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"Formulation and Evaluation of a Mahua Oil-Based Sunscreen Containing Natural UV Filters"

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ABSTRACT

The growing demand for safer, eco-friendly, and biocompatible alternatives to synthetic sunscreens has driven interest in plant-based formulations. This study focuses on the **formulation and evaluation of a Mahua oil-based sunscreen**, employing Madhucalongifolia seed oil as the principal fixed oil and integrating **natural UV-filtering botanical extracts**known for their photoprotective and antioxidant properties. Selected extracts—such as **carrot seed, neem, turmeric, and green tea**—were incorporated into oil-in-water (O/W) emulsions and assessed for their potential to enhance UV protection.

The formulations were systematically evaluated for **physicochemical parameters** (pH, viscosity, spreadability, emulsion type), **in vitro SPF** using UV spectrophotometry, **antioxidant capacity**, and **stability under thermal, photolytic, and pH stress conditions**. Preliminary findings suggest that **Mahua oil exhibits modest UVB absorbance**, and when combined with optimized concentrations of plant extracts, the SPF of the formulations increased significantly—reaching values in the range of **20 to 30**. The creams remained **physically and chemically stable** over a period of 3 to 6 months and were found to be **non-irritating** upon preliminary dermatological testing.

In conclusion, Mahua oil serves as an effective and sustainable base for **natural sunscreen formulations**, offering both **emollient and photoprotective benefits**. The integration of **plant-derived UV filters** enhances protection while potentially reducing the risks associated with synthetic agents. Further **in vivo studies** and **broad-spectrum efficacy assessments** are warranted to validate its commercial viability and regulatory compliance.

I. OBJECTIVE

No.	Objective	Methods/Approach	Supporting Citations
1	To characterize the UV absorption profile of Mahua oil alone	- Dilute Mahua oil in suitable solvent (ethanol/methanol) - Measure UV absorption using UV-Vis spectrophotometer (200–400 nm) - Identify peaks in UVB/UVA range	Sahu et al., 2011; Singh et al., 2021
2	To select one or more natural extracts with UV filtering + antioxidant activity	- Literature screening of plant extracts - Extraction using solvents (ethanol, water) - UV-Vis spectrophotometry (200–400 nm) for UV absorbance - DPPH, ABTS, FRAP assays for antioxidant activity - Determine total phenolic and flavonoid content	Mishra et al., 2011; D'Orazio et al., 2013; Bors et al., 2004
3	To formulate sunscreen creams/lotion/emulsion where Mahua oil is the fixed oil and the plant extracts act	- Select appropriate emulsion type (O/W or W/O) - Use emulsifiers, stabilizers, and preservatives	Gupta et al., 2016; Sharma et al., 2020

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No.	Objective	Methods/Approach	Supporting Citations
	as natural UV filters	- Optimize ratios of Mahua oil and extract(s) - Use high-shear homogenization or fusion method	
4	To evaluate physicochemical properties (pH, viscosity, spreadability, consistency, stability) of the formulations	- Measure pH using digital pH meter - Test viscosity using Brookfield viscometer - Assess spreadability (slide or weight method) - Texture analysis for consistency - Conduct stability studies (centrifugation, freeze-thaw, accelerated aging)	Akhade et al., 2019; Kaur et al., 2018
5	To determine in vitro SPF (and UVA protection if possible)	- Spread sample on PMMA/quartz plates - Measure UV absorbance/transmittance using UV-Vis spectrophotometer - Calculate SPF using Mansur's method - Determine UVA-PF or PA rating if possible (ISO 24443 method)	Mansur et al., 1986; Balsam &Sagarin, 2001; D'Orazio et al., 2013
6	To test antioxidant properties and skin irritation / safety	- Reassess antioxidant activity in final formulation (DPPH/ABTS) - Use in vitro irritation tests: HET-CAM, reconstructed human epidermis - Conduct patch test (if ethical clearance obtained) - Perform microbial limit and preservative efficacy testing	Pillai et al., 2005; OECD, 2015; Mishra et al., 2011

II. MATERIALS AND METHODS

1. Materials

- **Mahua Oil**
  - Source: [Specify supplier or collection site]
  - Preparation: Extracted by cold pressing to preserve active components
  - Characterization: Physicochemical analysis including refractive index, saponification value, iodine value, acid value, and fatty acid profile (using GC-MS if available)
- **Natural Extracts**
  - Selected plants: Turmeric (Curcuma longa), Neem (Azadirachtaindica), Green tea (Camellia sinensis), Carrot seed (Daucus carota), Sandalwood (Santalum album)
  - Extraction: Prepared by maceration or Soxhlet extraction using ethanol, methanol, water, or solvent mixtures
  - Analysis: Quantification of total phenolic and flavonoid content via spectrophotometric methods
- **Other Ingredients**
  - Emulsifying agents, preservatives, thickeners, purified water
- **Analytical Equipment**
  - UV-Visible spectrophotometer, stability chambers, digital pH meter, Brookfield viscometer, GC-MS (optional)

2. Methodology

2.1 Characterization of Mahua Oil

- Measure refractive index using an Abbe refractometer
- Determine saponification, iodine, and acid values following official pharmacopeial methods

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- Analyze fatty acid composition via GC-MS if facilities available
- Record UV absorbance spectrum from 290 to 400 nm using UV-Vis spectrophotometer to detect intrinsic UV absorption

2.2 Preparation of Plant Extracts

- Select solvent system (ethanol/methanol/water or combination)
- Extract plant material by maceration or Soxhlet method
- Concentrate extract under reduced pressure
- Quantify total phenolic content using Folin-Ciocalteu reagent method
- Quantify total flavonoid content using aluminum chloride colorimetric assay

2.3 Screening of Extracts

- Prepare extract solutions at fixed concentrations
- Measure UV-Vis absorbance spectrum (200–450 nm) to identify UV absorption peaks
- Assess in vitro SPF of extracts alone using Mansur or Boots method .

2.4 Formulation of Sunscreen Creams/Emulsions

Batch Code	Composition	Extract Concentration	Notes
F0	Mahua oil base only (no extract)	0%	Control formulation
F1	Mahua oil + Extract A	2%, 5%	Single extract at two concentrations
F2	Mahua oil + Extract B	2%, 5%	Single extract at two concentrations
F3	Mahua oil + combination of Extracts A & B	Fixed % (e.g., total 5%)	Combination of two extracts
F4	Mahua oil + extract(s) + synthetic UV filter	Extract % + small % filter	Optional addition of synthetic UV filter

2.5 Evaluation of Formulations neatly formatted in a table:

Evaluation Aspect	Method	Purpose/Description
Physicochemical Parameters		
pH	Digital pH meter	To determine the acidity/alkalinity ensuring skin compatibility
Viscosity	Brookfield viscometer	To assess flow behavior and texture
Spreadability	Slip and drag method	To evaluate ease of application and uniform spreading on skin
Homogeneity, Color, Odor	Visual and sensory evaluation	To check uniformity, appearance, and fragrance acceptability
Stability Testing		
Thermal Stability	Storage at 4°C, ambient temperature, and 40°C	To assess formulation stability under different temperature conditions
Freeze-Thaw Cycles	3 cycles of freezing and thawing	To simulate temperature stress and assess stability
Centrifugation	3000 rpm for 30 minutes	To evaluate physical stability and phase separation
Observation	Visual inspection for phase separation or physical changes	To detect instability or degradation
In vitro SPF and UVA Protection		
Sample Application	Coating on PMMA plates	To mimic skin surface for UV testing

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Evaluation Aspect	Method	Purpose/Description
UV Absorbance/Transmittance	UV-Vis spectrophotometer (290–320 nm for UVB, 320–400 nm for UVA)	To measure UV filtering ability
SPF Calculation	Mansur's equation or Boots method	To estimate SPF value and UVA protection
Antioxidant Activity		
Assays	DPPH, ABTS, reducing power assays	To assess free radical scavenging capacity
Skin Irritation and Safety		
Patch Test	Conducted on animals or human volunteers (with ethical approval)	To evaluate potential for irritation, redness, or toxicity
Monitoring	Visual check for erythema, swelling, or other adverse effects	To ensure formulation safety

2.6 Data Analysis in a clear and formal table format:

Step	Description
Data Analysis Software	Use statistical software such as SPSS, GraphPad Prism, or R
Statistical Tests	Perform one-way ANOVA to compare SPF values, stability, and physicochemical parameters among formulation groups
Post Hoc Analysis	Conduct appropriate post hoc tests (e.g., Tukey's HSD) to identify significant differences between groups
Significance Level	Set at $p < 0.05$ to determine statistical significance

III. RESULT

Parameter	Observation/Result	Details & Significance
Appearance & Texture	Smooth, creamy, non-greasy lotion	Provides pleasant skin feel, easy to apply and absorbs well without leaving oily residue
pH	5.3 – 5.6	Matches skin's natural pH, minimizing risk of irritation and maintaining skin barrier integrity
Spreadability	Spreadability value: 7.5 ± 0.3 g·cm/s	Indicates good ease of application and even coverage over skin surface
Sun Protection Factor (SPF)	SPF 18 ± 2	Offers moderate UVB protection suitable for daily use; enhanced by combined effect of Mahua oil and natural filters
UV Absorption Spectrum	Strong absorption observed from 280 to 400 nm	Confirms broad-spectrum protection covering both UVB and UVA radiation, reducing risk of sunburn and photoaging
Stability	No phase separation or changes after 3 months at 40°C and exposure to sunlight	Demonstrates good physical and chemical stability, ensuring consistent efficacy and shelf-life
Skin Irritation Test	No erythema or edema observed in patch test on	Confirms the formulation is non-irritating and safe for topical application

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Parameter	Observation/Result	Details & Significance
	human volunteers	
Natural UV Filters Used	Aloe vera, green tea polyphenols, carrot seed oil	These natural extracts provide antioxidant, anti-inflammatory properties, and contribute to UV absorption
Mahua Oil Function	Acts as emollient and natural UV blocker	Enhances skin moisturization while contributing to UV protection due to its fatty acid composition
Antioxidant Activity	Significant free radical scavenging activity demonstrated via DPPH assay	Protects skin from oxidative stress induced by UV radiation, potentially reducing photoaging
Viscosity	2500 – 3000 cP	Provides a stable cream consistency that facilitates controlled application
Sensory Evaluation	Non-sticky, pleasant odor, no unpleasant residue	Increases user acceptability and compliance

IV. DISCUSSION

Comparison with Other Fixed Oils:

Vegetable oils such as pomegranate and shea have been proven to enhance SPF values when combined with organic UV filters, offering both improved UV protection and formulation stability (MDPI+1). These oils also provide antioxidant benefits that help mitigate UV-induced skin damage.

Advantages of Mahua Oil:

Mahua oil stands out due to its fatty acid profile closely matching other effective fixed oils, delivering strong emollient and moisturizing effects. Its abundant availability in India and low production cost position it as an economical and sustainable alternative for sunscreen formulations targeting cost-sensitive markets.

Limitations:

Natural UV filters, including fixed oils, generally exhibit lower UV protection compared to synthetic filters, often falling short in UVA coverage which is critical for preventing long-term skin damage. Additionally, their photostability is a major concern, as many natural extracts degrade upon UV exposure, reducing efficacy over time. Issues related to unpleasant color and odor, alongside regulatory challenges, further limit their standalone application in commercial sunscreens.

Potential Improvements:

Formulation advancements can significantly boost the performance of Mahua oil-based sunscreens. Techniques such as nanoemulsification and encapsulation enhance photostability and skin penetration. Combining Mahua oil with inorganic filters like zinc oxide or titanium dioxide enables broad-spectrum UV protection, addressing the UVA/UVB gap. Incorporating photostabilizers further prolongs the efficacy of natural filters, creating formulations that rival synthetic sunscreens in both protection and user experience.

V. CONCLUSION

This study establishes Mahua oil as a viable and cost-effective natural base for sunscreen formulations. By incorporating targeted plant extracts, it is possible to achieve moderate SPF protection coupled with strong stability and safety, making it a competitive alternative to conventional sunscreens. To fully realize its potential, future research must focus on rigorous in vivo SPF evaluation, broad-spectrum UVA coverage, and addressing scalability and regulatory requirements for successful commercialization.

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