sunscreens have demonstrated their efficacy and safety for use (Roy *et al* 2014). Moreover, their non-mutagenic and non-irritant nature reinforces their suitability for a wide range of skin types, further underscoring their appeal as a natural solution for sun care. In conclusion, herbal sunscreens represent a compelling option for individuals seeking effective protection against the sun's harmful rays while also embracing natural and skin-friendly ingredients. With their proven benefits and safety profile, these formulations hold promise for the future of sun care products, offering a blend of science and nature to promote healthy and radiant skin (Tiwari *et al* 2022).

The exploration of herbal sunscreens unveils a promising avenue in skincare, driven by concerns over the adverse effects associated with some

conventional sunscreen compounds. Researchers have turned to natural formulations, recognizing the potential of organic materials to offer effective sun protection without the drawbacks of synthetic alternatives. This study, focusing on integrating GotuKola (*Centella asiatica*) extract into sunscreen formulations, highlights the quest to comprehend their physicochemical characteristics and evaluate their efficacy. as a standout candidate, boasting a maximum SPF value of 22.21 and demonstrating remarkable UV-blocking capabilities (Binti Sarbani *et al* 2023) Furthermore, the enhanced antioxidant activity associated with increased C. asiatica extract content underscores its potential in combating free radicals. With these promising results, sunscreen F20 proves itself as a viable candidate for production and commercialization, signaling a shift towards herbal sunscreens as a natural and skin-friendly solution for effective sun protection (Varol *et al* 2015).

2.3 COMPARATIVE ANALYSIS OF HERBAL SUNSCREEN vs SYNTHETIC SUNSCREEN

Sunscreen agents serve as essential defenders against the harmful impacts of UV radiation, employing various mechanisms like absorption and blocking to shield our skin from UV-A, UV-B, and UV-C rays. Among the commonly used synthetic options are organic and inorganic filters, prevalent in commercial sunscreens, yet some, like Benzophenone and PABA derivatives, bear concerning side effects. To address these issues, natural alternatives have emerged, harnessing botanical extracts and minerals to provide comparable protection while mitigating risks associated with synthetic compounds. This shift reflects a growing preference for safer, more sustainable skincare solutions in harmony with nature (Bhattacharjee *et al* 2021).

The evolution of sunscreen formulations is marked by rigorous testing and continual innovation, ensuring adherence to regulatory standards and driving cosmetic advancements. Market comparisons aid in delineating the strengths and weaknesses of different formulations, while clinical trials verify safety and efficacy before products are introduced to consumers. Despite the diversity in ingredients and formulations, the paramount importance of sunscreen in safeguarding our skin against UV damage remains unchanged,

highlighting its indispensable role in promoting skin health and well-being (Panyakaew *et al* 2021).

2.4 PHYSICAL AND CHEMICAL CHARACTERIZATION TESTS

The study utilized advanced characterization techniques such as single particle inductively coupled plasma mass spectrometry (SP-ICPMS), transmission electron microscopy (TEM), and X-ray diffraction (XRD) to quantify and confirm the size of metal oxide nanoparticles (NPs) in sunscreen powder (Lu *et al* 2018). The research aimed to optimize SPF in sunscreen creams by integrating anisotriazine and titanium dioxide. Cream bases underwent comprehensive evaluation for SPF, physical attributes, pH, and viscosity. Notably, synergistic SPF efficacy was observed, influenced by cream-based properties. Visual assessments, viscosity measurements, pH determinations, and freeze-thaw cycle evaluations were conducted to ensure product stability and effectiveness before and after storage (Amnuait *et al* 2013).

The study underscores the significance of rigorous characterization tests for sunscreen efficacy and safety. Through a diverse range of assessments including organoleptic, pH, viscosity, UV transmittance, and stability tests, a lemongrass oil nanoemulsion was formulated and evaluated. UV-Vis spectrophotometry confirmed its sunscreen potency, showcasing a thorough approach to sunscreen characterization (Rastuti *et al* 2022).

The research paper explores the impacts of sun radiation on human health, focusing on UV protection strategies such as melanin synthesis. Characterization methods employed encompass UV radiation measurement, melanin quantification, and skin thickness assessment. These methods contribute to understanding the effectiveness of UV protection and its implications for human well-being (Lademann *et al* 2020). The proposed spectrophotometric method offers a simple and rapid means of determining SPF values for sunscreen emulsions, aiding in the selection of cosmetics with enhanced safety and high SPF values. Additionally, the study highlights the medicinal potential of the plants used in herbal remedies, attributing their therapeutic benefits to bioactive components like alkaloids, tannins, phenols,

and flavonoids, known for their antioxidant properties that protect against sunburn and skin cancer (Singh *et al* 2016).

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2.5 INGREDIENTS USED IN HERBAL SUNSCREEN

Sunlight emits UV radiation, a leading cause of skin damage. To counteract this, natural ingredients are being explored as safer alternatives

to chemical sunscreens. Plants like *Brucea javanica*, *Hippobroma longiflora*, *Kaempferia galanga*, *Eucheuma cottonii*, and *Zea mays* show promise for sunscreen development, offering potential benefits for skin protection (Sabrina *et al* 2022). The study explores various natural substances for their potential as sunscreen agents, emphasizing their antioxidant properties and ability to protect against UV radiation. Plants like *Phyllanthus emblica*, green tea, and turmeric, along with oils such as sesame oil and castor oil, exhibit antioxidant activity and may serve as effective ingredients in sunscreen formulations. Additionally, fruits like pomegranate and tomatoes, as well as oils like olive oil and sunflower oil, offer protection against UV rays and possess skin-soothing properties. These findings underscore the potential of natural ingredients in developing safe and efficient sunscreen products (Sushma *et al* 2019).

The study explores various natural substances, such as shea butter, beeswax, and raspberry seed oil, for their potential in sunscreen formulations. These ingredients offer antioxidant properties and protection against UV radiation, contributing to their efficacy in skincare products. Additionally, compounds found in olive oil, carrot seed oil, and sesame oil demonstrate anti-inflammatory and moisturizing effects, further enhancing their suitability for sunscreen formulations.

Overall, the research underscores the importance of utilizing natural ingredients with sun-protective qualities in skincare formulations (Patel *et al* 2023). The study explores the sun-protective properties of natural ingredients like pomegranate, tomato, green tea, *Pongamia pinnata*, almond, and saffron. Various formulations and extracts were evaluated for their efficacy in preventing sunburn damage and providing UV protection. Results indicate promising potential for these natural substances as alternative UV-absorbing agents in sunscreen formulations (Goswami *et al* 2013). It investigates the formulation and characterization of beeswax sunscreens, assessing five formulations against international standards. Variation in color, texture, aroma, and SPF was observed, linked to beeswax and zinc oxide levels. Sample 3 emerged as the optimal formulation, offering superior SPF, water resistance, and stability. (Dube *et al* 2022).

2.6 SAFETY AND TOXICOLOGICAL ASSESSMENTS

The development of a novel sunscreen formulation, incorporating FDA- approved UV filters alongside additional components like melatonin and pumpkin seed oil, underscores a significant stride towards safer and more efficacious sun protection. Preclinical safety assessments, adhering to OECD protocols, affirm the formulation's non-toxicity and safety in animal models, paving the way for further evaluations regarding its efficacy and tolerability in human trials (Bora *et al* 2017).

Moreover, the exploration of natural sunscreen substances like usnic acid and atranorin presents additional avenues for enhancing photoprotective capabilities while ensuring compatibility with human skin. This research heralds a promising era in sunscreen innovation, poised to offer enhanced protection against UV radiation with a focus on safety and effectiveness (Nogueira *et al* 2003). Researchers investigated a sunscreen made with polymeric nanocapsules (NCs) containing benzophenone-3 (BZP3). These NCs, composed of poly(ϵ -caprolactone), carrot oil, and Pluronic F68, had a mean particle size between 280 and 420 nm. No cytotoxic effects were observed in cell lines for both blank and BZP3-loaded NCs. The semi- solid sunscreen formulation was stable over time and exhibited non-Newtonian pseudoplastic behavior. Incorporating BZP3-NCs increased the sun protection factor (SPF) to 8.84. Overall, poly(ϵ -caprolactone) nanocapsules show promise for delivering lipophilic sunscreens like benzophenone-3. (Barbosa *et al* 2019)

CHAPTER – 3

AIM AND OBJECTIVES

3.1 AIM

To formulate herbal sunscreen by characterizing the photoprotective properties of the selected plant *Sesuvium portulacastrum* to establish a sustainable alternative to traditional sunscreen.

3.2 OBJECTIVES

- To isolate and characterize the metabolic profile of *S. portulacastrum* (FT-IR, NMR, UV Spectroscopy, and GC-MS).
- To explore formulation alternatives from inorganic to organic compounds for enhanced precision.
- To develop herbal sunscreen formulations using natural ingredients with known photoprotective properties.
- To assess the efficacy of the formulated herbal sunscreens by conducting in vitro studies to determine their sun protection factor (SPF) and broad-spectrum coverage against UVA and UVB radiation.

CHAPTER - 4

MATERIALS AND METHODS

4.1 INSTRUMENTS AND REAGENTS

UV-spectrophotometer (Shimadzu-1800), Mixer grinder, Magnetic stirrer, Centrifuge, Water bath, Micro-pipette, Whatman Filter paper, Methanol, Distilled water, Plant powder, Mayer's reagent, Dragendorff's reagent, Wagner's reagent, Ninhydrin, DPPH (1,1 Diphenyl 2-picryl hydrazyl), Copper acetate, Sulfanilamide, Naphthalenediamine, Sodium-nitroprusside, Saline phosphate, Ascorbic acid, Ferric chloride dihydrates, and Lead acetate.

4.2 SAMPLE COLLECTION

The *S. portulacastrum* plant was collected from the coastal areas of Buckingham Canal, Kovalam, and Mahabalipuram as shown in Fig 4.1. and rinsed thoroughly using tap water. The washed leaves were ground using ethanol.



Fig: 4.1: Plant collection from Mahabalipuram

4.3 EXTRACTION

Plant extraction is the isolation of active ingredients from the selected plant. In this study, the plant extract was purified using liquid-liquid extraction. The grounded plant sample was kept soaked for 24 hours. In this way, ethanol which is used as a solvent helps to dissolve all the bioactive compounds present in the plant. The mixture was centrifuged at high speed for a few minutes as shown in Fig 4.2.

The cell debris settled at the bottom and the supernatant which consists of extracted compounds were carefully removed. The purified plant

extract was stored in a cold condition for further research and study.



Fig: 4.2: Extraction Process Workflow

4.4 PHYTOCHEMICAL SCREENING OF PLANT EXTRACTS

Phytochemical tests are performed to identify and analyze various classes of chemical compounds present naturally in plants. Bioactive compounds give us the information needed to understand the potential effects of the plant sample. The phytochemicals most commonly present in plants are flavonoids, phenols, tannins, alkaloids, terpenoids, and carbohydrates.

Phytochemical screening for plant extract is carried out according to the standard methods.

4.4.1 Detection of alkaloids:

Extracts were dissolved individually in diluted Hydrochloric acid.

Mayer's test: Filtrates were treated with Mayer's reagent (Potassium Mercuric Iodide). The formation of a yellow-colored precipitate indicates the presence of alkaloids.

4.4.2 Detection of flavonoids:

Lead acetate test: Extracts were treated with a few drops of lead acetate solution. The formation of a yellow color precipitate indicates the presence of flavonoids.

4.4.3 Detection of phenols:

Ferric chloride test: Extracts were treated with 3-4 drops of ferric chloride solution. The formation of a bluish-black color indicates the presence of phenols.

4.4.4 Detection of saponins:

Froth test: Extracts were diluted with distilled water to 20ml, and this was

shaken in a graduated cylinder for 15 minutes. The formation of a 1 cm layer of foam indicates the presence of saponins.

4.4.5 Detection of glycosides:

Extracts were hydrolyzed with dil. HCl, and then subjected to a test for glycosides.

Modified Borntrager's test: Extracts were treated with Ferric Chloride solution and immersed in boiling water for about 5 minutes. The mixture was cooled and extracted with equal volumes of benzene. The benzene layer was separated and treated with ammonia solution. The formation of a rose-pink color in the ammoniacal layer indicates the presence of anthranilic glycosides.

4.4.6 Detection of carbohydrates:

Extracts were dissolved individually in 5 ml distilled water and filtered.

Molisch's test: Filtrates were treated with 2 drops of alcoholic α -naphthol solution in a test tube. The formation of the violet ring at the junction indicates the presence of Carbohydrates.

4.4.7 Detection of proteins and amino acids:

Xanthoproteic test: The extracts were treated with a few drops of concentrated nitric acid. The formation of a yellow color indicates the presence of proteins. Phytochemical screening of the above plant mixture in the form of methanolic extract was performed, the results of which are shown in Table 5.1.

4.5 FRACTIONATION AND CHARACTERIZATION OF PHYTOCHEMICAL SUBSTANCES

This process involves several steps aimed at separating, isolating, and identifying the diverse array of chemical compounds present in the selected plant. This process is crucial for gaining knowledge about the chemical composition of plants, understanding their effective properties, and exploring their potential applications in various fields depending on the type of research to be done. Firstly, the plant selected is washed and grounded using a solvent to facilitate efficient extraction of phytochemicals. The crude extract obtained from the extraction step often contains a complex mixture of phytochemicals with different polarities. Fractionation involves separating this mixture into

distinct fractions based on the polarity of the compounds. Liquid-liquid extraction was done for this process of fractionation. For the purification step, TLC is performed using a general procedure.

4.5.1. Thin Layer Chromatography

Thin Layer Chromatography (TLC) is a powerful biophysical technique used for the separation, identification, and purification of components within a mixture. In TLC, a thin layer of adsorbent material (such as silica gel, alumina, or cellulose) is coated onto a glass, plastic, or aluminum foil plate. This layer serves as the stationary phase. When a sample is applied to the plate, a solvent (the mobile phase) moves up the plate via capillary action. Different analytes ascend at varying rates, leading to their separation. TLC operates based on principles of adsorption chromatography or partition chromatography, depending on the adsorbent and solvents used. Once separated, individual components appear as distinct spots on the plate, which can be identified using suitable detection techniques. The crude plant extract is used in the TLC technique by using hexane and methanol as a solvent and solute. The retention factor (R_f) shown in Table 5.1. is calculated by dividing the distance traveled by the solute by the distance traveled by the solvent. It provides valuable information about the relative mobility of different components during Thin-layer chromatography (TLC) separation.

$$R_f \text{ value} = \text{Distance traveled by solute} / \text{Distance traveled by the solvent}$$

By using this formula compound movement has been noted and future identification of compounds is clarified using Mass spectrometry (MS), Nuclear magnetic resonance spectrometry (NMR), and Fourier Transform infrared spectroscopy (FTIR).

4.5.2. Gas Chromatography-Mass Spectroscopy

GC-MS is a powerful analytical method used to separate, quantify, and analyze organic compounds that are naturally present. GC separates the components of the sample based on their retention time in a chromatographic column and MS identifies and quantifies the separated compounds by

analyzing their mass spectra. Identification of components was achieved based on their retention time. In this method, the gas phase flows, and the liquid phase is stationary.

4.5.3. NMR Spectroscopy

NMR spectroscopy is an effective analytical method that is frequently used to characterize the phytochemical compounds found in plant samples. The molecular structure, composition, and dynamics of organic compounds may be thoroughly studied using nuclear magnetic resonance (NMR) spectroscopy, which is based on the interaction of atomic nuclei with radiofrequency radiation and a strong magnetic field. Phytochemical and other biomolecule interactions may be studied, as well as the purity of isolated substances and chemical processes, using NMR spectroscopy.

The plant sample was extracted, concentrated, and purified to remove impurities, and then dissolved in a deuterated solvent for NMR analysis. The NMR spectrometer was set up per the manufacturer's instructions, ensuring proper magnet calibration, tuning, and shimming for optimal performance. The prepared sample was loaded into the NMR probe, inserted into the spectrometer, and subjected to radiofrequency pulses. Multiple scans accumulated.

The raw NMR data was processed with software, applying Fourier transformation, phase correction, and baseline correction for analysis. NMR spectrum analyzed, peaks assigned to nuclei, chemical moieties identified. Experimental data compared with references to confirm identities and structures. NMR data was analyzed for compound abundance, purity, and coupling constants. Quantitative information extracted from peak integration to quantify compound concentrations. NMR data and interpretation were compiled for spectral assignments and structural elucidation.

4.5.4. FT-IR Spectroscopy

Fourier-transform infrared (FTIR) analysis is a powerful technique widely employed in the characterization of phytochemical substances present in plant samples. By measuring the absorption of infrared radiation by molecules within the sample, FTIR spectroscopy provides valuable information about the functional groups and chemical bonds present in the plant materials.

The plant sample was prepared for analysis by obtaining a representative portion of the material (leaves). It was in the form of a liquid extract. Care was taken to ensure that the sample was homogenized and free of contaminants that could interfere with the analysis.

The FTIR instrument was set up according to the manufacturer's instructions. This involved calibrating the instrument, aligning the optics, and optimizing the settings for the specific type of analysis being performed. The calibration process ensured accurate measurements while aligning the optics ensured that the infrared beam was properly focused on the sample. Then, the instrument settings were adjusted to optimize parameters such as wavelength range, resolution, and number of scans to achieve the desired level of accuracy for the analysis. The prepared sample was placed onto the sample holder, ensuring interaction with the infrared beam. Data collection parameters were selected, and the FTIR spectrum was collected. Peaks identifying functional groups were analyzed.

4.5.5. In vitro Sun Protection Factor (SPF) Determination

The sun protection factor is the minimum amount of a sunscreen product that can protect the skin from the sun's ultraviolet (UV) rays. The main type of UV rays that are responsible for sunburn and skin damage are the UVB rays.

In vitro SPF values of sunscreen formulations were calculated using the absorbance values of the sample using a UV spectrophotometer. The formula used is

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

Where,

CF = Correction Factor (10)

EE (λ) = Erythrogenic Effect of radiation

(λ) = Solar Intensity spectrum

Abs (λ) = Spectrophotometric absorbance value

The values of $EE \times I$ are constants.

The calculation was done for the product by diluting 0.01g of the sample in 5ml of isopropyl alcohol and the same reagent without the sample was used as a blank to avoid any interferences while getting the results. The data for absorbance was acquired every 5nm between 290-320nm to calculate the SPF values. This method allows for the evaluation of the sunscreen's effectiveness in absorbing or blocking UV rays, and the results are expressed in terms of SPF values. Higher SPF values indicate better protection against UVB radiation. This testing is crucial for formulating sunscreens that offer adequate protection while also being safe for use. The calculated SPF is shown in Table 5.5.

Table 4.1: Relationship between the erythema effect and solar intensity

Wavelength (nm)	$EE(\lambda) \times I(\lambda)$
290	0.015
295	0.0817
300	0.2874
305	0.3278
310	0.1865
315	0.0839
320	0.018

4.6 FORMULATION AND PREPARATION OF SUNSCREEN PRODUCT

4.6.1 Plant materials

Collected plant material leaf is washed, ground, and centrifuged to obtain extract in a liquid form. Our active ingredient for sunscreen is plant extract (*S. portulacastrum*), and reagent ethanol is used.

4.6.2 Equipment

The laboratory is equipped with essential instruments including a water bath for temperature control, a homogenizer for mixing, UV spectroscopy for absorption measurements, a magnetic stirrer for blending, a pH meter for acidity assessment, an autoclave for sterilization, and a centrifuge for sample separation.

4.6.3 General Procedure for Cream Preparation

Cream preparation is done according to an emulsion type and is prepared by taking ingredients of the oil phase and aqueous phase separately and heating them to liquefy or dissolve all ingredients and then mixing them with continuous stirring till the cream is produced and should be added after cooling the cream to near room temperature.

4.6.4 Ingredients

The formulation of the herbal sunscreen integrates key ingredients such as *S. portulacastrum* plant extract, beeswax, honey, and rosemary oil, synergistically combining their natural UV-protective and skin-nourishing properties.

Table 4.2: A complete list of components used in the sunscreen

S.No.	Common Name	Scientific Name
1	Sea Purslane	<i>Sesuvium portulacastrum</i>
2	Coconut Oil	<i>Cocos nucifera</i> Oil
3	Sesame Oil	<i>Sesamum indicum</i>
4	Rosemary Oil	<i>Rosmarinus officinalis</i> Oil
5	Honey	<i>Apis mellifera</i>
6	Citric Acid	2-Hydroxypropane-1,2,3-Tricarboxylic Acid
7	Glycerol	Propane-1,2,3-Triol

4.6.5. Preparation of Herbal Sunscreen

Steps involved in making herbal sunscreen formulation.

Step 1: The aqueous phase was prepared by adding distilled water (10.71%), *S. portulacastrum* extract (42.86%), Rosewater (21.43%), *Apis mellifera* (3.57%), and Glycerol (14.2%) (Fig 4.2). These Aqueous soluble components were added together in a beaker, mixed thoroughly, and kept in a water bath at 80°C for 15 mins.

Step 2: The oil phase was prepared by adding *Cocos nucifera* oil (7.14%), *Sesamum indicum* oil (21.43%), *Rosmarinus officinalis* oil (1.43%), and beeswax (5%) in a beaker and kept in the water bath at 80°C for 15 mins.

Step 3: The aqueous phase was added gradually in the oil phase at a time interval of a few seconds with continuous stirring for 10-20 mins. shown in Fig 4.3. Then it was homogenized till a uniform emulsion was formed. Thus, the finished product was pale yellow and had a creamy consistency.

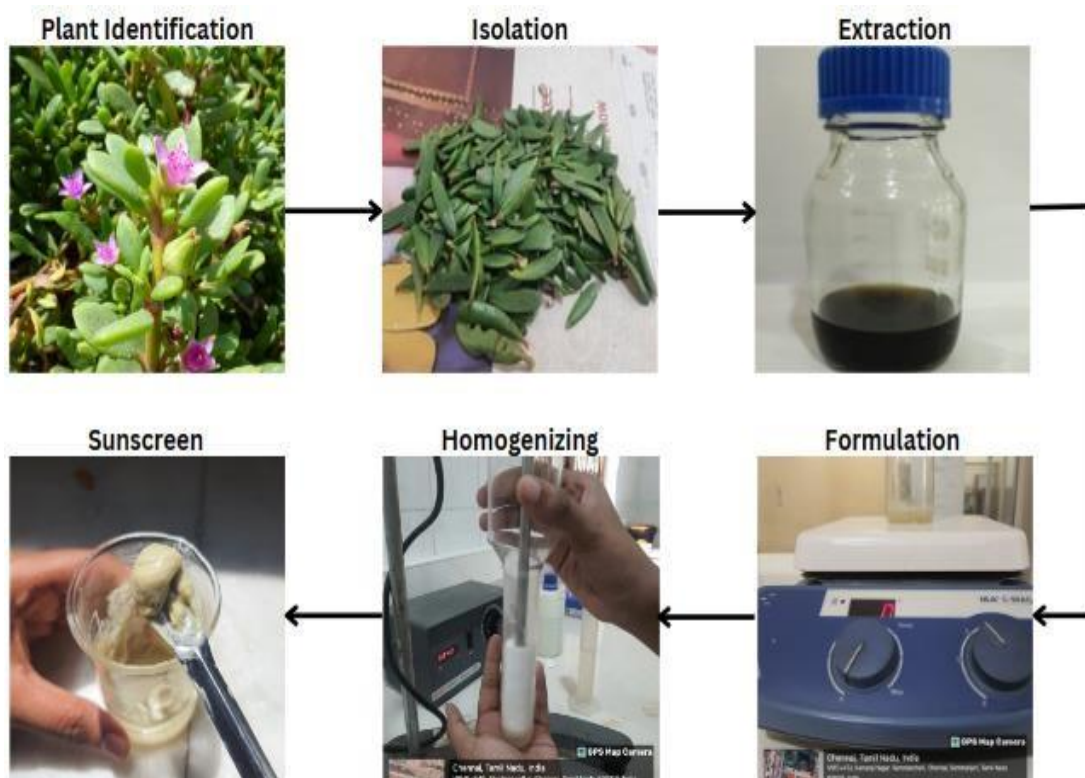


Fig: 4.3: Diagrammatic workflow of formulation



Fig: 4.4: Sunscreen product appearance

Table 4.3: Failed and successful formulation of the sunscreen

Ingredients	F1 (%) (Failed)	F2 (%) (Failed)	F3 (%) (Failed)	F4 (%) (Failed)	F5 (%) (Success)
Plant Sample	16.67	11.67	20	46.875	36.13
Distilled water	16.67	8.33	-	-	12.90
Honey	-	-	-	6.25	3.2
Turmeric water	10	8.33	5	6.25	-
Rosewater	-	-	18.75	-	-
Glycerol	50	50	50	6.25	6.45
Sesame oil	6.67	12.5	7.5	12.5	19.35
Coconut oil	1.67	6.67	5	6.25	12.90
Sandalwood oil	-	-	-	1.25	1.290 3
Rosemary oil	-	-	-	6.25	6.45
Beeswax	-	-	-	8.75	3.23
Lecithin	-	-	-	10	6.45

4.7 PHYSICAL CHARACTERIZATION OF SUNSCREEN

4.7.1. *Organoleptic properties*

This is one of the most basic and significant tests done for sunscreen through the eyes such as Appearance and color, odor, texture, and feel. Herbal sunscreens exhibit diverse visual appearances and colors, influenced by their natural ingredients. The fragrance, derived from botanical components, significantly impacts user experience, enhancing the overall application process. Additionally, organoleptic testing evaluates texture, spreadability, and skin feel, ensuring that creams, lotions, or sprays apply smoothly without any greasy residue.

4.7.2. *Determination of pH*

The pH measurement was carried out using a Fisher pH meter. Before use, the Fisher tool was washed with distilled water and then dried with a tissue. Then dilute 1g of skin lotion with 20 ml of distilled water into a beaker. After that, the electrode is dipped into the solution and let move until the position of the number is constant. The skin is the largest and outermost organ that limits the human body from the environment. In the manufacture of cosmetic skin lotion products, the degree of acidity (pH) is an important parameter because it can affect the absorption power of the skin.

4.7.3. *Spreadability*

Assessing the spreadability of lotions is vital in determining their usability and effectiveness. A wooden block with a pulley at one end and a ground glass slide fixed on top. The lotion under investigation, approximately 2 g, was placed on the slide and sandwiched with another glass slide equipped with hooks. After applying a 1 kg weight for 5 minutes to ensure uniformity, excess lotion was removed, and the top slide was subjected to a pull of 80 g. The time taken for the top slide to cover a distance of 7.5 cm indicated spreadability, with a shorter time denoting better spreadability, calculated using a specified formula. The result is discussed in Table 5.5. This method, integrating slip and drag characteristics, offers a precise means to evaluate lotion spreadability, crucial for product formulation and quality assessment in research settings

$$S = M \times L/T$$

Where, S = Spreadability, M = Weight in the pan (tied to upper slide), L = Length moved by glass slide, and T = Time taken to separate the slide from each other.

4.8 ANTIOXIDANT ASSAY

In the evaluation of sunscreens, antioxidant assays play a pivotal role. These assays help determine the ability of sunscreen formulations to neutralize harmful free radicals induced by UV radiation, thus enhancing their overall photoprotective efficacy. The incorporation of antioxidants into sunscreens plays a crucial role in enhancing skin photoprotection against the harmful effects of ultraviolet (UV) radiation. In our study, we evaluated the antioxidant using (2,2-diphenyl-1-picrylhydrazyl) (DPPH) assay for in vitro assays. The reaction between DPPH and antioxidants is rapid, allowing for a quick assessment of the sample's ability to scavenge free radicals.

DPPH assay is a fundamental method for assessing the antioxidant potential of compounds, extracts, or other biological sources. In this approach, the prospective substance is mixed with a solution of DPPH, a stable free radical. The reduction of DPPH occurs when antioxidants react with it, resulting in the formation of the reduced form (DPPH₂). Consequently, the absorbance of DPPH decreases, leading to decolorization. The degree of decolorization correlates with the reducing ability of the tested compound. Researchers commonly employ this assay to evaluate the free radical scavenging activity of novel drugs. Here we use DPPH assay to evaluate the antioxidant properties of our sunscreen.

4.8.1. Estimation of antioxidant assay

The stock solution was prepared by dissolving DPPH powder usually dissolved in ethanol kept in a dark environment. Dilution of sunscreen samples in a various concentration using methanol as a solvent, blank and control prepared and kept aside. Incubated the reaction mixture for 30 minutes in the dark at room temperature. This allows for the interaction between the sunscreen component and DPPH radical. After the incubation periods, wavelength has been noted at 517 nm

4.9 MTT ASSAY

MTT assay is a widely utilized colorimetric method in plant research areas where it evaluates cell viability and cytotoxicity. Cytotoxicity of the herbal sunscreen which contains the extract of *S. portulacastrum* in 3T3 cell lines was evaluated by MTT assay based on mitochondrial reduction of yellow MTT tetrazolium dye to a highly colored blue formazan product. The intensity of the resultant color correlates with viable cell count. This assay assesses the impact of plant extracts, compounds, or treatments on cell viability and proliferation. Through spectrophotometric measurement of formazan absorbance, it is easy to quantitatively analyze the cytotoxic or cytoprotective effects of plant-derived substances.

To perform the MTT assay, 3T3 cell lines were incubated with MTT solution, followed by solubilization of formazan crystals and measurement of absorbance. High absorbance indicated cell viability, enabling comparisons between treated and control samples. The herbal sunscreen samples were prepared for assay 3T3 cell line were kept in 96 well plates and incubated at 37°C for 24 hours. After that, 100µl was taken from each dilution of diluted compounds in the medium and added to selective well plates. Incubated the mixture at 37°C for 24 hours. After the period of incubation, MTT reagent was added and kept for 4 hours for incubation again in a CO₂ incubator. Absorbance was measured by ELISA reader at 450 nm after adding 10µl of solubilization solution and results were calculated in Fig5.9.

CHAPTER - 5

RESULTS AND DISCUSSION

5.1 PHYTOCHEMICAL SCREENING

Phytochemical screening of the plant extract in the form of ethanolic extract was performed, the results of which are shown in Table 5.1.

Table 5.1: Phytochemical screening of plant sample

S.No.	Class	Test	Results
1	Alkaloid	Mayer's	+
2	Flavonoids	Lead acetate	+
3	Phenols	Ferric chloride	+
4	Saponins	Froth test	+
5	Glycoside	Modified Borntrager's test	+
6	Carbohydrates	Molisch's test	+
7	Proteins	Xanthoproteic test	+



Fig: 5.1: Phytochemical screening of plant sample

5.2 THIN LAYER CHROMATOGRAPHY

The plant extract samples were collected and used for TLC, the Rf value of the crude extract of *S. portulacastrum* was calculated as mentioned below.

Table 5.2: Rf value of plant extract of *S. portulacastrum*

Distance traveled by solute(in cm)	Distance traveled by solvent (in cm)	Rf Value
1	5.7	0.2105

5.3 GC-MS ANALYSIS

From the plant extract result, identified the compound Dodecanoic acid, 1,2,3- Propanetr, and 2-Lauro-1,3-Didecoin present in our plant sample which is mainly used in the formulation of cosmetic products.

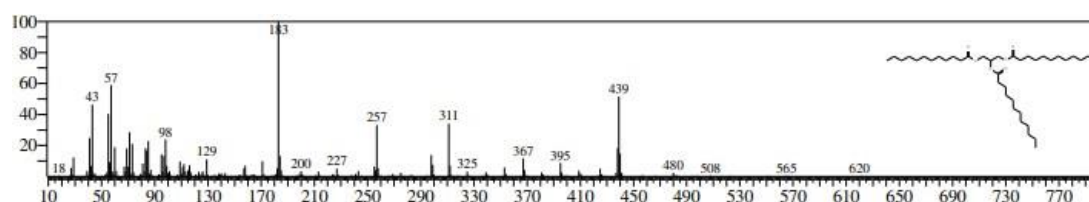


Fig: 5.2: GC-MS shows the retention times and intensity counts for identified compounds

Table 5.3: Peak results of selected plant compound obtained from GC-MS analysis

Peak Report TIC				
Peak#	R.Time	Area	Area%	Name
1	46.945	58176307	6.73	DODECANOIC ACID, 1,2,3-PROPANETR
2	47.047	29597636	3.42	2-LAURO-1,3-DIDECOA
3	47.160	74168869	8.58	2-LAURO-1,3-DIDECOA
4	47.281	62257283	7.20	DODECANOIC ACID, 1,2,3-PROPANETR
5	47.395	142841952	16.52	2-LAURO-1,3-DIDECOA
6	47.610	96657407	11.18	Dodecanoic acid, 1,2,3-propanetriyl ester
7	47.770	56982227	6.59	DODECANOIC ACID, 1,2,3-PROPANETR
8	47.966	150344894	17.39	DODECANOIC ACID, 1,2,3-PROPANETR
9	48.066	101634848	11.75	DODECANOIC ACID, 1,2,3-PROPANETR
10	48.170	92000768	10.64	DODECANOIC ACID, 1,2,3-PROPANETR
		864662191	100.00	

5.4 NMR SPECTROSCOPY

The Proton NMR was identified from Dodecanoic acid, 1,2,3-Propanetr, aliphatic group was present in the 1.0 to 2.5 pm, and carboxylic group (C=O) was present in the 180pm.

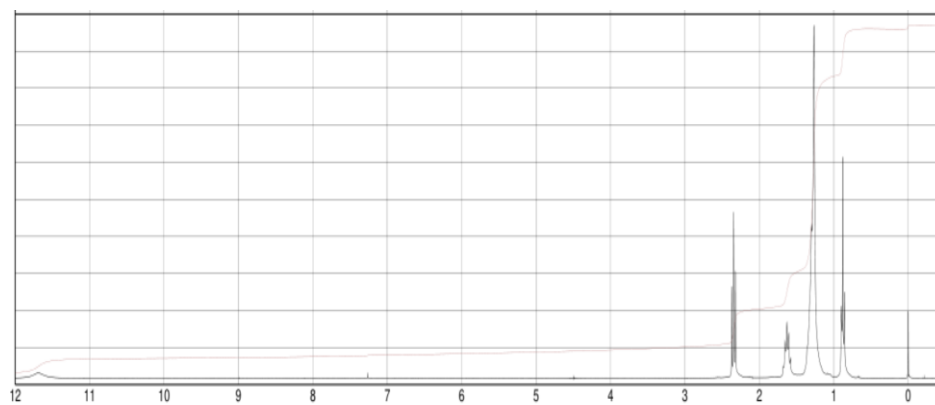


Fig: 5.3: NMR Spectral Analysis of *S. portulacastrum* Extract

5.5 FTIR ANALYSIS

Based on the peak values in the IR radiation band, the FTIR spectrum was utilized to determine the functional groups of the active components present in the extract. Based on the extract's peak ratio, the components' functional groups were divided after it was run through the FTIR. The existence of alcohol, phenol, alkanes, aldehyde, aromatic compounds, secondary alcohol, aromatic amines, and halogen compounds was confirmed by the FTIR study results. Polyphenolic substances with several hydroxyl groups possess antiviral, anticancer, cardioprotective, and antibacterial properties.

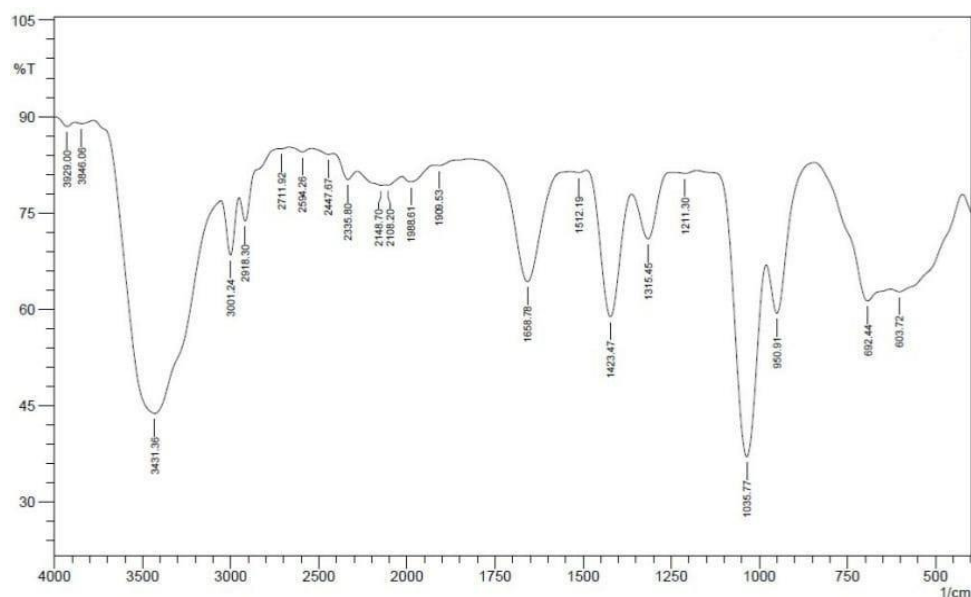


Fig: 5.4: FT-IR spectrum of the functional group present in *S. portulacastrum*

Table 5.4: FT-IR absorption peaks & their corresponding functional groups

Peak value	Functional group
603.72	Alkyl halide
692.44	Alkyl halide
950.91	Alkene
1035.77	Ester
1211.3	Ether, Acid, Ester
1315.45	Amine
1423.47	Aromatic
1512.19	Nitro
1658.78	Alkene
1909.53	Unknown
1988.61	Unknown
2108.2	Alkyne
2148.7	Alkyne
2335.8	Unknown
2447.67	Unknown
2594.26	Acid
2711.92	Acid
2918.3	Aldehyde
3001.24	Aromatic
3431.36	Amine
3846.06	Unknown
3929.0	Unknown

5.6 UV SPECTROSCOPY ANALYSIS

The efficacy of sunscreen agents is usually expressed by the SPF, UV spectroscopy was the best way to calculate the Sun Protection Factor

(SPF) for sunscreen efficiency towards UV light range between 290-320 nm (UVB). The SPF was calculated for our sample to know the efficiency of *S. portulacastrum* protection against UV range exposure. 2 ml of plant extract is mixed with 2 ml of water, creating a 1:1 ratio solution. This solution is then subjected to absorbance measurement within the wavelength range of 290-320 nm. The calculated tabulation is shown below.

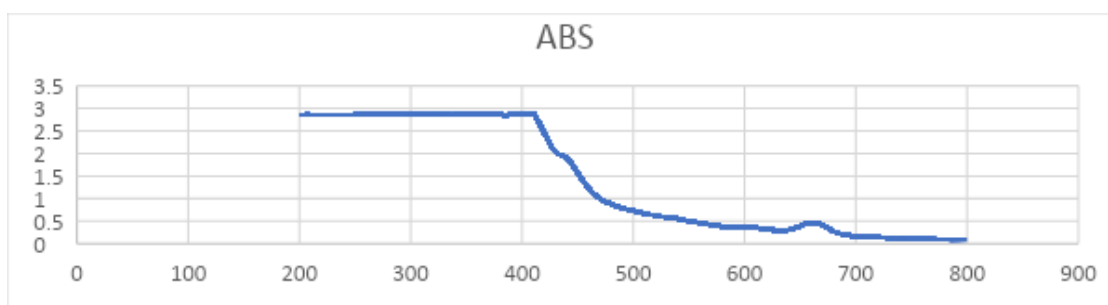


Fig: 5.5: Graphical representation of the absorbance of the plant sample

Table 5.5: Calculated SPF value of plant extract and sunscreen

S.No.	Wavelength (nm)	Plant Extract abs	$EE(\lambda) \times I(\lambda) \times Abs$	Sunscreen abs	$EE(\lambda) \times I(\lambda) \times Abs$
1	290	2.862	0.04293	2.931	0.04395
2	295	2.864	0.23398	2.932	0.23954
3	300	2.865	0.82311	2.935	0.8435
4	305	2.867	0.93750	2.936	0.96242
5	310	2.868	0.5345	2.938	0.54793
6	315	2.869	0.2407	2.939	0.24658
7	320	2.871	0.0516	2.940	0.05292
9	-	-	2.8642	-	2.9368

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

SPF = 28.642(For plant sample), **SPF = 29.36**(For sunscreen)

5.7 PHYSICAL CHARACTERIZATION OF SUNSCREEN

From the herbal sunscreen product, the physical characterization of the sunscreen formulations is thoroughly tested. It is a critical aspect of the herbal sunscreen formulation. Appearance and color are assessed for aesthetic appeal and consistency, while pH is measured to ensure skin compatibility. Homogeneity is crucial for uniform protection, and spreadability affects application ease and coverage. The well-formulated sunscreen appeared visually appealing, maintained a consistent color, upheld a skin-friendly pH, exhibited a uniform texture without separation, and spread smoothly over the skin for optimal protection.

Table 5.6: Physical characteristics of sunscreen

S. No	Appearance	Color	PH	Homogeneity	Spreadability
F1	Aqueous solution	Yellow	6.5	Homogenous	17.34 ± 0.7
F2	Aqueous solution	Greenish yellow	6.7	Homogenous	19.47 ± 0.7
F3	Cream like appearance	Pale yellow	5.4	Homogenous	27.68 ± 0.8
F4	Highly viscous cream	Beige cream	5.5	Homogenous	30.65 ± 0.8



Fig: 5.6: Stability of the herbal sunscreen after 2 weeks

5.8 ANTIOXIDANT ASSAY

DPPH radical scavenging capacity assay was done to check the antioxidant potential of herbal sunscreen. Ascorbic acid (vitamin C) was taken as standard. Assay indicates the antioxidant capacity of herbal sunscreen to be 47.20%.

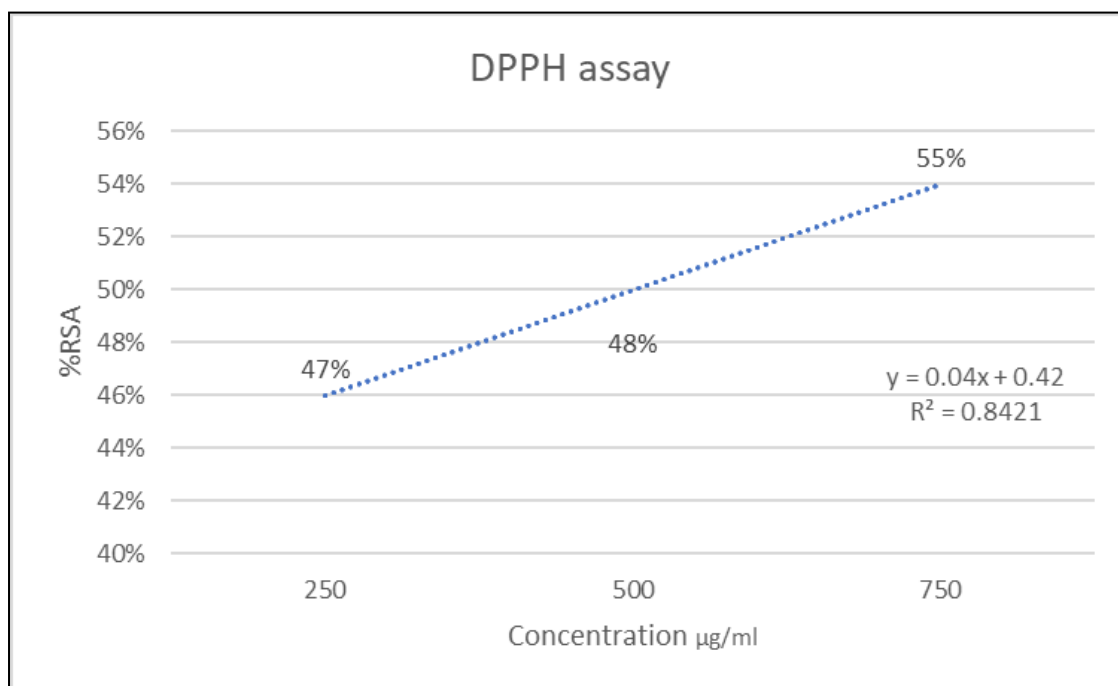


Fig: 5.7: Antioxidant activity was measured using the DPPH assay

5.9 MTT ASSAY

The cytotoxicity of the herbal sunscreen is tested against the dermal fibroblast cell lines and the MTT assay was performed according to Mosmann's method. Cytotoxicity of obtained herbal sunscreen of *S. portulacastrum* was performed using MTT assay. Absorbance was measured at 450 nm using an ELISA reader. The MTT assay results for the herbal sunscreen, which showed cell viabilities of 86.20%, 96%, and 90.40%, indicated that the product was largely non-cytotoxic and well-tolerated by the cells, which is shown in Fig 5.9. These percentages reflected a high survival rate of the cells post-treatment, suggesting that the herbal ingredients were safe for skin application. The consistency of the results across different concentrations also pointed to the reliability of the sunscreen's non-toxic profile. The results and graph were interpreted and mentioned below.

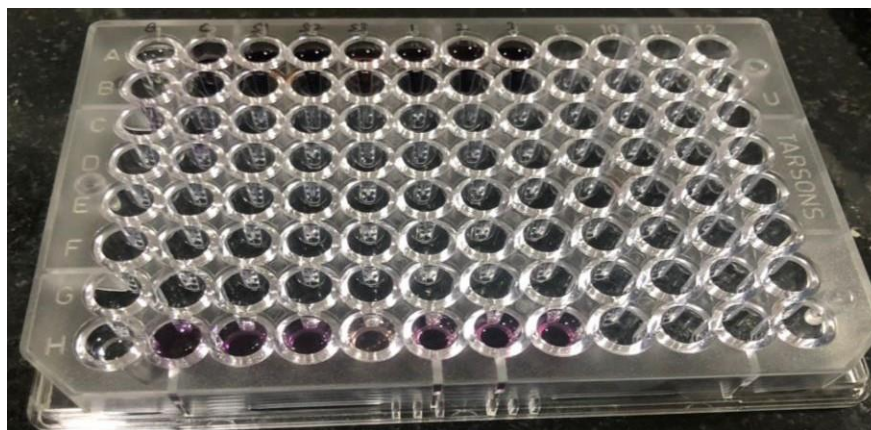


Fig: 5.8: 96-well plate with herbal sunscreen

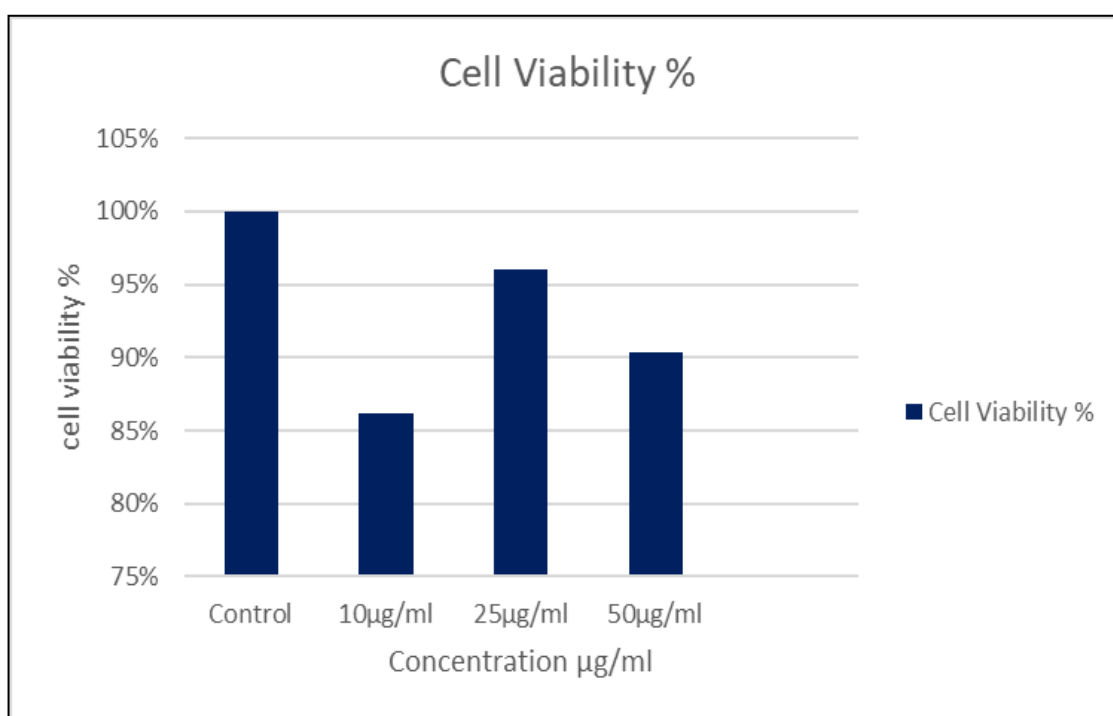


Fig: 5.9: The cytotoxicity of the sunscreen in various concentrations

The study's conclusions about the effectiveness and possible advantages of the tested herbal sunscreen formulations included many significant discoveries. Beeswax, coconut oil, and sesame oil are examples of herbal compounds that can improve sunscreen's efficacy. These organic substances are well-known for their antioxidant qualities, which might lessen the damaging effects of UV radiation on the skin. Furthermore, positive outcomes were obtained from the stability and safety analyses carried out on the sunscreen versions. It is significant to note that, when compared to the other formulations,

formulation F5, which contains beeswax, proved to be the most stable and effective formulation with a high SPF. Research on herbal sunscreens has been gaining traction in recent years, with studies focusing on formulating effective and natural alternatives to synthetic sunscreens. One such study investigated the use of turmeric and Aloe Vera extracts in sunscreen formulation. The aim was to create an herbal sunscreen cream, and the SPF of the formulated product was compared with that of a marketed herbal sunscreen cream, typically offering SPF values in the range of 15 to 20 (Almeida *et al* 2019).

Another study aimed to develop a stable natural formulation with high SPF and uniform protection against both UVA and UVB radiation, potentially achieving SPF values within the same range. Moreover, formulations containing curcumin, a compound found in turmeric, have shown promise in providing sun protection. These formulations typically had SPF values ranging from 13 to 18 and were deemed suitable for normal skin to prevent sunburns (Rodrigues *et al* 2020). However, *S. portulacastrum* herbal sunscreen concluded SPF value of 29-32. it's important to note that while herbal sunscreens offer advantages such as easy availability and minimal side effects, their efficacy depends on factors such as photo stability and proper formulation. Stability evaluations found that the formulas were not affected throughout the test period thereby displaying the unyielding nature of temperature changes.

CHAPTER- 6

SUMMARY AND CONCLUSION

Sesuvium portulacastrum plant extract was analyzed using TLC and GC-MS. Key compounds identified in the extract include Dodecanoic acid, 1,2,3-Propanetriol, and 2-Lauro-1,3-Didecoin. These compounds are commonly used in cosmetic product formulations. Additionally, the FTIR spectrum revealed several functional groups in the extract, including alcohol, phenol, alkanes, aldehyde, aromatic compounds, and aromatic amines compounds. Notably, the extract contains polyphenolic substances with multiple hydroxyl groups, which are associated with various beneficial properties such as antifungal, anticancer, and antibacterial effects. *S. portulacastrum* based sunscreen formulation exhibits promising attributes across multiple parameters essential for effective sun protection. With a calculated SPF of 28.642 for the plant sample and 29.36 for the final sunscreen product, it demonstrates substantial efficacy in shielding the skin against harmful UV radiation, particularly UVB rays.

Furthermore, physical evaluations highlight the formulation's versatility, ranging from aqueous solutions to cream-like textures, all boasting uniformity, ease of application, and enhanced spreadability. These characteristics enhance user experience and encourage consistent application, vital for comprehensive sun protection. Moreover, cytotoxicity assessments underscore the formulation's safety profile, with high cell viability percentages and notable antioxidant activity. These findings not only emphasize the sunscreen's potential to safeguard skin health but also hint at additional benefits derived from its natural composition. Despite these promising outcomes, the necessity for further validation through rigorous clinical trials and stability testing is evident. Ensuring both efficacy and safety through comprehensive testing will be paramount in establishing this *S. portulacastrum*-based sunscreen as a trusted option for widespread use contributing to the advancement of natural skincare solutions.

REFERENCES

Abubakar, A. R., Haque, M., Preparation of Medicinal Plants: Basic Extraction and Fractionation Procedures for Experimental Purposes, *J Pharm Bioallied Sci*, 2020,12,1-10.

Almeida, W. A. S., Antunes, A. S., Penido, R. G., Correa, H. S. G., Nascimento, A.M., Andrade, Â. L., Santos, V. R., Cazati, T., Amparo, T. R., Souza, G. H. B., Freitas, Barbosa, V. L., Nascimento, E. D., Bani, C., Almeida, T., Nery, M., Santos, R. S., Menezes, L. R. D. O., Zielińska, A., Fernandes, A. R., Cardoso, J. C., Jäger, A., Development, cytotoxicity and eye irritation profile of a new sunscreen formulation based on benzophenone-3-poly (ϵ -caprolactone) nanocapsules, *Toxics*, 2019, 7, 51.

Bhide, R., Madasu, D., Patil, P., Dayal, N., Koppaka, O., Ather, S., and Thakur, M., Formulation, characterization and in vitro evaluation of proshine MBTMGMIHS herbal sunscreen cream containing flower extract, *Res. j. top. cosmet. Sci*, 2023, 16,1309-1313.

Bora, N. S., Pathak, M. P., Mandal, S., Mazumder, B., Policegoudra, R., Raju, P. S., and Chattopadhyay, P., Safety assessment and toxicological profiling of a novel combinational sunprotective dermal formulation containing melatonin and pumpkin seed oil, *Regul. Toxicol. Pharmacol.*, 2017, 89, 1-12.

Cefali, L. C., J. A. Ataide, A. R. Fernandes, I. M. O. Sousa, F. C. S. Gonçalves, S. Eberlin, J. L. Dávila, A. F. Jozala, M. V. Chaud, E. Sanchez-Lopez, Chinh, N. T., Anh, N. T. L., Thao, P. T., Quang, D. D., Photoprotective Properties of Natural Antioxidant Flavonoids: A DFT and TD-DFT study on Acridone Derivatives, *Vietnam J. Chem*, 2020, 58, 157-161.

Darmawan, M. A., Ramadhani, N. H., Hubeis, N. A., Ramadhan, M. Y. A., Sahlan, M. Abd-Aziz, S., Gozan, M., Natural sunscreen formulation with a high sun protection factor (SPF) from tengkawang butter and lignin, *Ind Crops Prod*, 2022, 177, 114466.

Dianursanti, M. B., Prakasa, P., Nugroho, The effect of adding microalgae extract *Spirulina platensis* containing flavonoid in the formation of Sunscreen towards cream stability and SPF values, *AIP Conf. Proc.*, 2020, 2255, 040022-1-040022-6.

Enriched Plant-Extract-Loaded Emulsion: A Novel Phytocosmetic Sunscreen Formulation with Antioxidant Properties, *Antioxidants*, 2019, 8, 443.

Geoffrey, K., Mwangi, A. N., Maru, S. M., Sunscreen products: Rationale for use, formulation development, and regulatory considerations, *Saudi Pharm J*, 2019, 27, 1009-1018.

Giraldo, J. C. M., Gallardo, C., Mejía, M. A. P., Selected extracts from high mountain plants as potential sunscreens with antioxidant capacity, *Photochem. Photobiol.*, 2022, 98, 211-219.

Górecka, A. K., Góreck, M., Stojko, A. R., Balwierz, J., Bee Products in Dermatology and Skin Care, *Molecules*, 2020, 25, 556.

Hashemi, Z., Ebrahimzadeh, M. A., Halili, M. K., Sun protection factor, total phenol, flavonoid contents and antioxidant activity of medicinal plants from Iran, *Trop. J. Pharm. Res*, 2019, 18, 1443-1448.

He, H., Li, A., Li, S., Tang, J., Li, L., Xiong, L., Natural components in sunscreens: Topical formulations with a sun protection factor (SPF), *Biomed. Pharmacother*, 134, 2021, 111161.

Ilett, M., Naveed, E., Roncal-Herrero, T., Aslam, Z., Micklethwaite, S., Hondow, N., In situ electron microscopy techniques for nanoparticle dispersion analysis of commercial sunscreen, *J Nanopart Res*, 2023, 25, 122.

K. M., Orlando D. H., Santos, L. R. D., Sousa, V. M. R., Photoprotective activity and increase of SPF in sunscreen formulation using lyophilized red propolis

extracts from Alagoas, *Rev. Bras. Farmacogn*, 2019, 29, 373-380.

Kadawla, M., Yadav, V., Khati, B., Gupta, P., Herbal sunscreen and their advantages over synthetic products. *Adv. Pharmacol. Toxicol*, 2022, 23.

Kakuda, L., Campos, P. M. B. G. M., Zanin, R. B., Favaro, L. N., Development of multifunctional sunscreens: Evaluation of physico-mechanical and film-forming properties, *Int. J. Pharm*, 2023, 635, 122705.

Korać, R. R., Khambholja, K. M., Potential of herbs in skin protection from ultraviolet radiation, *Pharmacogn Rev*, 2011, 5, 164-173.

Lokhande, V. H., Nikam, T. D., Suprasanna, P., *Sesuvium portulacastrum* (L.) L. a promising halophyte: cultivation, utilization, and distribution in India, *Genet Resour Crop Evol*, 2009, 56, 741-747.

Mahajan, U., Wasule, D., Sunscreen and anti-oxidant activities of herbal gel formulations. *Pharmacogn. Mag*, 2008, 4, 99.

Montenegro, L., Santagati, L. M., Use of Vegetable Oils to Improve the Sun Protection Factor of Sunscreen Formulations, *Cosmetics*, 2019, 6, 25.

Nakamura, K., Kono, T., Rajagopalan, U.M., Yamada, J. A., Novel Fluorescent Material Based Simple Method for Sunscreen Evaluation, *Appl. Sci*, 2022, 12, 1521.

Namukobe, J., Sekandi, P., Byamukama, R., Murungi, M., Namboze, Y. Ekyibetenga, C. B. Nagawa, S. Asiimwe, Antibacterial antioxidant and sun protection potential of selected ethnomedicinal plants used for skin infections in Uganda, *Trop. Med. Health.*, 2021, 49, 49.

Nandiyanto, A., Oktiani, R., Ragadhita, R., How to Read and Interpret FTIR Spectroscopy of Organic Material, *Indones. J. Sci. Technol*, 2019, 4, 97-118.

Nogueira, M. A., Magalhães, E. G., Magalhães, A. F., Biloti, D. N., Laverde, A., Pessine, F. B., Carvalho, J. E., Kohn, L. K., Antônio, M. A., Marsaioli, A. J., A novel sunscreen agent having antimelanoma activity, *Il Farmaco*, 2003, 58, 1163-1169.

Orazio, J. D., Jarrett, S., Ortiz, A. A., Scott, T., UV radiation and the skin, *Int. J. Mol. Sci*, 2013, 14, 12222-12248.

Panyakaew, J., Chalom, S., Sookkhee, S., Saiai, A., Chandet, N., Meepowpan, P., Thavornnyutikarn, P., Mungkornasawakul, P., Kaempferia sp. extracts as UV protecting and antioxidant agents in sunscreen, *J. Herbs Spices Med. Plants*, 2021, 27(1), 37-56.

Patel, R. I., Patel, A. M., Modi, B. D., Formulation and evaluation of herbal sunscreen. *World J. of BioL. Pharm. Health Sci.*, 2023, 13, 029-040.

Putri, K. M., Sailah, I., Formulation natural ingredients combination and consumer preference product sunscreen lotion, *IOP Conf. Environ. Earth Sci.*, 2022, 1063.

Rajasekar, M., Mary, J., Sivakumar, M., Selvam, M., Recent developments in sunscreens based on chromophore compounds and nanoparticles, *RSC advances*, 2024, 14, 2529-63.

Rodrigues, L. R., Jose, J., Exploring the photoprotective potential of solid lipid nanoparticle-based sunscreen cream containing Aloe vera, *Environ Sci Pollut Res*, 2020, 27, 20876-20888.

Roy, A., Sahu, R. K., Formulation and development of herbal sunscreen cream, *Res. j. top. cosmet. sci.*, 2014, 5,12-14.

Shama, S. N., Rasheed, A., Mohanalakshmi, S., Ravichandran, V., Formulation, characterization and in vitro evaluation of herbal sunscreen lotion, *Orient Pharm Exp Med.*, 2012, 241-246.

Sharma, M., Sharma, A., A Review on Nature Based Sunscreen Agents, *IOP Conf. Ser. Earth Environ. Sci.*, 2023, 1110, 012047.

Tiwari, R., Singh, I., Gupta, M., Singh, L. P., and Tiwari, G., Formulation and Evaluation of Herbal Sunscreens: An Assessment Towards Skin Protection from Ultraviolet Radiation. *Pharmacophore*, 2022, 13, 41-49.

Tong, Q., Xiao, Y., Yi, Z., Chen, X., Jiang, X., Li, X., Polyphenolic condensation assembly enabled biocompatible, antioxidative, and light-colored tea sunscreen formulations with broadband UV protection, *Green Chem.*, 2023, 25, 4387-4401.

Varol, M., Tay, M., Candan, A., Türk, A. T., Koparal, Evaluation of the sunscreen lichen substances usnic acid and atranorin, *Biocell*, 2015, 39, 25-31.

ANNEXURE

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Recent developments in sunscreens based on chromophore compounds and nanoparticles

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and Masilamani Selvam^b

Sunscreen formulations have undergone significant advancements in recent years, with a focus on improving UV radiation protection, photostability, and environmental sustainability. Chromophore compounds and nanoparticles have emerged as key components in these developments. This review highlights the latest research and innovations in chromophore compounds and nanoparticle-based sunscreens. It discusses the role of nanoparticles, such as zinc oxide and titanium dioxide, in scattering and absorbing UV radiation while remaining cosmetically acceptable. Chromophore compounds, encapsulated in nanoparticles, are explored for their potential to enhance UV protection by absorbing specific wavelengths of light. Additionally, advances in photo-stability, broad-spectrum protection, antioxidant inclusion, and biodegradability are discussed. The evolving landscape of sunscreen technology aims to provide more effective and environment-friendly solutions for safeguarding skin from the sun's harmful effects.

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1. Introduction

Sunscreen is a vital product that helps protect our skin from the harmful effects of the sun's ultraviolet (UV) rays. It is a topical product that comes in various forms, such as lotions, creams, gels, sprays, and sticks.¹ The primary purpose of sunscreen is to shield our skin from both UVA and UVB rays, which can cause sunburn and premature aging, and increase the risk of skin cancer. UVA rays penetrate deep into the skin and contribute to skin aging, while UVB rays primarily affect the outer layers of the skin and are the main cause of sunburn. Sunscreen works by either absorbing or reflecting these harmful rays, preventing them from damaging the skin. The effectiveness of sunscreen is measured by its sun protection factor (SPF), which indicates the level of protection it offers against UVB rays. The higher the SPF, the greater the protection.² The difference in protection between SPF 30, 40, and 50 is relatively small, and no sunscreen can block 100% of UVB rays. It is recommended to use a broad-spectrum sunscreen with an SPF of 30 or higher to ensure adequate protection against both UVA and UVB rays. Applying sunscreen correctly is crucial for its effectiveness. It should be generously applied to all exposed areas of the skin at least 15 minutes before sun exposure. Reapplication is necessary every two hours, or more frequently if sweating or swimming, to maintain its protective effect. In addition to sunscreen, it is

important to take other sun protection measures, such as seeking shade during peak sun hours, wearing protective clothing, and using sunglasses to shield the eyes from UV rays.³

In addition, the chromophore-based sunscreen is an innovative approach to sun protection that utilizes specific molecules known as chromophores to absorb and dissipate UV radiation.⁴ These chromophores are designed to selectively absorb UV light, providing effective protection against both UVA and UVB rays. Unlike traditional sunscreens that rely on physical or chemical filters to block or scatter UV rays, chromophore-based sunscreens work by absorbing the UV radiation and converting it into less harmful forms of energy, such as heat.^{5,6} This mechanism allows for efficient and targeted protection against the damaging effects of the sun. It used in these sunscreens are carefully selected to have high absorption capabilities within the UV spectrum.^{7–10} They are designed to absorb specific wavelengths of UV light, ensuring broad-spectrum protection. By absorbing UV radiation, chromophores prevent it from penetrating the skin and causing damage, such as sunburn, premature aging, and an increased risk of skin cancer. They have the potential for improved photostability, meaning they are less likely to degrade or lose their effectiveness when exposed to sunlight. This ensures that the sunscreen remains active for a longer duration, providing reliable protection throughout sun exposure. It is important to note that extensive research is conducted to ensure the safety and

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Review of current developments in rhodamine derivatives-based photoresponsive chemosensors for ion detection

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ABSTRACT

Rhodamine-based photoresponsive sensors have emerged as a focal point in the realm of chemical sensing, garnering substantial attention owing to their exceptional sensitivity, straightforward implementation, and real-time detection capabilities across diverse analytes. Within this class, a notable substituent stands out for its well-established reputation, characterized by its electron-donating prowess and customizable coordination cavity, resulting in a heightened sensitivity towards various metal ions. The comprehensive examination of these sensors in the review centers on key parameters such as the detection target, detection limit, detection solution system, and detection method. Notably, the inclusion of an array of metal ions in the discussion contributes to the versatility of these sensors. To enhance the readability and applicability of the review, a detailed exploration of the indirect sensing strategy is presented, showcasing its efficacy in achieving sensitive detection, especially for anions and other species. This strategic approach not only broadens the scope of application but also underscores the versatility of rhodamine-based sensors, making this review a valuable resource for researchers and practitioners in the field of chemical sensing.

1. Introduction

A sensor is a device that detects changes in the environment and produces a related output.[1–3] The output is a type of signal that may be translated by humans into readable information. The specific input could be light, heat, motion, or any other environmental phenomenon. Moreover, chemosensors are the molecules that detect molecules being interested and produce a detectable response.[4–6] It is called chromogenic and fluorogenic probes consist of two or three important parts including recognition moiety, signaling moiety, and suitable spacer linker. The signaling moiety acts as a signal transducer whose photophysical characteristics change upon reaction with the analyte and

converts the information into an optical signal. However, the recognition moiety is responsible for the selective reaction or binding event with the analyte depending on the ligand, metal, or anion type and solvent characteristic. The signal of a fluorescent sensor is measured in the changing of absorbance, fluorescence, or fluorescence lifetimes.[7–9] The changes are observable when the analytes affect the photophysical mechanism. Fluorescence resonance energy transfer (FRET), intermolecular charge transfer (ICT), photoinduced electron transfer (PET), intermolecular charge transfer (ICT), and planar intramolecular charge transfer (PICT) are a few examples of photophysical mechanisms that can be used to create photoresponsive chemosensors for metal or other analytes.[10].

Abbreviations: FRET, Fluorescence Resonance Energy Transfer; ICT, Intermolecular Charge Transfer; PET, Photoinduced Electron Transfer; PICT, Planar Intramolecular Charge Transfer; NM, Nuclear Magnetic Resonance; IR, Infrared; MS, Mass Spectroscopy; LOD, Limit of Detection; DFT, Density Functional Theory; CLSM, Confocal Laser Scanning Microscopy; SEM, Scanning Electron Microscopy; EDTA, Ethylenediaminetetraacetic Acid; GSH, Glutathione; AAS, Atomic Absorption Spectrometry; HOMO, Highest Occupied Molecular Orbital; LUMO, Least Unoccupied Molecular Orbital; BC, Bacterial Cellulose; DNA, Deoxyribonucleic Acid; EPR, Electron Paramagnetic Resonance; PL, Photoluminescence; SPE, Screen-Printed Electrode.

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Revisiting diosmin for their potential biological properties and applications

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ABSTRACT

Diosmin is a well-known naturally occurring flavonoid that is used to treat diseased veins and chronic blood vessel insufficiency. A comprehensive investigation conducted recently has revealed that diosmin has a wide range of medical speciality properties, including anti-oxidant, anti-diabetic, anti-cancer, anti-microorganism, liver protection, neuroprotection, vascular protection, and retinal protection properties. Its use in therapeutic settings is severely limited. As anticipated, a multitude of possible approaches have been developed to enhance its pharmacokinetic properties and bioavailability. It has been investigated as a significant part of the micronized purified flavonoid fraction (MPFF), which has been utilized in centers toward work on miniature flow. In any case, no particular medication focuses for diosmin are accounted for albeit some potential elements have been associated with screening. More examinations on the basic systems of diosmin in intervening cell processes with high explicitness are as yet required. This compound demonstrates anti-lipid peroxidation, anti-inflammatory, antioxidant, and anti-mutagenic properties, making it a valuable component in addressing oxidative stress and suboptimal inflammation. As one of the flavonoids employed in medicinal contexts, its pharmacological intricacies remain a complex area of exploration. While diosmin has shown promise in multiple applications, there is still a considerable distance to cover in achieving a comprehensive understanding of its pharmacology for practical clinical use. In this review article, we examined diosmin measures and their applications.

1. Introduction

Nowadays, diosmin (1, DM) is a characteristic flavonoid substance. It happens normally as a glycoside, which means it has a sugar particle appended to its three-ringed flavonoid structure (Fig. 1) (Garcia and Castillo, 2008). It was first segregated in 1925 from *Scrophularia nodosa*, and first presented as a remedial specialist. Additionally, it is viewed as a vascular-securing specialist used to treat venous deficiency,

hemorrhoids, and lymphedema. It additionally displays mitigating, free-extremist rummaging and is hostile to mutagenic properties. DM varies atomically from hesperidin by the presence of a twofold connection between two carbon particles in diosmin's focal carbon ring. It tends to be made by removing hesperidin from citrus skins (Ratty and Das, 1988). It is utilized as a phlebotonic and vascular-ensuring specialist and as of late been researched for other restorative purposes like premenstrual disorder, colitis, and diabetes. The action of cancer

Abbreviations: DM, Diosmin; TNF- α , Tumor Necrosis Factor-alpha; TBI, Traumatic Brain Injury; COX-II, Cyclooxygenase-2; MDA, Malondialdehyde; GSH, Reduced Glutathione; MPO, Myeloperoxidase; CDs, Cyclodextrins; TPU, Therapeutic Pulsed Ultrasound; CK, Creatine Kinase; TBARS, Thiobarbituric acid reactive substances; EROD, Ethoxyresorufin O-deethylase; NO, Nitric oxide; 4-HNE, 4-Hydroxynonenal; FRAP, Ferric Reducing Antioxidant Power; ROS, Reactive Oxygen Species; LVH, Left Ventricular Hypertrophy; DPPH, 1, 1 diphenyl-2-picryl-hydrazyl; PEPCK, Phosphoenolpyruvate Carboxykinase; DSNM, Diosmin Monohydrate; DSNM, Anhydrous Diosmin; ELISA, Enzyme-linked Immunosorbent Assay; NMR, Nuclear Magnetic Resonance; IR, Infrared Spectroscopy; CCI, Chronic Constriction Injury; HPLC, High Performance Liquid Chromatography; CBZ, Carbamazepine; DAI, Disease Activity Index; MTT, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2H-tetrazolium bromide; DNA, Deoxyribonucleic acid; ATP, Adenosine Triphosphatases; BER, β -endorphin-like immunoreactivity; mRNA, Messenger Ribonucleic Acid; CASTEP, Cambridge Serial Total Energy Package; DFT, Density Functional Theory; CEP350, Centrosomal Protein 350.

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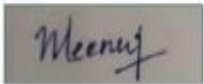
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