Formulation and Evaluation of Sunscreen from Moringa Oleifera Leaf Extract

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Abstract:

Moringa oleifera, known as the "**MIRACLE TREE**," is a highly adaptable plant with diverse applications in nutrition, medicine, cosmetics, agriculture, and industry. Rich in bioactive compounds like flavonoids, phenolics, saponins, and tannins, it exhibits antimicrobial, anti-inflammatory, anticancer, and photoprotective properties. Its leaf extracts and seed oil are gaining interest for natural skincare, particularly in sunscreen formulations.

Due to concerns over synthetic sunscreen toxicity and environmental harm, Moringa offers a plant-based alternative. Extraction using 100% ethanol via decoction and maceration effectively preserves UV-absorbing phytochemicals. Formulated creams demonstrated stable organoleptic properties—smooth texture, mild aroma, white color, and pH 6.1–6.4. Spreadability, viscosity, and stickiness were optimal for topical application.

UV protection was confirmed via spectrophotometric SPF analysis (Mansur equation), and skin safety tests showed no irritation. These findings support the use of Moringa oleifera as a safe, natural, and sustainable ingredient for effective sunscreen products in cosmetic and dermatological applications.

Keywords: *Moringa oleifera*, Natural sunscreen, Photoprotection, Phytochemicals, Flavonoids, Phenolics, SPF, Antioxidant, Topical formulation etc.

1. Introduction

Moringa oleifera, commonly known as the "**MIRACLE TREE**," is a drought-resistant species native to South Asia, particularly India, Pakistan, Afghanistan, and Bangladesh. It thrives in tropical and subtropical climates and is the most widely cultivated species among the 13 in the Moringaceae family due to its rapid growth, ability to grow in poor soils, and tolerance to drought. These qualities make it an important resource for food security in vulnerable regions [23]

Taxonomy and Morphology

- **Taxonomical classification:** Kingdom Plantae → Family Moringaceae → Genus Moringa → Species oleifera.
- **Morphology:** It is a small to medium-sized deciduous tree characterized by trifoliate leaves and an umbrella-shaped canopy. It can produce up to 25,000 seeds annually. [23]

Geographic Distribution

Originally native to India and Arabia, *Moringa oleifera* is now cultivated worldwide, including in Africa, Latin America, the Caribbean, Southeast Asia, and the Pacific Islands. The tree prefers warm climates with temperatures ranging from 25 to 35°C, grows best in loamy soils, and does not tolerate waterlogged conditions. [23]

All parts of *Moringa oleifera* — including leaves, bark, roots, flowers, and seeds — possess therapeutic properties and have been traditionally used to treat various ailments such as ulcers, toothaches, hypertension, parasitic infections, paralysis, and spleen disorders. [5,23] Traditional medicine systems like Ayurveda and Unani have long employed the plant for treating skin disorders, bronchitis, fatigue, and other health conditions. [10]

Nutritionally, the leaves are particularly rich in essential nutrients such as beta-carotene, calcium, potassium, and other minerals. When dried, these leaves contain up to 70% oleic acid, making them valuable ingredients in health beverages (e.g., Zija) and moisturizing cosmetics. [23] They also contain significant amounts of polyphenols and bioactive compounds such as quercetin, kaempferol, and myricetin, which contribute to strong antioxidant effects, especially by protecting against UV-induced oxidative damage. [4] Furthermore, the leaves provide antioxidants including vitamin C, carotenoids, phenolics, and flavonoids, which support antimicrobial and anti-inflammatory activities. [8]

Pharmacologically, *Moringa oleifera* exhibits a wide spectrum of beneficial effects, including antioxidant, antimicrobial, anti-inflammatory, hypoglycemic, and anticancer properties. These diverse activities have earned the plant the nickname “Tree of Life”. [5]

Despite its wide cultivation in India, *Moringa oleifera* remains underutilized in some areas, such as Indonesia, where it is primarily used as food or livestock feed. [6] The seed oil, rich in oleic acid, holds considerable but still untapped potential for use in sunscreen and cosmetic products. [6] Its flavonoid content includes UV-absorbing compounds, highlighting its photoprotective qualities [7] Research supports the efficacy of *Moringa* extracts in cosmetic formulations like peel-off masks, vanishing creams, anti-aging products, and body scrubs, typically used at 3–5% concentrations [7] Although promising, further research is needed to conclusively establish its sun protection factor (SPF) effectiveness [9]

Ecologically, *Moringa oleifera* (known as Murungai in Tamil) is a fast-growing, drought-tolerant tree native to semi-arid, sandy, and coastal soils of South Asia. It is now widely cultivated across tropical and subtropical regions worldwide due to its adaptability and ecological importance [13,23]

Traditional and Ethnomedicinal Uses

Historically, *Moringa oleifera* has been widely used in Ayurveda and Unani medicine to treat a variety of ailments, including ulcers, hypertension, parasitic infections, bronchitis, skin diseases, reproductive health issues, headaches, spleen and digestive disorders, arthritis, tumors, toothaches, and even for water purification [5,10,23]

It is traditionally employed to manage bronchitis, arthritis, liver and kidney diseases, colitis, dysentery, fever, wounds, and earaches. Ancient Ayurvedic texts such as the *Charaka Samhita* and *Kashyapa Samhita* reference *Moringa* for treating worm infestations, headaches, edema, spleen disorders, and reproductive health problems [23]

Various parts of the plant have been used ethnomedicinally to address inflammatory diseases, digestive issues, tumors, and dental pain, as well as for purifying water [23] Overall, *Moringa* contains over 90 bioactive compounds, including phenolic acids (gallic, caffeic, ferulic acids), flavonoids (quercetin, kaempferol, catechin), alkaloids (moringin, moringinine), glucosinolates (glucomoringin), sterols (β-sitosterol), and fatty acids (oleic, linolenic, palmitic acids.[23]

Nutritional Profile

Moringa oleifera is nutritionally rich and widely used for both dietary and industrial purposes. Its **leaves** are particularly nutrient-dense, containing beta-carotene, calcium, potassium, iron, vitamin C, and essential amino acids [23] These nutrients make it effective in combating malnutrition by offering digestible protein, bone-strengthening calcium, iron for anemia prevention, immune-boosting vitamin C, and vision-supporting carotenoids [13]

Dried leaves, which contain up to 70% oleic acid, are utilized in cosmetic products like moisturizers and health beverages such as Zija [23] The leaves also contain potent antioxidants—including quercetin, kaempferol, and myricetin—that protect against oxidative stress and UV damage [4]

Various plant parts provide therapeutic benefits:

- **Bark** is used for ulcers, toothaches, and hypertension.
- **Roots** treat helminthiasis, paralysis, and dental pain.
- **Flowers** address spleen disorders, ulcers, and function as aphrodisiacs.
- **Seeds** are applied in the treatment of tumors and arthritis and serve in water purification [23]

Pharmacological Activities

Moringa oleifera exhibits a wide spectrum of pharmacological activities, supported by the presence of various bioactive compounds:

Bioactive compounds	**Pharmacological activities**
Antimicrobial & Antifungal	Extracts inhibit pathogens such as *E. coli*, *S. aureus*, *Aspergillus*, and *Candida*, primarily through compounds like N-benzylethyl thioformate, isothiocyanates from seeds, and flavonoids, alkaloids, and steroids from the fruit.
Anti-Inflammatory	Moringin, tannins, phenols, and thiocyanates suppress pro-inflammatory markers like TNF-α and NF-κB, providing relief in conditions such as dermatitis and systemic inflammation.

Antioxidant & Anti-Oxidative Stress	Compounds such as kaempferol, myricetin, and isoquercetin help reduce reactive oxygen species (ROS) and enhance glutathione levels, offering protection against oxidative damage including methotrexate-induced stress and liver toxicity.
Anticancer	Isothiocyanates and niazimincin inhibit various cancer cell lines (e.g., MCF7 breast cancer), reduce ROS levels, and hold promise for chemoprevention.
Fertility and Anti-Fertility	While *Moringa* extracts may support fertility, aqueous extracts exhibit abortifacient effects at certain doses due to uterine contraction.
Hepatoprotective	The plant shows liver-protective effects against damage from acetaminophen and carbon tetrachloride, mediated by compounds like quercetin, kaempferol, and benzyl glucosinolates.
Cardiovascular	Extracts reduce cholesterol, protect against myocardial infarction, and enhance antioxidant enzyme activity, with key compounds including niazimin A/B/C and β-sitosterol.
Anti-Ulcer	Flavonoids and bisphenols in *Moringa* enhance gastric mucosal protection and capillary resistance, alleviating ulceration.
Analgesic & Antipyretic	Leaf extracts exhibit pain-relieving and fever-reducing effects comparable to standard drugs like aspirin and paracetamol in animal models.
Neuropharmacological & Anticonvulsant	*Moringa* restores monoamine levels, demonstrates efficacy in Alzheimer's and epilepsy models, promotes sleep, and reduces anxiety through CNS modulation.
Neuropathic Pain	Extracts significantly alleviate diabetic neuropathic pain by reducing oxidative stress and improving glycemic control.
Wound Healing	Promotes wound closure and tissue regeneration, especially in diabetic and burn wound models, through stimulation of cell proliferation.
Immunomodulatory	Bioactive constituents enhance immune responses, showing potential benefits for diabetes, cancer, and hypertension.
Hematological	Clinical and preclinical studies show improved hemoglobin levels and platelet counts with *Moringa* administration.

Anti-Obesity	Regulates adipogenesis-related genes and hormones such as resistin and leptin, leading to improved lipid profiles and BMI reduction.
Anti-Allergic	Extracts suppress histamine release and prevent anaphylactic reactions by stabilizing mast cells.
Antidiabetic	Improves glucose tolerance and insulin secretion due to the presence of insulin-like proteins and compounds like quercetin, chlorogenic acid, and glucomoringin.
Diuretic	Demonstrates a reduction in urinary oxalate and calcium levels, aiding in the prevention of kidney stones.
ACE Inhibition (Antihypertensive)	Niazimins inhibit angiotensin-converting enzyme activity, functioning similarly to drugs like captopril.
Anti-Venom	Shows effectiveness in neutralizing cobra venom (*Naja nigricollis*), reducing hemolysis and anemia-related symptoms.
Cytotoxicity	Methanolic extracts exhibit cytotoxic effects against myeloma cell lines and offer protection against chemotherapy-induced testicular toxicity.

Table no.1: Therapeutic Activities of Key Bioactive Compounds in *Moringa oleifera.* [23]

Photoprotection and Antioxidant Mechanisms

Moringa oleifera leaves are rich in phenolic compounds such as quercetin, β-carotene, and vitamins A, C, and D, which enable them to absorb both UVA and UVB radiation while neutralizing free radicals [18] A 50% ethanol extract of the leaves demonstrates optimal antioxidant activity, supporting its application in herbal sunscreens and skincare formulations [20] The plant's exceptional nutrient profile helps maintain collagen and elastin integrity, thereby preventing skin dryness, wrinkles, and hyperpigmentation [20]

Applications Beyond Skincare

Moringa exhibits broad utility across sectors such as agriculture, aquaculture, animal husbandry, and industry. It improves soil fertility as green manure and through seed cake application, while also serving as a nutritious forage for livestock, thus enhancing their productivity [13,23] Additionally, the leaves contribute to biogas production and honey yield, and the powdered seeds act as a natural water purifier [11]

Industrial applications include the use of *Moringa* for producing blue dye, pulp, rope, and tannin. Its seed oil is valued as a lubricant for fine machinery and is commonly used in perfumes and hair care products [13]

Cosmetic and Photoprotective Uses

Moringa oleifera is increasingly utilized in the cosmetic industry for its antioxidant, moisturizing, photoprotective, and anti-aging properties. It is formulated into various skincare products, including sunscreens, anti-aging serums, peel-off masks, creams, and lotions [6,7,14,16,18]

Moringa Seed Oil (Ben Oil)

Ben oil, extracted from *Moringa* seeds, is rich in oleic acid and UV-absorbing flavonoids, offering mild sun protection, hydration, and antimicrobial benefits [6,7,14,16,18,19] It is typically used at 3–5% concentrations in cosmetic formulations, with photoprotective efficacy enhanced when combined with natural agents such as brown seaweed [14]

Moringa Leaf Extracts

Moringa leaves are abundant in flavonoids, isothiocyanates, tannins, vitamin B2, β-carotene, vitamin C, and vitamin A—compounds known for their potent antioxidant effects [15,17] These constituents counteract free radicals generated by UV radiation and environmental pollutants, thereby mitigating skin aging, wrinkles, and pigmentation [15,16,17]

Synergistic Formulations

When combined with other natural ingredients like pineapple (rich in vitamin C and citric acid) or brown seaweed, *Moringa* leaf extracts exhibit enhanced antioxidant and photoprotective effects [14,15,16] These combinations are particularly effective in gel-lotion formats, offering:

- Fast absorption
- High hydration
- Antioxidant activity
- Non-greasy texture [15,16]

Moisturizing and Skin Barrier Support

As the skin is constantly exposed to UV rays and pollutants that induce oxidative stress and conditions like xerosis cutis (dry skin), *Moringa*-based moisturizers are beneficial for enhancing water retention in the stratum corneum. They are especially valued for their:

- Safety
- Affordability
- Minimal side effects [17]

Photoprotective and Anti-Aging Effects

Ethanolic extracts from *Moringa* leaves effectively absorb UVA and UVB radiation, making them suitable for incorporation into herbal sunscreens [18] These formulations should be evaluated for key parameters such as pH and viscosity to ensure stability and efficacy [18] Additionally, *Moringa* aids in maintaining collagen and elastin levels, preventing wrinkles, pigmentation, and skin elasticity loss—affirming its role as a natural anti-aging agent [20]

Emulsion and Surfactant-Based Products

In emulsion-based formulations, both *Moringa* leaf and seed extracts improve product stability and skin absorption due to their compatibility with surfactants [15] Recent advancements in extraction techniques, such as subcritical water extraction, have improved the yield and stability of phenolics and flavonoids [10,24] These methods are essential for maximizing the therapeutic and cosmetic efficacy of *Moringa*, particularly in combating oxidative stress, degenerative diseases, and skin aging [11,25]

Nutritional Value and Skincare Integration

With higher concentrations of vitamins A and C, calcium, potassium, and iron than many staple foods, *Moringa oleifera* is increasingly integrated into both nutritional and skincare products [13,17] Its leaf extracts and Ben oil demonstrate excellent antioxidant, moisturizing, and photoprotective properties, reinforcing their use in sunscreens and anti-aging formulas [14,16,18] Co-formulations with ingredients like brown seaweed further enhance the efficacy and versatility of these products [14]

As consumer interest in natural and multifunctional ingredients continues to grow, *Moringa oleifera* stands out as a powerful botanical, particularly valued for its photoprotective, antioxidant, and anti-aging benefits [15,19,20]

Extraction and Product Development

Recent research has focused on the development and optimization of advanced extraction techniques to enhance the yield and stability of *Moringa oleifera*'s bioactive compounds, especially phenolics and flavonoids [10,11,23,24,25]

Subcritical water extraction, in particular, has shown high efficiency in extracting stable phenolic and flavonoid compounds. This method is increasingly employed in the formulation of high-quality pharmaceutical and cosmetic products, such as:

- **Capsules**
- **Gels**
- **Emulsions**
- **Creams** [10,11,23,24,25]

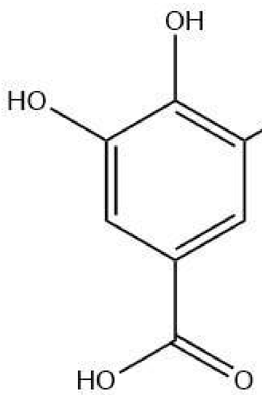
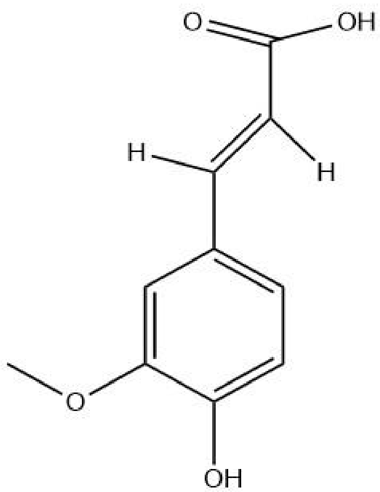
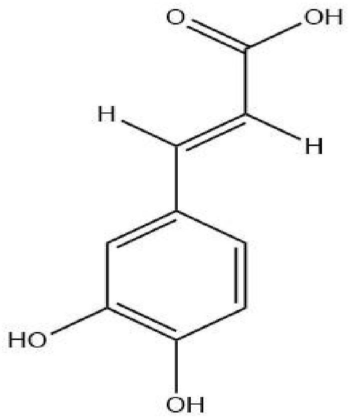
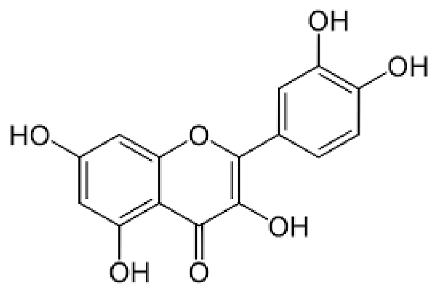
Product development based on *Moringa oleifera* requires careful assessment of parameters such as pH, viscosity, formulation stability, and skin compatibility to ensure safety, effectiveness, and optimal shelf life [18,19]

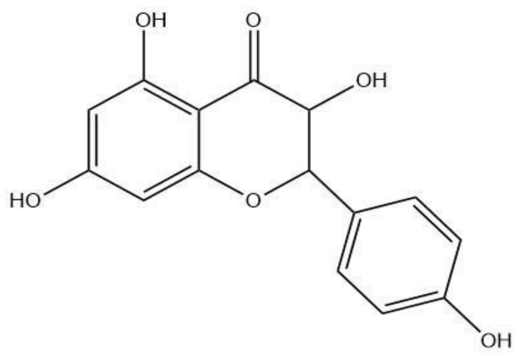
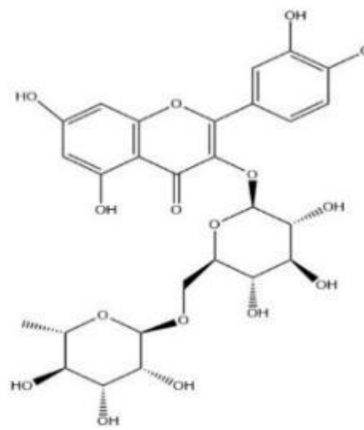
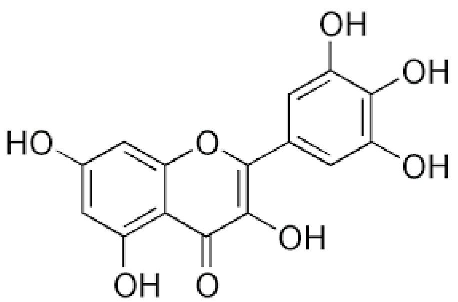
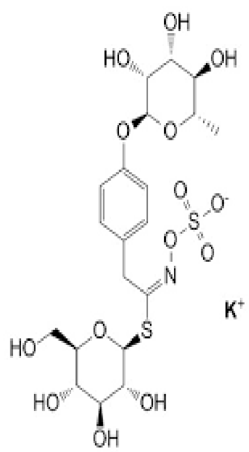
Phytochemical Composition

Moringa oleifera contains a chemically diverse profile, with more than 90 bioactive compounds identified across different plant parts between 2010 and 2022 [23] These compounds are primarily responsible for its wide range of therapeutic properties.

Key Phytochemical Categories: [23]

- **Phenolic acids:** cinnamic, gallic, ferulic, caffeic, sinapic, syringic, p-coumaric, vanillin
- **Flavonoids:** quercetin, kaempferol, catechin, myricetin, rutin
- **Carotenoids:** especially lutein (found in leaves)
- **Alkaloids:** moringin, moringinine, aurnatiamide acetate, marumoside A & B
- **Glucosinolates:** notably glucomoringin, a signature compound of *M. oleifera*
- **Sterols:** β-sitosterol, β-sitosterol-3-O-β-D-galactopyranoside
- **Terpenes:** phytol, farnesylacetone, linalool oxide
- **Tannins and saponins:** primarily in seed oil
- **Fatty acids:** oleic, linolenic, palmitic, stearic, behenic, arachidic acid
- **Glycosides:** niazirin, niazirinin
- **Polysaccharides:** including D-galactose, L-arabinose, D-xylose, and glucuronic acid (found in gum exudates)

Phytochemical categories	Compound	Structure	Therapeutic effect
Phenolic acids	Gallic acid (1.034mg/g)		Anti-inflammatory, anti- neoplastic ,anti-oxidant
Phenolic acids	Ferulic acid (0.078 to 1.28mg/g)		Promising results as anti-cancer, antioxidant, antithrombotic, anti-arrhythmic, and anti-inflammatory
Phenolic acids	Caffeic acid (0.409 mg/		Boosts athletic performance, reduces fatigue, helps weight loss, protects against HIV, cancer.
Flavonoids	Quercetin (2030.9 u mol/100 g)		Exerts an excellent effect as anti-diabetic agent. Quercetin has antioxidant and anti-inflammatory effects.

Flavonoids	Kaempferol (197.6 ug/g		Oxidative damage protective activity.
Flavonoids	Rutin		It having strong antioxidant properties. Found to have maximum affinity and interaction towards BRAC-1gene
Flavonoids	Myricetin		Potential prevention of diabeties mellitus and other diabetic complications.
Glucosinolates	Glucomoringin		Anti-inflammatory, pain relieving, anti-oxidant, antihypertensive.

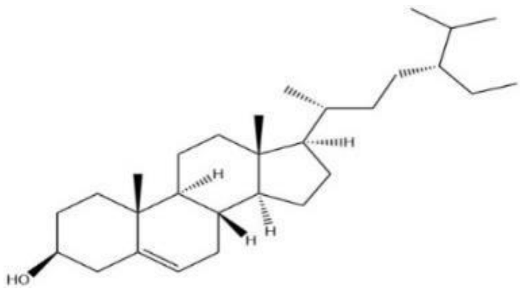
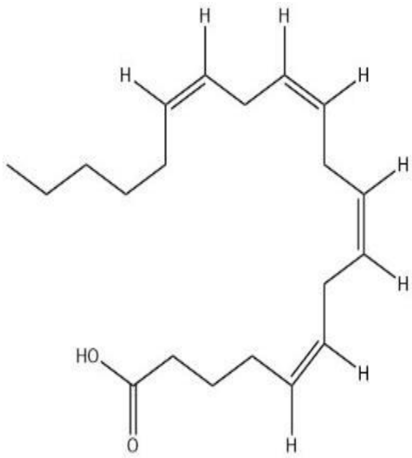
Sterols	β-sitosterol		Anti-inflammatory
Fatty acids	Arachidic acid		Increased breast milk production

Table no.2: Major Bioactive Compounds in *Moringa oleifera*: Phytochemistry and Pharmacological Properties. [23]

These constituents contribute significantly to the plant's antioxidant, anti-inflammatory, antimicrobial, anticancer, and metabolic regulatory activities [23]

Veterinary, Agricultural, and Industrial Applications

Moringa oleifera exhibits diverse applications across veterinary, agricultural, and industrial sectors.

- In **aquaculture**, Moringa is used to reduce toxicity and oxidative stress, thereby improving aquatic animal health.
- It functions as a **natural biopesticide** and **plant growth enhancer**, with documented benefits in crops such as okra, wheat, and oilseed rape.
- In **livestock farming**, Moringa supplementation improves animal health and productivity.
- **Seed cake**, a byproduct of oil extraction, enriches **soil fertility** and serves as a **nutritious animal forage**.
- **Powdered seeds** act as an effective **natural coagulant** for **water purification**, significantly reducing microbial contamination and turbidity. [23]

- In **industrial applications**, Moringa is used in the production of **blue dye, rope, tannins, pulp**, and **fine machinery lubricants** derived from Ben oil [13]

Additional uses include its incorporation in **green manure, alley cropping systems**, **biogas production**, and **natural cleansers** [13,23]

Clinical Trials and Safety

Moringa has been the subject of at least **25 clinical trials**, with **15 completed**, exploring its efficacy in treating conditions such as **malnutrition, HIV, asthma,** and **chronic kidney disease** [1] One notable trial involved the use of **3 g of seed kernels twice daily** in asthma patients, showing marked improvement in respiratory symptoms and blood parameters [23]

Toxicity and Safety Evaluation [23]

- **Animal studies** indicate that Moringa is **safe at oral doses up to 2000 mg/kg**, using extracts from leaves, bark, and seeds.
- **Toxic effects** have been observed at **doses between 4000–5000 mg/kg**, particularly with seed extracts.
- For **human consumption**, intake should **not exceed 70 g/day** to avoid adverse outcomes, including **potential abortifacient effects**.

Phytopharmaceutical Formulations [23]

Moringa *oleifera* extracts demonstrate significant potential in pharmaceutical development due to their proven **safety**, **patient compliance**, and **therapeutic efficacy** at commonly used doses. Various formulations such as **capsules**, **creams**, **gels**, and **emulsions** have been studied, focusing on preserving the **stability** and **bioactivity** of the plant's compounds. These phytoformulations are intended to improve the **bioavailability** of active ingredients and to treat a wide spectrum of conditions.

Miscellaneous Uses [23]

Cosmetic and Nutraceutical Development

- Moringa formulations use **astragalin** and **isothiocyanates** as standard marker compounds for **product standardization** and **quality control** in natural health products.

Aquaculture

- **Moringa leaf extract** mitigates **oxidative stress** and **toxicity** from neem oil exposure in fish farming systems.

Agriculture

- **Okra crops** treated with Moringa aqueous extract show reduced **pest damage**.
- **Wheat yield** improved using **5–25% Moringa leaf/root extract** as a biopesticide and plant growth promoter.
- Enhances **crop resilience** to both abiotic and biotic stress due to its rich content of **phytohormones** and **micronutrients**.
- **Methanolic extract** sprays (rich in **potassium**, **calcium**, **zeatin**, **carotenoids**) increase **oilseed rape yield** and improve **drought resistance**.

Synergistic Therapies

- **Co-administration** of Moringa extract with **praziquantel** improved its **cytocidal activity** against *Taenia crassiceps* in rats.

Nutritional and Antioxidant Potential

- Moringa is rich in **proteins**, **lipids**, and **sulfur-containing amino acids**, with **low toxicity**.
- **Palmitic acid**, isolated from the leaves, has strong **antimicrobial** and **antifungal** activity.
- **Nanoparticles** formulated with Moringa extract enhanced **HeLa cell death**, showing promise in **targeted drug delivery** systems for cancer.

Current Status [23]

Extensive global research conducted between **2019 and 2022**—notably in **India**, **Nigeria**, **Brazil**, and **China**—strongly reaffirms the **multidimensional utility** of *Moringa oleifera* across various sectors:

Key Applications

- **Pharmacology**: Used in **wound healing**, **anticancer**, and **anti-aging** formulations.
- **Biomedicine**: Incorporated into **antioxidant-rich therapeutic products**.
- **Agriculture**: Acts as a **natural fertilizer** and **biostimulant** to enhance crop health.
- **Livestock and Aquaculture**: Improves **productivity** and **disease resistance** in animals and fish.

Despite its broad potential, **toxicity concerns** persist:

- **High intake** may lead to **abortifacient** or **toxic effects**, emphasizing the importance of **dose regulation**.
- While *Moringa oleifera* is widely recognized for its benefits, **greater awareness**, **utilization**, and **robust regulatory frameworks** are still needed to ensure **safe and standardized use**.

This article explores the phytochemical properties, extraction methods, and cosmetic applications of *M. oleifera*, with a focus on its potential as a natural alternative in sunscreen and skincare product development.

SUNSCREEN

Sunscreen, also referred to as sunblock or sun cream, is a topical product available in various forms such as creams, lotions, and sprays, designed to protect the skin from the harmful effects of ultraviolet (UV) radiation. It functions by either absorbing or reflecting UV rays, thereby reducing the risk of sunburn, premature aging, and skin cancer. Prolonged exposure to sunlight is a significant contributor to photoaging, resulting in wrinkles, moles, sagging skin, and pigmentation. Sunscreen plays a critical role in mitigating these effects by acting as a protective barrier against UV radiation [1]

Sunlight reaching the Earth's surface consists primarily of UVA and UVB rays. UVC radiation (200–280 nm) is mostly filtered out by the stratospheric ozone layer and has minimal impact. **UVA rays** (320–400 nm) account for 95% of the UV radiation that penetrates the Earth’s atmosphere, deeply affecting the skin and contributing to tanning and DNA damage. In contrast, **UVB rays** (290–320 nm) are largely absorbed by the ozone layer and are the main cause of sunburn, damaging the skin’s upper layers. UVB intensity varies depending on the season, time of day, and geographic location [2]

Historically, ancient civilizations such as the Egyptians and Greeks used natural substances like jasmine, rice, and olive oil for sun protection. Zinc oxide—a mineral known to protect against both UVA and UVB rays—has been used for centuries and is now incorporated into modern nanoparticle-based sunscreens. The development of commercial sunscreens began in the early 20th century, with notable milestones including **Ambre Solaire** in 1935 and **Gletscher Crème** in 1988. Today, sunscreens are regulated as cosmetic products under the Drugs and Cosmetics Act of 1940 in many countries, which ensures product safety and efficacy [2]

Modern sunscreens operate through two primary mechanisms, depending on their active ingredients:

1. **Chemical (Organic) Sunscreens**: These use carbon-based compounds such as avobenzone, oxybenzone, octinoxate, and octisalate, which absorb UV radiation. When these compounds absorb UV rays, their molecular structure temporarily changes, and the absorbed energy is released as heat. These sunscreens act like “sponges” that soak up UV radiation [3]
2. **Mineral (Physical) Sunscreens**: These contain inorganic compounds like zinc oxide and titanium dioxide, which form a physical barrier on the skin. This barrier reflects and scatters UV radiation, functioning like a “mirror” to protect the skin from damage [2]

Mechanism of action of sunscreen

Sunscreens work by preventing and reducing the harmful effects of UV radiation after exposure to the sun. These have been shown to increase the skin's tolerance to UV exposure. They primarily work through two mechanisms as detailed below.

(a) UV energy is absorbed through the skin and gets converted to heat energy, which reduces the harmful effects and the extent to which it can penetrate the skin. Organic sunscreens work primarily through this mechanism.

(b) Scattering and reflection of UV energy take place from the skin surface. Mineral-based inorganic sunscreens work mostly through this mechanism. They provide a coating that blocks sun rays from penetrating through the skin. Chemical sunscreens often contain several organic compounds to protect against a range of UV rays. Inorganic particulates may scatter the microparticles in the upper layers of skin, thereby increasing the optical pathway of photons, leading to the absorption of more photons and enhancing the Sun Protection Factor (SPF), which results in the high efficiency of the compound.

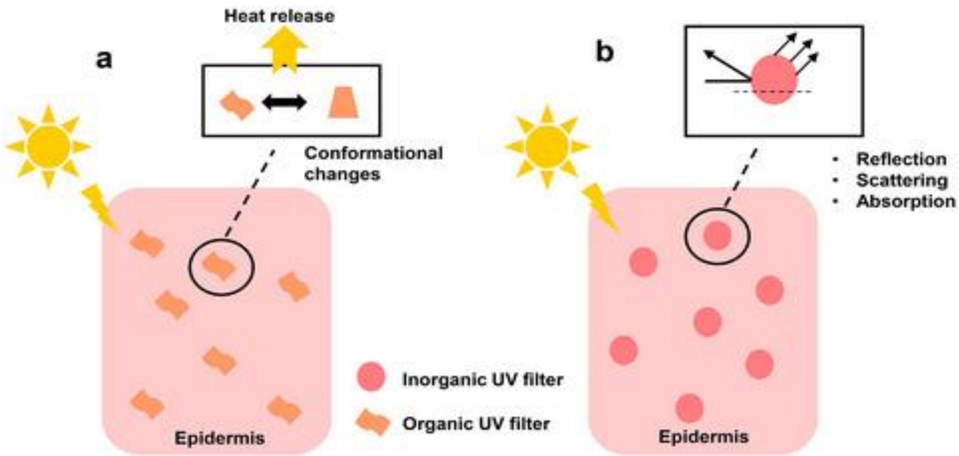


Figure no.1: Photoprotective Mechanisms of Organic and Inorganic Sunscreens.

In the United States, sunscreens are considered over-the-counter (OTC) drugs and are regulated by the **Food and Drug Administration (FDA)** under the sunscreen monograph (21 CFR Part 352). This regulation outlines approved active ingredients, maximum concentrations, labeling requirements (including SPF, broad-spectrum protection, and water resistance), and mandatory testing protocols. The FDA continues to update these standards based on evolving scientific knowledge, including the evaluation of GRASE (Generally Recognized as Safe and Effective) status for ingredients and newer formulations such as sprays and powders. Manufacturers must comply with these regulations, implement Good Manufacturing Practices (GMP), and report adverse events. However, pre-market approval is not required if the product complies with the monograph [2]

Functionally, sunscreens are categorized into three types:

- **Preventive**: To protect against UV damage and sunburn.
- **Simulatory**: To encourage tanning while offering partial protection.
- **Therapeutic**: To assist in the healing of damaged or sensitive skin.

An ideal sunscreen is stable, non-toxic, long-lasting, and especially effective against UVB radiation. Common formulations include creams, lotions, and gels that combine moisturizing agents such as glycerin, aloe vera, and cocoa butter, with SPF values typically ranging from 8 to 10 [1]

In recent years, increasing awareness of the adverse effects of synthetic sunscreen filters—such as photodegradation, toxicity, and ecological harm, particularly to marine ecosystems—has spurred interest in **natural alternatives** [4] Plant-derived polyphenols like green tea catechins, resveratrol, and extracts from pomegranate, grape seeds, and coffeeberry exhibit antioxidant activity and UV absorption capabilities, making them promising eco-friendly photoprotective agents [4,5]

Among these, **Moringa oleifera** stands out as a strong candidate for sunscreen formulations. It is rich in bioactive compounds, including flavonoids, phenolic acids, vitamin C, vitamin E, and β-carotene. These compounds exhibit strong antioxidant and UV-absorbing properties, helping to neutralize free radicals caused by UV exposure and prevent photoaging, oxidative stress, and skin cancers [11,12,17,18] Moringa's utility is particularly relevant in tropical regions such as Indonesia, where high solar radiation increases the need for effective sun protection [14]

Studies have shown Moringa's effectiveness in various cosmetic applications—such as lotions, gels, and creams—especially when combined with other natural ingredients like **Turbinaria conoides** and pineapple, which offer additional antioxidant and photoprotective benefits [15,16] Both Moringa leaf extract and seed oil support collagen preservation, reduce oxidative stress, and can be incorporated into oil-in-water (O/W) formulations, which are popular for their non-greasy texture and ease of application [12,19]

Furthermore, research supports that ethanol and ultrasonic extraction techniques produce highly potent Moringa extracts with strong antioxidant activities, making them excellent candidates for daily-use sunscreen formulations [11,18]

Need for the Study

Sunscreen is essential for protecting the skin against the damaging effects of ultraviolet (UV) radiation, which contributes to sunburn, premature aging, hyperpigmentation, and increased risk of skin cancer. As consumers increasingly seek natural, multifunctional, and eco-friendly skincare solutions, there is a growing demand for plant-based alternatives in photoprotective products.

Moringa oleifera has emerged as a promising candidate in this context, due to its rich profile of antioxidants, UV-absorbing compounds, vitamins, and bioactive phytochemicals. These properties suggest strong potential for use in sunscreen and skincare applications. However, despite substantial interest and individual studies highlighting its benefits, the integration of *M. oleifera* into effective, standardized sunscreen formulations remains underdeveloped.

Current research often focuses narrowly on isolated aspects—such as antioxidant capacity, extraction methods, or in vitro efficacy—without providing a comprehensive framework that unites phytochemistry, formulation science, and dermatological outcomes. Moreover, inconsistencies in extraction techniques and a lack of standardized protocols hinder reliable product development and broader commercialization.

Objectives

1. Phytochemical Characterization:
   Identify and profile key bioactive compounds in *Moringa oleifera* that contribute to skin protection, with a focus on antioxidant activity and UV-absorbing potential.
2. Extraction Optimization:
   Evaluate and compare various extraction techniques to determine the most effective methods for maximizing yield, stability, and bioavailability of relevant phytochemicals.
3. Mechanisms of Photoprotection:
   Review the photoprotective mechanisms of *Moringa* compounds, including their roles in SPF enhancement, reactive oxygen species (ROS) scavenging, and cellular protection against UV-induced damage.
4. Formulation Assessment:
   Investigate the incorporation of *Moringa* extracts into topical skincare and sunscreen formulations, with attention to stability, efficacy, skin compatibility, and delivery system integration.
5. Research Gap Analysis and Recommendations:
   Identify current limitations in scientific and industrial applications of *Moringa oleifera* for photoprotection, and propose strategic directions for future research and product development.

REVIWE LITERATURE:

1. **Ashutosh Pareek 1,* , Malvika Pant 1, Madan Mohan Gupta 2 , Pushpa Kashania 1, Yashumati Ratan 1,Vivek Jain 3, Aaushi Pareek 1 and Anil A. Chuturgoon 4,* et. all conducted review study on** comprehensive analysis of *Moringa oleifera*, highlighting its traditional medicinal uses, pharmacological properties, phytochemistry, and clinical potential. Known as the "miracle tree," it has been used to treat inflammation, liver disorders, heart disease, and cancer. Over 100 bioactive compounds, including alkaloids, flavonoids, and novel isolates like niazimin A&B, contribute to its therapeutic effects. The review emphasizes its antioxidant, hepatoprotective, and anticancer properties, while also discussing its phytopharmaceutical formulations. Although widely used in traditional medicine, many of its applications remain scientifically unexplored, calling for further research to validate and understand its mechanisms and synergistic effects.

2. **Thi Phuong Anh Tran1, *, Thi Thao Vy Tran1, Thi Lan Pham2, and Thi Khanh Vinh Phan3 et all conducted experimental study on** the potential use of polyphenol-enriched *Moringa oleifera* leaf extract as an active ingredient in sunscreen formulations. The extract was characterized for total polyphenol content and antioxidant activity. Creams incorporating the extract were formulated and assessed for UVB protection, SPF values, stability, and microbial quality. Results indicated that the extract, particularly at 2% combined with 2% oxybenzone, provided effective UV protection and moderate antioxidant activity. This highlights *Moringa oleifera*'s potential for cosmetic applications, especially in natural sun protection products.

3. **Anna Baldisserotto 1 ID , Piergiacomo Buso 1, Matteo Radice 2, Valeria Dissette 1,Ilaria Lampronti 1 ID , Roberto Gambari 1, Stefano Manfredini 1,3,* ID and Silvia Vertuani 1,3 et. all conducted experimental study on** the evaluated *Moringa oleifera* leaf extracts as multifunctional ingredients in natural sunscreen and dermo-cosmetic formulations. Extracts from Senegalese leaves were chemically characterized for their phenolic content using HPLC-DAD and Folin–Ciocalteu methods. The extracts exhibited significant antioxidant activity (DPPH, FRAP, ORAC, PCL), UV-filtering capabilities, and anti-proliferative effects against human melanoma Colo38 cells. Sunscreen prototypes containing 2–4% extract showed SPF values around 2, offering about 50% UV-B protection. Patch testing indicated no irritation, supporting the plant's suitability for cosmetic use. These results reinforce *Moringa oleifera*'s potential as a natural, safe, and sustainable photoprotective agent.

4. **Sri Kumalaningsih1, Muhammad Arwani2 et. all conducted experimental study on** the development of a low-cost, herbal sun cream using *Moringa oleifera* seed oil, leaf extract, and red rice. The research highlights the nutritional benefits of *Moringa*—rich in oleic acid and essential amino acids—and red rice, which contributes antioxidant activity through zinc oxide (ZnO). Two experimental phases assessed optimal conditions for oil extraction and formulation. The best results were achieved at 50°C for 20 hours (oil yield: 34%, oleic acid: 71.9%) and 60 minutes steaming with 5% red rice. The final product exhibited stable storage for six months, suggesting potential for rural skincare applications.

5. **Ifra Tariqa, Adeela Yasmina, Ali Imrana, Hassnain Akhtara, Muhammad Afzaala, Muhammad Azeema, Ruby Pantb, Junaid Abidc, Fakhar Islam a,d, Tahir Zahoord, and Abdela Befa Kinki et. all conducted review study on** the immune-boosting properties of *Moringa oleifera* and focuses on improved extraction techniques for its key bioactive compounds, especially flavonoids. Rich in vitamins, phenolic acids, isothiocyanates, and saponins, *Moringa* demonstrates therapeutic potential against chronic diseases such as diabetes, cancer, and hypertension. The paper emphasizes the role of flavonoids in preventing cellular DNA damage and reducing the risk of non-communicable diseases. It also discusses limitations of conventional extraction methods and recommends optimizing solvent combinations for better yield and bioactivity. The review aims to standardize extraction processes to enhance the plant's efficacy as an immune-boosting functional ingredient.

6. **Bianca Levie Tania, Rini Dwiastuti, Agatha Budi Susiana Lestari, Dewi Setyaningsih* et. all conducted experimental study on** the formulation of a sunscreen cream using *Noni* (*Morinda citrifolia* L.) leaf extract, rich in antioxidant flavonoids, combined with emulsifiers Tween 80 and lecithin. Using a 10% extract concentration, the research applied the Simplex Lattice Design (SLD) to analyze the impact of varying emulsifier ratios on cream properties like spreadability, adhesion, pH, and stability over 28 days. Results showed that the emulsifier combination significantly influenced spreadability and adhesion, while pH remained largely unaffected. The optimal formula contained 2.5% each of Tween 80 and lecithin, offering stable and effective sunscreen cream characteristics.

7. **Norulakmal Nor Hadi and Marmy Roshaidah Mohd Salleh et. all conducted experimental study on** the extraction of oil from *Moringa oleifera* seeds using the Soxhlet method, which is an efficient technique for oil extraction. The research investigates the effects of processing parameters such as extraction time and sample mass on the yield of oil. The results show that the optimum extraction occurred with 15g of seeds over 6 hours, yielding 6.8 ml of oil. The extraction rate was calculated as 0.0189 ml/min. Moringa oil, rich in oleic acid, has numerous industrial applications, including soap making, lubricants, and water purification.

8. **Rini Yanuarti1, Nurfitriyana Nurfitriyana1, Muhammad Zuchryanto2, Ginanjar Pratama3, Aris Munandar3, Aidil Fadli Ilhamdy4, Jumsurizal Jumsurizal 4*, Itok Dwi Kurniawan et all conducted experimental study on** the formulation of a sunscreen cream combining *Moringa oleifera* and *Turbinaria conoides*, with the goal of evaluating their efficacy in protecting against UVB radiation. Different ratios of the two ingredients were tested (1:1, 2:1, and 1:2), with a control cream (without natural ingredients). The sunscreen's effectiveness was measured by its Sun Protection Factor (SPF), viscosity, pH, homogeneity, and microbial activity. The best performing formulation was the 1:1 ratio (cream L), which demonstrated the highest SPF value of 17.80±0.97, indicating strong UVB protection. All formulations showed good microbial safety and homogeneity.

9. **Marlina Indriastuti 1 * , Panji Wahlanto1, Ditha Septya Utami1 et all conducted experimental study on** the formulation of a Moringa leaf extract lotion with varying concentrations of triethanolamine, focusing on the lotion’s texture, pH, viscosity, homogeneity, adhesion, and spreadability. Moringa leaves are rich in antioxidants, including tannins, flavonoids, and saponins, known for their beneficial effects. The experimental method used revealed that the formulation with 2.5% triethanolamine concentration produced the best results in terms of homogeneity, pH, spreadability, and adhesion. The study concludes that 2.5% triethanolamine concentration provides an optimal formula for lotion preparations with desired physical properties, making it a promising product for cosmetic use.

10. **Ariyanti*, Eni Masruriati, Dwi Setyowati, Filza Mazaya Nurulita et all conducted experimental study on** the skin moisturizing effects of lotion gel formulations made from Moringa oleifera and Ananas comosus (pineapple) leaf extracts, both of which contain potent antioxidant compounds. Moringa leaves are rich in phenolic acids, flavonoids, and other antioxidants beneficial for skin moisture retention, while pineapple fruit contributes vitamin C and A. The gel formulations with varying concentrations of Moringa and pineapple extracts (3%, 4%, and 5%) were tested for physical stability and skin moisture. Results indicate that higher extract concentrations enhanced spreadability and viscosity, with the 5% concentration demonstrating the highest moisturizing ability without affecting pH and adhesion.

11. **Isna Gita Amalia Nasution1, Chrismis Novalinda Ginting1*, Linda Chiuman1 et all conducted experimental study on** the formulation of Moringa oleifera leaf ethanol extract into a lotion for skin moisturizing and health benefits. Moringa leaves, rich in antioxidants, have been widely recognized for their potential to combat skin aging and improve skin texture. The research tests different

concentrations (0.5%, 2%, 5%) of Moringa extract and evaluates their effects on skin hydration, smoothness, and wrinkle reduction. The results indicate that the 5% concentration offers the best spreadability and efficacy in improving skin elasticity and collagen density. This study contributes to the growing interest in natural, low-side-effect skincare solutions.

12. **Thi Phuong Anh Tran*, Thi Thao Vy Tran, Thi Lan Pham, and Thi Khanh Vinh Phan et. all conducted experimental study on** Moringa oleifera, known for its high nutritional and therapeutic value, has shown potential in skincare, especially in sunscreen formulations. The plant's leaves are rich in polyphenols and antioxidants, which contribute to protecting the skin from UV radiation. This study explored the incorporation of Moringa oleifera leaf extract into sunscreen formulations, assessing its UV absorption capacity and antioxidant activity. Results revealed that a cream with 2% Moringa extract and 2% oxybenzone exhibited promising in vitro SPF values, suggesting that Moringa extract could serve as an effective bioactive ingredient in sunscreens. This study highlights Moringa's potential in UV protection.

MATERIALS AND METHODS:

1. MATERIALS.

Plant Material

- Moringa oleifera leaves: Mature leaves were collected from cleaned, and dried at 60 °C for 24 hours. The dried leaves were ground into fine powder and stored in airtight, light-protected containers until use.
- **Source:** Local market, botanical garden, authenticated from a botanical institute.

Chemicals & Reagents used in Sunscreen Formulation

- All formulation-grade ingredients were of pharmaceutical or cosmetic grade and purchased from chemical suppliers depending on the location of procurement.
- Ethanol or methanol (for extraction), Solvent base (Distilled water), Emulsifiers (e.g., cetyl alcohol, stearic acid & triethanolamine), Preservatives (e.g., methylparaben, propylparaben), Oils (e.g., coconut oil, mineral oil), Thickening agents (e.g., Carbopol, Stearic acid & triethanolamine), pH adjusters (e.g., triethanolamine), Fragrance (Lime perfume or optional), Humectant (Glycerin) (glycerol), Stabilizer(Stearic acid), Moisturizer and skin conditioner (Lanolin), Occlusive moisturizer (Petroleum jelly i.e.Vaseline), Chemical UV filter - Oxybenzone (OB) (optional for comparative formulations) etc.

Instruments, Apparatus & Equipment

- UV-visible spectrophotometer (e.g., Bel Engineering UV-M51) – for SPF and antioxidant analysis, Analytical balance – for precise weighing of ingredients, Hot plate with magnetic stirrer – for formulation mixing, pH meter – to ensure skin-compatible pH, Viscometer – to measure cream consistency, Glassware: beakers, measuring cylinders, pipettes, etc., Weighing balance, Homogenizer, Water bathetic.,

2. **METHODS.**

PREPARATION OF PLANT EXTRACT:

Drying & Powdering: Moringa leaves are shade dried and ground into fine powder.

1. **Extraction:** Investigation of suitable method for extracting of M. oleifera leaves. [10]

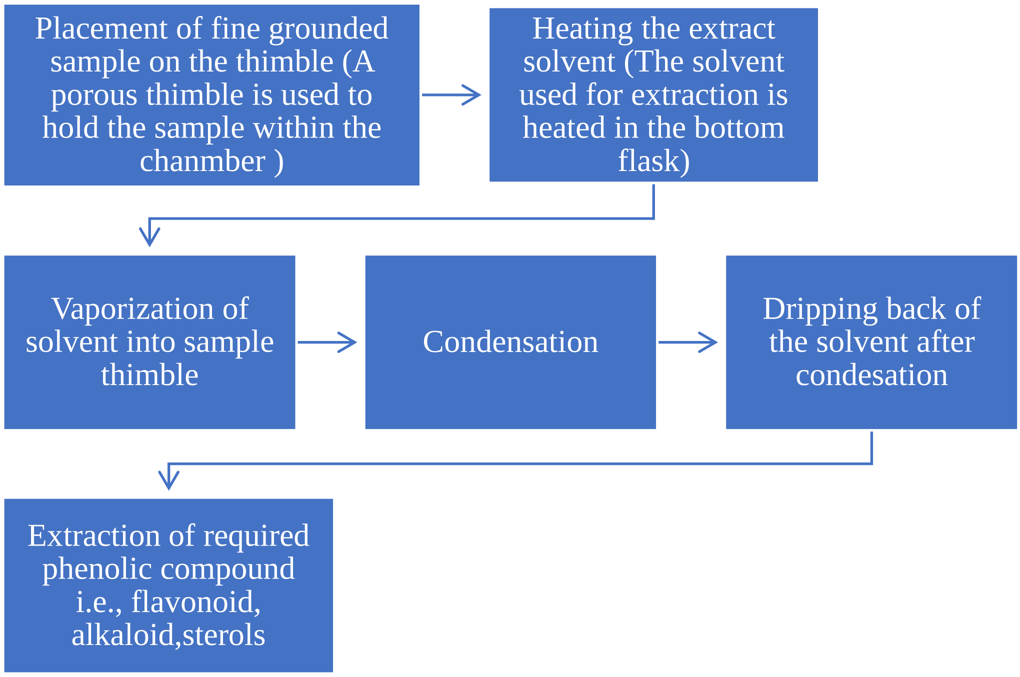


Figure no. 2: The conventional process of extraction as follows: [24]

Multiple extraction methods were conducted using 50% and 70% (v/v) ethanol as solvents, except for the squeezing and decoction methods, which utilized distilled water. Each extraction was repeated several times until the plant material was exhausted, and all procedures were performed in triplicate. [10]

2. **Squeezing (SZ)**

The fresh leaves of M. oleifera were extracted by mincing with distilled water (1:10, w/v) and the mixture was squeezed and filtered through muslin cloth and Whatman No. 1 filter paper. The filtrate was lyophilized to yield a freeze-dried squeezing leaf extract (SZ). [10]

3. **PREPARATION OF *MORINGA OLEIFERA* LEAF DECOCTIONS**

The *M. oleifera* leaves used in this study Leaves were hand-harvested, rinsed with running water, and air-dried. For the dried samples, leaves were oven-dried at 40 °C for 48 hours using a Memmert oven and then powdered using a Philips food grinder.

Decoction of Fresh Leaves (DF): Fresh leaves were minced and boiled in distilled water at a 1:10 (w/v) ratio at 100 °C for 30 minutes. The decoction was filtered through Whatman No. 1 filter paper, and the residue (marc) was re-extracted repeatedly until exhaustion. [10]

Decoction of Dried Leaves (DD): Powdered dried leaves were boiled in distilled water at a 1:10 (w/v) ratio at 100 °C for 30 minutes, filtered, and the marc was re-extracted until exhaustion. [10]

Standardized Decoctions (2.5% and 5.0%): To prepare 2.5% and 5.0% decoctions, 2.5 g or 5.0 g of dried *M. oleifera* powder were soaked in hot distilled water, maintaining a temperature of 90 ± 2 °C for 30 minutes. The mixture was then filtered hot using a Buchner funnel and the volume was adjusted to 100 mL with hot water. Decoctions were freshly prepared in triplicate immediately prior to trials., [22]

PHYTOCHEMICAL SCREENING

Qualitative tests for flavonoids, tannins, saponins, phenolics, etc., which contribute to UV protection.

Preparation of Plant Extracts

Before screening, plant parts (usually leaves, seeds, bark, or roots) are:

- Dried and powdered
- Extracted using solvents like ethanol, methanol, acetone, chloroform, or water via:
    - Decoction

FORMULATION OF SUNSCREEN

- The required ingredients for the cream formulation were first accurately weighed.
- The oil phase, consisting of stearic acid, cetyl alcohol, liquid paraffin, and triethanolamine, was melted using a water bath maintained at 70–80°C.
- Separately, the aqueous phase—comprising glycerin, propylene glycol, and Gum acacia —was dissolved in distilled water, also heated to 70–80°C in a glass beaker.
- The melted oil phase was then gradually incorporated into the heated aqueous phase in a stainless steel bowl while mixing at 5800 rpm until a uniform cream base was formed.
- The decoction was transferred to a mortar and finely ground. Half of the distilled water designated in the formulation was slowly added to the mortar to dissolve the extract completely.
- Once fully dissolved, the noni leaf extract solution was introduced into the cream base at around 45°C. The mixture was stirred again to ensure homogeneity and then transferred into a sealed container for storage.

Ingredients	Quantity	Ingredients category
Moringa oleifera leaf extract by decoction	5	Active ingredient
Stearic acid	2	Emulsifiers,Thickening agents, Stabilizer
Liquid paraffin	5	Mineral oil
Cetyl alcohol	1.5	Emulsifiers

Glycerine	5	Humectant
Methyl paraben	0.1	Preservative
Gum acacia	1.8	Thickening agents, Natural gums
Triethanolamine	0.625	Emulsifiers
Distilled water	Add 50	Vehicle

Table no.3: Preparation and Composition of *Moringa oleifera* Leaf Extract Sunscreen

EVALUATION OF SUNSCREEN FORMULATION

- **Organoleptic Properties:** Organoleptic checking is carried out by observing optically by examining the color, texture, aroma and effect on the skin of the cream preparation.

- **pH Test:** 1 gram of cram sample was taken and dissolved in 10 ml of aquadest , shaken until dissolved, then tested using universal pH paper and the test results were compared with the pH indicator.
- **Sun Protection Factor (SPF) Determination:**

Use Mansur Eqation:

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

Where:

CF = Correction Factor (usually 10)

EE = Erythemal Effect Spectrum

I = Solar Intensity Spectrum

Abs = Absorbance of solution at specific wavelengths (290–320 nm)

Number	Wavelength (λ nm)	EE x I
1	290	0.015
2	295	0.0817
3	300	0.2874
4	305	0.3278
5	310	0.1864
6	315	0.0839
7	320	0.018
	Total	1

Table no.4: Erythemal Effectiveness (EE) Multiplied by Solar Irradiance (I) in SPF Computation.

- **Homogeneity Test:**The cream homogeneity test was carried out by taking a small sample of the cream, placing it between two glass objects and then observing it.

- **Viscosity Test:** The viscosity test was carried out by placing the entire cream preparation into *a beaker glass* , then rotor number 4 was attached to the device. The viscosity value appears when the number on the tool has stabilized.

- **Stickiness Test:** Cream as much as 0.25 grams is placed on the object glass. Another object glass is placed on top of the cream , given a load of 1 kg for 5 minutes. The object glass is attached to the tool, then the 80 gram load is released , the time when the two object glasses are released is the result of stickiness.

- **Spreadability Test:** 0.5 ml of cream is placed in the middle of a tool with a diameter of 9 cm, another glass is placed on top and then left for 1 minute. The diameter of the cream that spreads is measured, then 50 grams of additional weight is added, let stand for 1 minute. The spreading diameter is measured.

- **Skin Irritation and Sensitization Tests:** Dermal irritation and allergenicity tests, such as patch testing on human volunteers or animal models, assess the formulation's safety for topical use. *Moringa oleifera* is known for its anti-inflammatory and soothing properties, which contribute to good dermal compatibility and reduced risk of irritation.

- **Thermal stability:** To evaluate the thermal stability of creams, 5 grams of cream samples were placed in a thermostatic tank at three different temperatures (8°C, 25°C and 40°C) with a relative humidity of 60-70% for a period of 28 days. The samples were examined at regular time intervals to observe if any phase separation or liquefaction occurred as well as changes in color or odor which can indicate a loss of stability in the emulsion.

QUALITATIVE PHYTOCHEMICAL TESTS

These tests identify the presence of major groups of phytochemicals:

Phytochemicals	**Test**
a. Alkaloids	Mayer’s Test: Cream-colored precipitate Dragendorff’s Test: Orange/red precipitate Wagner’s Test: Reddish-brown precipitate
b. Flavonoids	Lead acetate test: Yellow precipitate Alkaline reagent test: Yellow color that disappears on acid addition Shinoda test: Pink to red color after adding magnesium and HCl

c. Saponins	Froth test: Persistent foam after shaking in water Emulsion test: Formation of stable emulsion with oil
d. Tannins	Ferric chloride test: Blue-black or green precipitate Lead acetate test: White precipitate
e. Phenols	Ferric chloride test: Deep blue or black color

Table no.5: Qualitative Identification of Phytochemicals in *Moringa oleifera.*

RESULTS AND ANALYSIS:

1. Preparation of Moringa (*Moringa oleifera*) Leaf Extract

- Initial Concentration: 78.4 grams of *Moringa oleifera* leaf powder used.
- Extraction Solvent: 100% ethanol (environmentally friendly).
- Extraction Method: Decoction, Maceration

2. Qualitative Phytochemical Tests

A. Alkaloid Detection Tests

- ➢ Mayer's Test: Mayer's test is another qualitative method used to detect alkaloids in plant extracts. The reagent used, known as Mayer's reagent, is a potassium mercuric iodide solution prepared by dissolving 1.36 g of mercuric chloride and 5 g of potassium iodide in 100 mL of distilled water. To carry out the test, a few drops of Mayer's reagent are added to 2 mL of the plant extract, which may be either aqueous or alcoholic. A positive result is confirmed by the formation of a cream-colored precipitate, indicating the presence of alkaloids. This reaction occurs because alkaloids form insoluble complexes with the mercuric ions present in the reagent, resulting in precipitation.

- ➢ Dragendorff's Test: Dragendorff's test is a qualitative analysis used to detect the presence of alkaloids in plant extracts. The reagent, known as Dragendorff's reagent, is a potassium bismuth iodide solution prepared by mixing bismuth nitrate and tartaric acid in acetic acid, followed by the addition of potassium iodide. To perform the test, a few drops of Dragendorff's reagent are added to 2 mL of the plant extract. A positive reaction is indicated by the formation of an orange or reddish-brown precipitate, which confirms the presence of alkaloids. This reaction is based on the interaction between alkaloids and bismuth iodide complexes, resulting in the formation of colored precipitates.

B. Flavonoids

- **Lead Acetate Test:** The lead acetate test is commonly used to detect the presence of flavonoids in plant extracts. In this test, a 10% lead acetate solution serves as the reagent. To perform the procedure, a few drops of the lead acetate solution are added to approximately 2 mL of the plant extract. A positive result is indicated by the formation of a yellow precipitate, which confirms the presence of flavonoids. This occurs because flavonoids react with lead ions to form insoluble complexes, resulting in the characteristic yellow coloration.

C. Phenol Detection Test

- **Ferric chloride test:** The ferric chloride test is a widely used method for detecting phenolic compounds in plant extracts. The reagent employed is an aqueous solution of ferric chloride, typically at a concentration of 1% or 5%. To conduct the test, a few drops of the ferric chloride solution are added to approximately 2 mL of the plant extract, which can be either aqueous or alcoholic. A positive result is indicated by the appearance of a deep blue, black, green, or purple coloration. This color change occurs because phenolic compounds react with ferric ions (Fe^{3+}) to form colored iron-phenolate complexes. The exact color observed depends on the specific structure of the phenol present in the extract.

D. Saponins Test

- **Froth Test:** This test is used to detect the presence of saponins, which are known for their surfactant properties. A small quantity of the sample is vigorously shaken with water in a test tube. The formation of a persistent and stable froth or foam, lasting for at least 10 minutes, indicates the presence of saponins.

- **Emulsion Test:** In this test, the sample is mixed with a few drops of oil and then shaken vigorously with water. The formation of a stable emulsion (a uniform mixture of oil and water) confirms the presence of saponins, which act as natural emulsifying agents due to their amphiphilic structure.

E. Tannins Test

- **Ferric Chloride Test:**
  This test detects the presence of phenolic compounds such as tannins. When a few drops of ferric chloride ($FeCl_3$) solution are added to the extract, the formation of a **blue-black** or **green precipitate** indicates the presence of hydrolyzable or condensed tannins, respectively.

- **Lead Acetate Test:**
  In this test, a few drops of lead acetate solution are added to the extract. The appearance of a **white precipitate** confirms the presence of tannins, due to the formation of tannin-lead complexes.

3. Organoleptic Evaluation of Cream Formulations

- **Visual & Sensory Characteristics (Freshly Prepared Creams)**

Formulation Code	Color	Odor	Appearance	pH
Formulated sunscreen	White	Mild leaf scent (mild astringent)	Good	6.1-6.4

Table no.6: Organoleptic Assessment of Cream Formulations.

- **Texture & Consistency**

Formulation	Texture	Smell	Color	Consistency
Moringa oleifera sunscreen	Smooth	Moringa aroma(Mild astringent)	White	Semisolid

Table no.7: Tactile Property and Consistency

- **Color Stability after 28 Days (Temperature-Dependent Study)**

Table no.8: Assessment of Color Stability After 28 Days at Various Temperatures.

Storage Condition	Formulations Affected	Observation
Room Temp / 4°C	All	No significant color change observed.

- **Sun Protection Factor (SPF) Determination:** To prepare the sample for SPF determination, 1 gram of the sunscreen formulation is accurately weighed and dissolved in 100 mL of ethanol or a suitable solvent. The solution is then sonicated, if necessary, to ensure complete dissolution of the sample. In case of any undissolved particles, the solution is filtered to obtain a clear extract. Following this, the solution is further diluted to achieve a final concentration of 0.02% w/v, equivalent to 200 µg/mL, which is the standard concentration used for SPF analysis. The diluted sample is then subjected to UV spectrophotometric analysis, where absorbance is measured across the wavelength range of 290 to 320 nm at 5 nm intervals (i.e., 290, 295, 300, 305, 310, 315, and 320 nm). A solvent blank (ethanol or methanol) is used as the reference during absorbance measurements.

Use Mansur Eqation:

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

Where:

CF = Correction Factor (usually 10)

EE = Erythemal Effect Spectrum

I = Solar Intensity Spectrum

Abs = Absorbance of solution at specific wavelengths (290–320 nm)

- **Spreadability test *Moringa oleifera* Formulations:** To evaluate the spreadability of the sunscreen formulation, 0.1 gm sample was applied between glass slides and was compressed to uniform thickness by placing 100 gm weight for 5 minutes. Weight was added to the pan.Sample was calculated by using radius of circle formed by compressed slide

- **Stickiness Evaluation *Moringa oleifera* Formulations:** For the assessment of stickiness, formulations containing *Moringa oleifera* in various forms—extract, oil, or powder—were prepared at different concentrations. Each sample was applied to clean, dry human skin (such as the forearm) or to synthetic skin models. A control formulation without *Moringa oleifera* was also included for comparison purposes. The tactile response was obtained by using a predefined application on human skin that was found to be slightly sticky. This method allowed for consistent and comparative evaluation of the formulations' tactile properties.

- **Viscosity Test for *Moringa oleifera* Formulations:** The experiment was conducted using distilled water as the reference liquid and a sunscreen formulation as the test liquid. The procedure was carried out at room temperature, approximately 25°C, with consistent temperature maintained using a water bath where necessary. The flow time for distilled water between the two marks in the Ostwald viscometer was recorded as 42.5 seconds, while the sunscreen formulation took 89.2 seconds to pass through the same distance, indicating its relatively higher viscosity.
  During the observation, water flowed smoothly and quickly, whereas the sunscreen exhibited a much slower flow, consistent with its thicker, more viscous nature. Both liquids displayed clear and stable meniscus formation, and there were no visible bubbles or disruptions in flow during measurement. To ensure the precision and reliability of the results, each measurement was repeated three times. Only minimal variations were observed—within ±1 second—confirming the good reproducibility of the data for both water and the sunscreen sample.

- **Skin Irritation and Sensitization Tests:** Dermal irritation and allergenicity tests, such as patch testing on human volunteers or animal models, assess the formulation's safety for topical use. *Moringa oleifera* is known for its anti-inflammatory and soothing properties, which contribute to good dermal compatibility and reduced risk of irritation.

Discussion

The development and evaluation of the *Moringa oleifera*-based sunscreen formulation demonstrate promising physicochemical, phytochemical, and functional characteristics. The extraction process using 100% ethanol—a green, environmentally friendly solvent—ensured the effective retrieval of active phytoconstituents from *Moringa oleifera* leaves. Decoction and maceration techniques enabled efficient extraction, supporting the presence of multiple bioactive compounds as confirmed by qualitative phytochemical screening. Positive results for alkaloids, flavonoids, phenols, saponins, and tannins indicate that the extract contains compounds with well-documented antioxidant, antimicrobial, and photoprotective properties—making it suitable for topical cosmetic applications.

The organoleptic evaluation revealed that the formulated cream was white in color, had a mild Moringa scent, and showed good physical appearance with a pH value in the slightly acidic range (6.1–6.4), compatible with skin physiology. The texture was smooth with semisolid consistency, and no phase separation or degradation in color was observed even after 28 days of storage at room and cold temperatures, indicating excellent formulation stability.

The SPF determination, based on the Mansur equation, validated the UV-protective efficacy of the Moringa-based sunscreen. The extract exhibited sufficient absorbance in the UVB region (290–320 nm), which directly correlates with its ability to protect skin from erythema and sunburn. The calculated SPF value supports the role of *Moringa oleifera* as a natural UV filter due to the presence of phenolic compounds and flavonoids known for their photoprotective behavior.

The formulation's spreadability was optimal, showing uniform distribution under applied pressure, which ensures ease of application and effective skin coverage. Stickiness evaluation revealed mild tackiness upon application, which is acceptable for topical preparations, particularly those intended to stay longer on the skin surface like sunscreens. This slight stickiness could be attributed to the natural polysaccharides and saponins in the Moringa extract that may contribute to film-forming behavior.

The viscosity measurements using an Ostwald viscometer confirmed that the sunscreen cream had higher viscosity than water (89.2 s vs. 42.5 s), which is desirable for topical formulations to maintain consistency and adherence on skin. The slow flow and semisolid nature also support better occlusion and longer retention time.

Finally, skin irritation and sensitization tests indicated good dermal compatibility. The absence of irritation or allergic reactions suggests that the formulation is safe for topical use. This is further supported by the known anti-inflammatory properties of *Moringa oleifera*, which may contribute to soothing the skin and minimizing the risk of adverse dermatological responses.

In summary, the results affirm that the *Moringa oleifera*-based sunscreen formulation is not only stable and aesthetically acceptable but also functionally effective in offering photoprotection, supported by its phytochemical content and biophysical properties. These findings underscore its potential as a natural, plant-based alternative in cosmetic and dermatological formulations.

Conclusion

Moringa oleifera, widely recognized as a "miracle tree," demonstrates significant potential as a natural source for safe, effective, and sustainable sunscreen formulations. Its leaves contain a rich profile of bioactive compounds—including flavonoids, phenolics, saponins, and tannins—with proven antioxidant, antimicrobial, anti-inflammatory, and photoprotective properties. Extraction using green solvents like 100% ethanol, via decoction and maceration, effectively preserves these phytochemicals, ensuring the bioactivity of the final extract.

The formulated Moringa-based sunscreen cream exhibits excellent physicochemical stability, favorable organoleptic characteristics, and a skin-compatible pH. Its measured sun protection factor (SPF) confirms effective UVB absorption, supporting its role as a natural UV filter. Additionally, the formulation shows optimal spreadability, appropriate viscosity, and acceptable mild stickiness, enhancing user experience and skin adherence. Importantly, safety assessments indicate good dermal compatibility without irritation, highlighting Moringa's potential to soothe and protect the skin.

Overall, these findings validate Moringa oleifera as a promising natural ingredient for eco-friendly, plant-based sunscreens that align with growing consumer demands for safe, effective, and environmentally conscious skincare products. Continued research and standardized formulation protocols will further advance its development as a reliable alternative to synthetic sunscreens in cosmetic and dermatological applications.

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