RESEARCH PAPER

Formulation, Optimization and Evaluation of A Polyherbal Hand Sanitizer

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ABSTRACT

Background: Hand hygiene is one of the most effective preventive measures for reducing the transmission of infectious microorganisms. Although alcohol-based hand sanitizers are widely used, frequent application may cause skin dryness, irritation, and discomfort. Herbal formulations containing plant-derived antimicrobial agents offer a promising alternative due to their efficacy, safety, and skin-friendly properties.
Objective: The present study aimed to formulate, optimize, and evaluate a polyherbal hand sanitizer gel containing extracts of Azadirachta indica (Neem), Ocimum tenuiflorum (Tulsi), Curcuma longa (Turmeric), Calendula officinalis (Calendula), and Aloe vera.
Materials and Methods: Herbal extracts were prepared using suitable solvent extraction methods and incorporated into a Carbopol 940 gel base. Three formulations (F1, F2, and F3) were prepared with varying concentrations of herbal extracts and gelling agent. The formulations were evaluated for organoleptic characteristics, pH, viscosity, spreadability, homogeneity, antimicrobial activity, minimum inhibitory concentration (MIC), skin irritation, and stability under different storage 0: All formulations exhibited acceptable physicochemical properties. Formulation F2 demonstrated optimum pH (6.2), excellent spreadability, desirable viscosity, and superior homogeneity. Antimicrobial evaluation revealed significant inhibitory activity against Escherichia coli and Staphylococcus aureus, with zones of inhibition of 18 ± 0.7 mm and 20 ± 0.5 mm, respectively. MIC values of F2 were found to be 2.5 mg/mL against E. coli and 2.0 mg/mL against S. aureus. Stability studies conducted for 30 days indicated no significant changes in physical appearance, pH, or viscosity. Skin irritation studies confirmed the safety of the optimized formulation.
Conclusion: The optimized polyherbal hand sanitizer gel (F2) demonstrated effective antimicrobial activity, excellent physicochemical characteristics, stability, and skin compatibility. The formulation may serve as a safe, effective, and eco-friendly alternative to conventional synthetic hand sanitizers.
Keywords: Polyherbal hand sanitizer, Azadirachta indica, Ocimum tenuiflorum, antimicrobial activity, Aloe vera, formulation optimization.
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INTRODUCTION

Hand hygiene is recognized globally as a fundamental strategy for preventing the transmission of infectious diseases in both healthcare and community settings. Proper hand sanitation significantly reduces the spread of pathogenic microorganisms responsible for respiratory, gastrointestinal, and skin infections. The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have emphasized routine hand hygiene as a primary preventive measure for controlling healthcare-associated infections and community-acquired diseases [1,2].

Human hands serve as major vehicles for microbial transmission due to their frequent contact with contaminated surfaces and infected individuals. Pathogenic microorganisms such as Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and various viral pathogens can survive on the skin surface for prolonged periods and contribute to disease transmission [3]. Consequently, effective hand sanitation practices are essential for interrupting the chain of infection.

Alcohol-based hand sanitizers have become increasingly popular because of their rapid antimicrobial action and ease of use. These formulations typically contain ethanol or isopropyl alcohol at concentrations ranging from 60–80%, which effectively denature microbial proteins and disrupt cellular membranes [4]. Despite their effectiveness, frequent use of alcohol-based sanitizers may result in excessive skin dryness, irritation, erythema, and dermatitis, particularly among healthcare professionals and individuals requiring repeated application [5]. Moreover, concerns regarding the long-term use of synthetic antimicrobial agents, environmental impact, and potential microbial adaptation have encouraged the exploration of safer and more sustainable alternatives [6].

Medicinal plants have been used traditionally for centuries due to their diverse therapeutic properties. Plant-derived bioactive compounds such as flavonoids, tannins, alkaloids, terpenoids, phenolic acids, and essential oils possess significant antimicrobial, antioxidant, anti-inflammatory, and wound-healing activities [7]. Herbal formulations containing these phytoconstituents provide broad-spectrum antimicrobial action while minimizing adverse skin reactions commonly associated with synthetic sanitizers [8].

Azadirachta indica (Neem) possesses well-documented antibacterial, antifungal, antiviral, and anti-inflammatory properties attributed to active constituents such as nimbin, nimbidin, and azadirachtin [9]. Ocimum tenuiflorum (Tulsi) exhibits potent antimicrobial and immunomodulatory activities due to the presence of eugenol, ursolic acid, and rosmarinic acid [10]. Curcuma longa (Turmeric) contains curcumin, a polyphenolic compound with remarkable antimicrobial and antioxidant properties [11]. Calendula officinalis is known for its wound-healing, anti-inflammatory, and antimicrobial effects, while Aloe vera contributes moisturizing, soothing, and skin-protective properties that improve user compliance during frequent application [12,13].

Recent studies have demonstrated that polyherbal formulations often exhibit enhanced therapeutic efficacy compared with single-herb preparations due to synergistic interactions among bioactive constituents [14]. Such synergism may improve antimicrobial potency, broaden the spectrum of activity, and reduce the concentration of individual ingredients required for effectiveness. Furthermore, herbal sanitizers are biodegradable, environmentally friendly, and generally considered safer for long-term use [15].

Although several herbal hand sanitizers have been reported, there remains a need for optimized formulations that combine strong antimicrobial efficacy with desirable physicochemical properties, skin compatibility, and stability. Therefore, the present study was undertaken to formulate, optimize, and evaluate a polyherbal hand sanitizer gel containing Azadirachta indica, Ocimum tenuiflorum, Curcuma longa, Calendula officinalis, and Aloe vera. The prepared formulations were assessed for physicochemical characteristics, antimicrobial activity, safety, and stability to identify the most suitable formulation for potential commercial application.

MATERIALS AND METHODS

Materials

Fresh leaves of Azadirachta indica (Neem) and Ocimum tenuiflorum (Tulsi), rhizomes of Curcuma longa (Turmeric), flowers of Calendula officinalis (Calendula), and fresh Aloe vera leaves were collected from local medicinal plant gardens of Maharashtra, India. The plant materials were authenticated by a qualified taxonomist from the Department of Botany, and voucher specimens were deposited for future reference.

Carbopol 940, glycerin, triethanolamine, and methyl paraben were procured from a certified pharmaceutical supplier. Analytical-grade ethanol and distilled water were used throughout the study.

Authentication of Plant Materials

The collected plant materials were thoroughly examined for macroscopic and microscopic characteristics according to standard pharmacognostic procedures. The authenticated samples were assigned voucher numbers and preserved in the departmental herbarium.

Preparation of Herbal Extracts

Preparation of Neem Extract (Azadirachta indica)

Fresh neem leaves were washed with distilled water and shade-dried for 10 days. The dried leaves were pulverized into coarse powder using a mechanical grinder. Approximately 100 g of powdered material was subjected to maceration with 70% ethanol for 72 h with intermittent shaking. The extract was filtered through

Whatman No. 1 filter paper and concentrated under reduced pressure using a rotary evaporator. The concentrated extract was stored in an airtight container at 4°C until further use.

Preparation of Tulsi Extract (Ocimum tenuiflorum)
Shade-dried Tulsi leaves were powdered and extracted using 70% ethanol by maceration for 72 h. The filtrate was concentrated and dried to obtain a semisolid extract, which was stored under refrigerated conditions.

Preparation of Turmeric Extract (Curcuma longa)
Dried turmeric rhizomes were powdered and extracted with ethanol using the maceration technique. The solvent was removed under reduced pressure to obtain a concentrated extract rich in curcuminoids.

Preparation of Calendula Extract (Calendula officinalis)
Dried calendula flowers were powdered and extracted using ethanol. The extract was filtered, concentrated, and stored in airtight amber-colored containers.

Preparation of Aloe vera Gel
Fresh Aloe vera leaves were washed thoroughly and the outer rind was removed aseptically. The inner gel was collected, homogenized, filtered through muslin cloth, and preserved under refrigerated conditions for formulation purposes.

Percentage Yield of Extracts
The percentage yield of each extract was calculated using the following equation:

Percentage Yield (%) = (Weight of Dried Extract / Weight of Crude Drug) × 100

The extractive values were recorded and utilized for formulation development.

Formulation Development of Polyherbal Hand Sanitizer Gel
A polyherbal hand sanitizer gel was prepared using Carbopol 940 as a gelling agent. The formulation was developed with the objective of obtaining optimum antimicrobial activity, desirable viscosity, good spreadability, and skin compatibility.

Formula Composition of Optimized Herbal Hand Sanitizer (F2)

Sr. No.	Ingredient	Quantity
1	Neem Extract	2.0 g
2	Tulsi Extract	2.0 g
3	Turmeric Extract	1.0 g
4	Calendula Extract	1.0 g
5	Aloe vera Gel	10.0 g
6	Carbopol 940	0.5 g
7	Glycerin	5 mL
8	Triethanolamine	q.s.
9	Methyl Paraben	0.2 g
10	Distilled Water	Up to 100 mL

Method of Preparation
Step 1: Carbopol 940 was dispersed slowly in distilled water under continuous stirring and allowed to hydrate for 24 h.

Step 2: Glycerin and methyl paraben were dissolved separately and incorporated into the hydrated gel base.

Step 3: Neem, Tulsi, Turmeric, and Calendula extracts were added gradually with continuous stirring to obtain uniform distribution.

Step 4: Fresh Aloe vera gel was incorporated into the mixture.

Step 5: Triethanolamine was added dropwise until a transparent gel with pH between 6.0 and 6.5 was obtained.

Step 6: The final volume was adjusted with distilled water and the prepared gel was packed in sterilized airtight containers.

Optimization of Formulation

Three formulations (F1, F2, and F3) were developed by varying concentrations of herbal extracts and Carbopol 940.

Ingredient	F1	F2	F3
Neem Extract (g)	1.5	2.0	2.5
Tulsi Extract (g)	1.5	2.0	2.5
Turmeric Extract (g)	0.5	1.0	1.5
Calendula Extract (g)	0.5	1.0	1.5
Aloe vera Gel (g)	8	10	12
Carbopol 940 (g)	0.4	0.5	0.6
Glycerin (mL)	4	5	6
Triethanolamine	q.s.	q.s.	q.s.
Distilled Water	Up to 100 mL	Up to 100 mL	Up to 100 mL

Evaluation Parameters

Organoleptic Evaluation

Prepared formulations were visually examined for appearance, color, odor, consistency, and texture.

Determination of pH

The pH of formulations was measured using a calibrated digital pH meter at 25 ± 2°C. Measurements were performed in triplicate and expressed as mean ± SD.

Viscosity Measurement

Viscosity was determined using a Brookfield Viscometer (Model DV-II+) at 25°C using spindle No. 64 at 50 rpm.

Spreadability Study

Spreadability was determined using the parallel plate method and calculated by:

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

Where:

S = Spreadability (g.cm/sec)

M = Weight tied to upper slide (g)

L = Length moved by glass slide (cm)

T = Time taken (sec)

Homogeneity

Homogeneity was evaluated by visual inspection for the presence of aggregates, lumps, and phase separation.

Antimicrobial Activity

Antimicrobial activity was evaluated using the agar disc diffusion method against:

- Escherichia coli (MTCC 443)
- Staphylococcus aureus (MTCC 96)

Sterile nutrient agar plates were inoculated with microbial cultures. Sterile discs impregnated with formulations were placed on the agar surface and incubated at 37°C for 24 h.

The zone of inhibition was measured in millimeters.

Determination of Minimum Inhibitory Concentration (MIC)

MIC values were determined by broth dilution technique. Serial dilutions of each formulation were prepared and inoculated with standardized microbial suspensions. Following incubation at 37°C for 24 h, the lowest concentration showing no visible growth was recorded as the MIC.

Skin Irritation Study

The skin irritation test was conducted on healthy volunteers following approval from the Institutional Ethics Committee. Small quantities of formulations were applied to the forearm and observed for 24 h for erythema, edema, itching, and irritation.

Stability Study
Accelerated stability studies were performed according to ICH Q1A(R2) guidelines.

Storage Conditions:

- 25 ± 2°C / 60 ± 5% RH
- 40 ± 2°C / 75 ± 5% RH

Duration: 30 days

Sampling Intervals:
- Day 0
- Day 7
- Day 15
- Day 30

Parameters Evaluated:
- Appearance
- Color
- Odor
- pH
- Viscosity
- Homogeneity
- Phase Separation

Statistical Analysis
All experimental values were expressed as Mean ± Standard Deviation (SD). Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test. Values of $p < 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Organoleptic Evaluation
The prepared polyherbal hand sanitizer formulations (F1, F2, and F3) were evaluated for physical appearance, color, odor, consistency, and texture. Organoleptic characteristics play an important role in consumer acceptance and product compliance.

Table 1: Organoleptic Evaluation of Polyherbal Hand Sanitizer Formulations

Parameter	**F1**	**F2**	**F3**
Appearance	Slightly Thin Gel	Smooth Gel	Thick Gel
Color	Light Green	Green	Dark Green
Odor	Mild	Pleasant	Strong
Consistency	Semi-solid	Uniform Smooth Gel	Highly Viscous
Texture	Good	Excellent	Sticky

Discussion
The organoleptic evaluation revealed noticeable differences among the formulations. F1 exhibited comparatively lower viscosity, resulting in a thinner consistency. F3 showed excessive thickness and stickiness due to higher concentrations of Carbopol and herbal extracts. Formulation F2 exhibited a smooth texture, uniform consistency, and pleasant odor, indicating superior patient acceptability and aesthetic characteristics. Similar findings have been reported in herbal gel formulations containing Aloe vera and medicinal plant extracts, where moderate polymer concentration contributed to optimal consistency and user compliance [16].

Physicochemical Evaluation
Physicochemical properties significantly influence product performance, stability, and skin compatibility.

Table 2: Physicochemical Evaluation of Polyherbal Hand Sanitizer Formulations

Parameter	F1	F2	F3

pH	5.8 ± 0.02	6.2 ± 0.03	6.5 ± 0.02
Viscosity (cP)	4850 ± 45	6120 ± 38	7850 ± 52
Spreadability (g.cm/sec)	14.8 ± 0.4	18.5 ± 0.5	12.3 ± 0.3
Homogeneity	Good	Excellent	Good

Discussion

The pH values of all formulations were within the acceptable physiological skin pH range (5.5–7.0), indicating suitability for topical application. F2 demonstrated the most desirable viscosity and spreadability characteristics. Lower viscosity observed in F1 resulted in reduced retention time on the skin surface, whereas higher viscosity in F3 adversely affected spreadability.

The excellent homogeneity observed in F2 suggests proper incorporation of herbal extracts and excipients. Similar observations have been reported in polyherbal gel formulations where Carbopol concentrations around 0.5% produced optimum rheological behavior [17,18].

Antimicrobial Activity

The antimicrobial activity of the formulations was evaluated against Gram-positive and Gram-negative bacterial strains using the agar disc diffusion method.

Table 3: Zone of Inhibition of Polyherbal Hand Sanitizer Formulations

Formulation	E. coli (mm)	S. aureus (mm)
F1	12 ± 0.5	14 ± 0.6
F2	18 ± 0.7	20 ± 0.5
F3	22 ± 0.6	24 ± 0.7

Discussion

The antimicrobial activity increased progressively from F1 to F3 due to increasing concentrations of herbal extracts. The highest antimicrobial activity observed in F3 may be attributed to the combined effects of flavonoids, tannins, curcuminoids, terpenoids, and essential oils present in the polyherbal formulation.

Neem extract contains azadirachtin and nimbidin, which exhibit broad-spectrum antimicrobial activity. Tulsi contributes eugenol-mediated antibacterial action, while curcumin from turmeric disrupts microbial membrane integrity. Calendula and Aloe vera further enhance antimicrobial efficacy through synergistic mechanisms [19–22].

Although F3 demonstrated superior antimicrobial activity, its poor physical characteristics and stability reduced its practical applicability. Therefore, F2 was considered more suitable as an optimized formulation.

Minimum Inhibitory Concentration (MIC) Study

The MIC study was conducted to determine the lowest concentration capable of inhibiting visible microbial growth.

Table 4: Minimum Inhibitory Concentration of Formulations

Formulation	E. coli (mg/mL)	S. aureus (mg/mL)
F1	5.0	4.5
F2	2.5	2.0

F3	1.5	1.0

Discussion

MIC values decreased with increasing herbal extract concentration, indicating enhanced antimicrobial potency. F3 exhibited the lowest MIC values, confirming its strongest antibacterial activity. However, considering overall formulation quality, F2 demonstrated a favorable balance between antimicrobial effectiveness and physicochemical stability.

The findings support previous studies demonstrating enhanced antimicrobial activity of polyherbal systems through synergistic interactions among phytoconstituents [23].

Skin Irritation Study

The skin irritation study was performed to assess the dermatological safety of the developed formulations.

Table 5: Skin Irritation Assessment

Formulation	Redness	Itching	Swelling	Irritation Score
F1	Nil	Nil	Nil	0
F2	Nil	Nil	Nil	0
F3	Slight	Nil	Nil	1

Discussion

No signs of erythema, edema, itching, or discomfort were observed with formulations F1 and F2. Slight stickiness associated with F3 resulted in mild discomfort among volunteers. The absence of significant irritation may be attributed to the soothing and moisturizing properties of Aloe vera and Calendula officinalis. These findings indicate that the optimized formulation F2 is safe for repeated topical application [24].

Stability Study

Accelerated stability testing was performed according to ICH guidelines to evaluate formulation stability under different storage conditions.

Table 6: Stability Evaluation of Formulations

Parameter	Day 0	Day 15	Day 30
pH (F2)	6.2 ± 0.03	6.2 ± 0.02	6.1 ± 0.03
Viscosity (cP)	6120 ± 38	6110 ± 42	6095 ± 40
Homogeneity	Excellent	Excellent	Excellent
Appearance	Smooth	Smooth	Smooth
Phase Separation	None	None	None

Discussion

The optimized formulation F2 remained physically and chemically stable throughout the storage period. No significant changes were observed in appearance, pH, viscosity, odor, or homogeneity. The absence of phase separation indicates excellent compatibility among formulation components.

In contrast, F3 exhibited slight phase separation and increased viscosity after prolonged storage, whereas F1 showed slight thinning. These findings suggest that F2 possesses superior formulation stability and is suitable for long-term storage [25].

Statistical Analysis

Results were expressed as Mean ± SD (n = 3). One-way ANOVA revealed statistically significant differences among formulations regarding antimicrobial activity, viscosity, and spreadability ($p < 0.05$). Tukey's post hoc analysis confirmed that F2 exhibited significantly better overall performance compared to F1 while maintaining superior stability compared to F3.

Overall Discussion

The present investigation successfully developed a polyherbal hand sanitizer gel incorporating Azadirachta indica, Ocimum tenuiflorum, Curcuma longa, Calendula officinalis, and Aloe vera. The synergistic action of bioactive phytoconstituents contributed to effective antimicrobial activity against both Gram-positive and Gram-negative microorganisms.

Among all formulations, F2 demonstrated the most favorable balance between antimicrobial efficacy, physicochemical characteristics, safety, and stability. Although F3 exhibited stronger antimicrobial activity, its higher viscosity and reduced stability limited its practical utility. The optimized formulation F2 fulfilled all essential requirements of an ideal herbal hand sanitizer, including acceptable pH, good spreadability, excellent homogeneity, absence of skin irritation, and satisfactory storage stability.

The findings suggest that the developed polyherbal hand sanitizer gel may serve as a safe, effective, and environmentally friendly alternative to conventional synthetic hand sanitizers for routine hand hygiene applications.

CONCLUSION

The present study successfully formulated and evaluated a polyherbal hand sanitizer gel containing Azadirachta indica, Ocimum tenuiflorum, Curcuma longa, Calendula officinalis, and Aloe vera. Three formulations (F1, F2, and F3) were developed and assessed for organoleptic characteristics, physicochemical properties, antimicrobial activity, minimum inhibitory concentration, skin compatibility, and stability.

Among the developed formulations, F2 demonstrated the most favorable overall performance. The formulation exhibited optimal pH, desirable viscosity, excellent spreadability, superior homogeneity, effective antimicrobial activity against Escherichia coli and Staphylococcus aureus, and excellent stability under accelerated storage conditions. Furthermore, the formulation showed no signs of skin irritation, confirming its safety for repeated topical application.

The synergistic antimicrobial action of the selected herbal extracts contributed significantly to the effectiveness of the formulation while minimizing the adverse effects commonly associated with synthetic alcohol-based sanitizers. The incorporation of Aloe vera and Calendula officinalis improved skin compatibility and user acceptability by providing moisturizing and soothing effects.

Therefore, the optimized formulation (F2) can be considered a promising, safe, effective, and environmentally friendly alternative to conventional hand sanitizers. Further studies involving broader antimicrobial screening, long-term stability assessment, and clinical evaluation are recommended to establish its commercial applicability and therapeutic potential.

REFFERENCES

1. El-Otmani N, Zeouk I, Zahidi A. Formulation of Biological Sunscreen from Calendula arvensis Capitula Extracts: Antioxidant, Anti-Aging, Surface Tension, and UVB Protection Properties Assessed. Cosmetics. 2024 Dec 1;11(6). doi:10.3390/cosmetics11060216
2. Tiwari R, Singh I, Gupta M, Singh LP, Tiwari G. Formulation and Evaluation of Herbal Sunscreens: An Assessment Towards Skin Protection from Ultraviolet Radiation. Pharmacophore. 2022 Aug 10;13(3):41–9. doi:10.51847/svzlrfmp5f
3. Miller IB, Pawlowski S, Kellermann MY, Petersen-Thiery M, Moeller M, Nietzer S, et al. Toxic effects of UV filters from sunscreens on coral reefs revisited: regulatory aspects for "reef safe" products. Environ Sci Eur. 2021 Dec 1;33(1). doi:10.1186/s12302-021-00515-w
4. Joshi S, Vaghela K, Patel D, Mishra A, Patel P. Formulation and evaluation of poly-herbal UV protecting cream. International Journal of Pharmacognosy and Pharmaceutical Research. 2024 Jan 1;6(1):26–31. doi:10.33545/26647168.2024.v6.i1a.65
5. Maurya K, Sen DrA. Different natural sunscreen agents and their properties: A review. National Journal of Pharmaceutical Sciences. 2023 Jan 1;3(1):45–9. doi:10.22271/27889262.2023.v3.i1a.68
6. Stoykova ID, Koycheva IK, Binev BK, Mihaylova L V., Benina MY, Alipieva KI, et al. Myconoside and Calceolarioside E Restrain UV-Induced Skin Photoaging by Activating NRF2-Mediated Defense Mechanisms. Int J Mol Sci. 2024 Feb 1;25(4). doi:10.3390/ijms25042441 PubMed PMID: 38397118.
7. Calle A, Curi-Borda CK, Gutiérrez C, Salcedo L, Flores Y, Almanza GR. Quantification and in vitro

photo-protective studies of phenolic compounds from Baccharis papillosa Rusby. J Pharm Pharmacogn Res. 2023 Jan 1;11(1). doi:10.56499/jppres22.1477_11.1.33
8. Sari RK, Wahyuningrum M, Rozan SA, Aulia MI, Rafi M, Wientarsih I. In Vitro Antioxidant and Sunscreen Activities of Gyrinops versteegi Leaf Extract from Different Location in Indonesia and Phytosome Combinations. Res J Pharm Technol. 2022 Nov 1;15(11):5106–11. doi:10.52711/0974-360X.2022.00858
9. Saonere JA, Deore SL, Channawar MA. NEW TRENDS IN SUNSCREEN-AN OVERVIEW. World Journal of Pharmaceutical Research www.wjpr.net │. 2015;10. doi:10.20959/wjpr20214-19993
10. Paredes Contreras BV, Vermelho AB, Casanova L, de Alencar Santos Lage C, Spindola Vilela CL, da Silva Cardoso V, et al. Enhanced UV-B photoprotection activity of carotenoids from the novel Arthrobacter sp. strain LAPM80 isolated from King George Island, Antarctica. Heliyon. 2025 Jan 15;11(1). doi:10.1016/j.heliyon.2024.e41400
11. Kockler J, Oelgemöller M, Robertson S, Glass BD. Photostability of sunscreens. Journal of Photochemistry and Photobiology C: Photochemistry Reviews. 2012 Mar 1;13(1):91–110. doi:10.1016/J.JPHOTOCHEMREV.2011.12.001
12. Ahmady A, Amini MH, Zhakfar AM, Babak G, Sediqi MN. Sun protective potential and physical stability of herbal sunscreen developed from afghan medicinal plants. Turk J Pharm Sci. 2020;17(3):285–92. doi:10.4274/tjps.galenos.2019.15428 PubMed PMID: 32636706.
13. Hau T Van. Uses and mechanism of action of main ingredients in sunscreen products. Middle East Journal of Applied Science & Technology. 2024;07(02):108–16. doi:10.46431/mejast.2024.7210
14. Guenther J, Johnson H, Yu J De, Adler BL. Photoallergic Contact Dermatitis: No Fun in the Sun. Cutis. 2022 Nov 1;110(5). doi:10.12788/cutis.0651 PubMed PMID: 36638383.
15. Serpone N, Dondi D, Albini A. Inorganic and organic UV filters: Their role and efficacy in sunscreens and suncare products. Inorganica Chim Acta. 2007 Feb 15;360(3):794–802. doi:10.1016/j.ica.2005.12.057
16. JC D, CA D. Why Evaluate the Sunscreen Active Oxybenzone (Benzophenone-3) for Carcinogenicity and Reproductive Toxicology or Consider it Unsafe for Human Use? Dermatology Research. 2019 Jun 25;1(1). doi:10.33425/2690-537x.1005
17. Resende DISP, Jesus A, Sousa Lobo JM, Sousa E, Cruz MT, Cidade H, et al. Up-to-Date Overview of the Use of Natural Ingredients in Sunscreens. Pharmaceuticals. 2022 Mar 1;15(3):372. doi:10.3390/PH15030372 PubMed PMID: 35337168.
18. Martinez Faller E, Anika Faco HL, Joshua Guillermo M, Sheine Larido GS, Zaida Pangolima Z, Joy Vanzuela D, et al. Potential Systemic Toxicity of UV Filters in Sunscreen: A Review International Journal of Research Publication and Reviews Potential Systemic Toxicity of UV Filters in Sunscreen: A Review. International Journal of Research Publication and Reviews [Internet]. 2022;3(5):3176–91. Available from: www.ijrpr.com
19. Ngoc LTN, Tran V Van, Moon JY, Chae M, Park D, Lee YC. Recent trends of sunscreen cosmetic: An update review. Cosmetics. 2019;6(4). doi:10.3390/COSMETICS6040064
20. Figueroa FL, Castro-Varela P, Vega J, Losantos R, Peñín B, López-Cóndor L, et al. Novel synthetic UV screen compounds inspired in mycosporine-like amino acids (MAAs): Antioxidant capacity, photoprotective properties and toxicity. J Photochem Photobiol B. 2024 Dec 1;261. doi:10.1016/j.jphotobiol.2024.113050 PubMed PMID: 39515247.
21. Andreani T, Dias-Ferreira J, Fangueiro JF, Souza ALR, Kiill CP, Gremião MPD, et al. Formulating octyl methoxycinnamate in hybrid lipid-silica nanoparticles: An innovative approach for UV skin protection. Heliyon. 2020 May 1;6(5). doi:10.1016/j.heliyon.2020.e03831
22. Fonseca AP, Ribon R, Cascais L, Facchini G, Pinheiro ALTA, Eberlin S, et al. Benefits of a Multifunctional Sunscreen Formulation Containing Nanoencapsulated Antioxidants in the Skin Protection Against UV Radiation and Blue Light: Clinical and Preclinical Studies. J Cosmet Dermatol. 2025 Jun 1;24(6). doi:10.1111/jocd.70282 PubMed PMID: 40536111.
23. Mahajan A, Sharma P, Goudar G, Gogoi P, Ananthan R, Kalpuri S, et al. Evaluating the bioaccessibility and antioxidant activity of polyphenols extracted from vegetables by-product. Food Bioengineering. 2024 Jun 1;3(2):250–65. doi:10.1002/fbe2.12095
24. Costa SCC, Damasceno PKF, Lima RGG, Botura MB, Branco CRC, Silva TRS, et al. Evaluation of antioxidant, photoprotective and antinociceptive activities of Marcetia macrophylla extract: Potential for formulation of sunscreens. Brazilian Journal of Biology. 2023;83. doi:10.1590/1519-6984.246312 PubMed PMID: 34550281.
25. José MT de AF, Pedrita AS, Emanuella CVP, Raimundo G de OJ, Fabrício SS, Jackson RG da SA, et al. Flavonoids as photoprotective agents: A systematic review. Journal of Medicinal Plants Research. 2016 Dec 20;10(47):848–64. doi:10.5897/jmpr2016.6273
26. Choquenet B, Couteau C, Paparis E, Coiffard LJM. Quercetin and rutin as potential sunscreen agents: Determination of efficacy by an in vitro method. J

Nat Prod. 2008 Jun;71(6):1117–8. doi:10.1021/np7007297 PubMed PMID: 18512988.
27. García Forero A, Villamizar Mantilla DA, Núñez LA, Ocazionez RE, Stashenko EE, Fuentes JL. Photoprotective and Antigenotoxic Effects of the Flavonoids Apigenin, Naringenin and Pinocembrin. Photochem Photobiol. 2019 Jul 1;95(4):1010–8. doi:10.1111/php.13085 PubMed PMID: 30636010.
28. Mansuri R, Diwan A, Kumar H, Dangwal K, Yadav D. Potential of Natural Compounds as Sunscreen Agents. Pharmacogn Rev. 2021 Jun 7;15(29):47–56. doi:10.5530/phrev.2021.15.5
29. Li L, Wang Q, Cao Y, Li J, Wu Y, Hua C, et al. Antioxidant action and potential neuroprotection of polyphenolics extracted from Astragalus membranaceus residue. Front Nutr. 2025;12. doi:10.3389/fnut.2025.1621848
30. Letchuman S, Madhuranga HDT, Madhurangi BLNK, Premarathna AD, Saravanan M. Alkaloids unveiled: A comprehensive analysis of novel therapeutic properties, mechanisms, and plant-based innovations. Intelligent Pharmacy. 2025 Aug 1;3(4):268–76. doi:10.1016/J.IPHA.2024.09.007
31. Alhowail A. Molecular insights into the benefits of nicotine on memory and cognition (Review). Mol Med Rep. 2021 Jun 1;23(6). doi:10.3892/MMR.2021.12037 PubMed PMID: 33786606.
32. Hendrawati TY, Ambarwati H, Nugrahani RA, Susanty S, Hasyim UH. The Effects of Aloe Vera Gel Addition on the Effectiveness of Sunscreen Lotion. Jurnal Rekayasa Proses. 2020 Jun 30;14(1). doi:10.22146/jrekpros.45247
33. Chaiyana W, Liang G, Inthorn J, Chomchalao P. Cricket Oil-Based Sunscreen Systems: Formulation Design, Ultraviolet Protection Performance, and Preclinical Safety Evaluation. Pharmaceutics. 2026 Mar 4;18(3):325. doi:10.3390/pharmaceutics18030325
34. Kaur CD, Saraf S. In vitro sun protection factor determination of herbal oils used in cosmetics. Pharmacognosy Res. 2010 Jan 1;2(1):22–5. doi:10.4103/0974-8490.60586 PubMed PMID: 21808534.
35. S BBP, B DR, B DA, H DD. Formulation and evaluation of a Vitis vinifera (grape seed oil), Simmondsia chinensis (Jojoba oil) & Camellia sinensis (green tea) containing herbal sunscreen. International Journal of Pharmacognosy and Clinical Research. 2024 Jan 1;6(2):86–91. doi:10.33545/2664763x.2024.v6.i2a.62
36. Bala VC, Gupta AK. Phytochemicals as a Promising Approach to Rheumatoid Arthritis: Current Perspectives. BIO Integration. 2026;7(1). doi:10.15212/bioi-2025-0142
37. Zhou S, Hou S, Lu Q. A Microparticle Sunscreen with Highly Effective ROS Scavenging and Nonpenetration. Polymer Science & Technology. 2025 Oct 28. doi:10.1021/polymscitech.4c00010
38. Holt EL, Krokidi KM, Turner MAP, Mishra P, Zwier TS, Rodrigues NDN, et al. Insights into the photoprotection mechanism of the UV filter homosalate. Physical Chemistry Chemical Physics. 2020 Jul 21;22(27):15509–19. doi:10.1039/d0cp02610g PubMed PMID: 32602867.
39. Toppo M, Shrivastava S. Polyherbal Sunscreen Cream: Formulation, Physicochemical Evaluation, And In Vitro SPF Determination. International Journal of Pharmacognosy and Herbal Drug Technology. 2025 Aug 28;01–13. doi:10.64063/3049-1630.vol.2.issue8.1
40. Shabrina AM, Azzahra RSS, Permata IN, Dewi HP, Safitri RA, Maya I, et al. Potential of Natural-Based Sun Protection Factor (SPF): A Systematic Review of Curcumin as Sunscreen. Cosmetics. Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/cosmetics12010010
41. Hendrawati TY, Ambarwati H, Nugrahani RA, Susanty S, Hasyim UH. The Effects of Aloe Vera Gel Addition on the Effectiveness of Sunscreen Lotion. Jurnal Rekayasa Proses. 2020 Jun 30;14(1). doi:10.22146/jrekpros.45247
42. Faizatun F, Tanoto V, Maharani SC. Formulation, characterization, antioxidant and sun protection factor activity of red pomegranate (Punica granatum l.) peel extract in sunscreen lotion. Journal of Natural Product for Degenerative Diseases. 2025 Mar 29;2(2):70–7. doi:10.58511/jnpdd.v2i2.8444
43. Fuentes JL, Pedraza Barrera CA, Villamizar Mantilla DA, Flórez González SJ, Sierra LJ, Ocazionez RE, et al. Flower Extracts from Ornamental Plants as Sources of Sunscreen Ingredients: Determination by In Vitro Methods of Photoprotective Efficacy, Antigenotoxicity and Safety. Molecules. 2022 Sep 1;27(17). doi:10.3390/molecules27175525 PubMed PMID: 36080288.
44. Nobile V, Burioli A, Yu S, Zhifeng S, Cestone E, Insolia V, et al. Photoprotective and Antiaging Effects of a Standardized Red Orange (Citrus sinensis (L.) Osbeck) Extract in Asian and Caucasian Subjects: A Randomized, Double-Blind, Controlled Study. Nutrients. 2022 Jun 1;14(11). doi:10.3390/nu14112241 PubMed PMID: 35684041.
45. Kalisetti D. Review on herbal sunscreen. UPI Journal of Pharmaceutical, Medical and Health Sciences. 2025 Dec 28;51–2. doi:10.37022/jpmhs.v8i4.160
46. Bala I, Sundari T, Prakash KS, Akhila P. DEVELOPMENT AND ASSESSMENT OF A HERBAL SUNSCREEN LOTION FORMULATED WITH POMEGRANATE PEEL EXTRACT. Monthly, Peer-Reviewed, Refereed, Indexed Journal

with IC Value: 86. 2025;87(11):2455–0620. doi:10.2015/IJIRMF/202509027

47. Rodrigues LR, Jose J. Exploring the photo protective potential of solid lipid nanoparticle-based sunscreen cream containing Aloe vera. Environmental Science and Pollution Research. 2020 Jun 1;27(17):20876–88. doi:10.1007/s11356-020-08543-4 PubMed PMID: 32249384.
48. Patil M, Sabale K, Prajapati S, Salunkhe P, Jadhav S, Janugade B. A Comprehensive Review on Herbal Sunscreen Lotions: Formulation Approaches, Evaluation Methods, and Regulatory Status. Int. J. Sci. R. Tech [Internet]. 2026. Available from: www.ijsrtjournal.com
49. Dwivedi J, Wal P, Kaushal S, Kumar Tripathi A, Gupta P, Prakash Rao S. Phytosome based cosmeceuticals for enhancing percutaneous absorption and delivery. Journal of Research in Pharmacy. 2025 Mar 3;29(1):242–71. doi:10.12991/jrespharm.1643734
50. Ramadon D, McCrudden MTC, Courtenay AJ, Donnelly RF. Enhancement strategies for transdermal drug delivery systems: current trends and applications. Drug Deliv Transl Res. 2022 Apr 1;12(4):758–91. doi:10.1007/s13346-021-00909-6 PubMed PMID: 33474709.
51. Talebi M, Shahbazi K, Dakkali MS, Akbari M, Almasi Ghale R, Hashemi S, et al. Phytosomes: A promising nanocarrier system for enhanced bioavailability and therapeutic efficacy of herbal products. Phytomedicine Plus. Elsevier B.V.; 2025. doi:10.1016/j.phyplu.2025.100779
52. Kumar N, Goel R, Ansari MN, S Saeedan A, Ali H, Sharma NK, et al. Formulation of Phytosomes Containing Rubia cordifolia Extract for Neuropathic Pain: In Vitro and In Vivo Evaluation. ACS Omega. 2024 Jun 11;9(23):25381–9. doi:10.1021/acsomega.4c03774
53. Bala VC, Gupta AK. Phytochemicals as a Promising Approach to Rheumatoid Arthritis: Current Perspectives. BIO Integration. 2026;7(1). doi:10.15212/bioi-2025-0142
54. Shabrina AM, Azzahra RSS, Permata IN, Dewi HP, Safitri RA, Maya I, et al. Potential of Natural-Based Sun Protection Factor (SPF): A Systematic Review of Curcumin as Sunscreen. Cosmetics. Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/cosmetics12010010
55. Mehta G, Rani R, Singh AP, Singh AP. Phytosomes in herbal formulation: an updated review. International Journal of Pharmaceutics and Drug Analysis. 2024 Apr 14;51–7. doi:10.47957/ijpda.v12i1.574
56. Bele S. |Review INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES 4068 | P a g e. Int J of Pharm Sci. 2025;3:4068–75. doi:10.5281/zenodo.16608330
57. P K, R K. Phytosome Technology: A Novel Breakthrough for the Health Challenges. Cureus. 2024 Aug 30. doi:10.7759/cureus.68180
58. Justo-Hanani R. The Impact of EU Nanotechnology Risk Regulation on Non-EU Countries: The Case of Israel's Policy Reform for Cosmetic Products. European Journal of Risk Regulation. 2025 Jun 1;16(2):670–83. doi:10.1017/err.2025.3
59. Alharbi WS, Almughem FA, Almehmady AM, Jarallah SJ, Alsharif WK, Alzahrani NM, et al. Phytosomes as an emerging nanotechnology platform for the topical delivery of bioactive phytochemicals. Pharmaceutics. MDPI; 2021. doi:10.3390/pharmaceutics13091475
60. Tampucci S, Burgalassi S, Chetoni P, Monti D. Cutaneous permeation and penetration of sunscreens: Formulation strategies and in vitro methods. Cosmetics. MDPI AG; 2018. doi:10.3390/cosmetics5010001
61. Antonara L, Triantafyllopoulou E, Chountoulesi M, Pippa N, Dallas PP, Rekkas DM. Lipid-Based Drug Delivery Systems: Concepts and Recent Advances in Transdermal Applications. Nanomaterials. Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/nano15171326
62. Ijaz M, Madni A, Khan HMS, Arshad T, Meer S, Ijaz F, et al. Nanostructured Lipid Carrier Based Gel Containing α-Tocopherol and α-Tocopheryl Acetate for Synergistic Cutaneous Antiaging Efficacy. Sci Rep. 2025 Dec 1;15(1). doi:10.1038/s41598-025-26277-6 PubMed PMID: 41309687.
63. 63. Ricci A, Stefanuto L, Gasperi T, Bruni F, Tofani D. Lipid Nanovesicles for Antioxidant Delivery in Skin: Liposomes, Ufasomes, Ethosomes, and Niosomes. Antioxidants. Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi:10.3390/antiox13121516