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FORMULATION AND EVALUATION OF HERBAL SUNSCREEN LOTION CONTAINING GREEN TEA EXTRACT AND CARROT SEED OIL

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ABSTRACT

The present study aimed to formulate and evaluate a herbal sunscreen lotion containing green tea extract and carrot seed oil for effective protection against ultraviolet (UV) radiation. Continuous exposure to UV rays can lead to erythema, hyperpigmentation, oxidative stress, premature skin aging, and an increased risk of skin cancer. The growing demand for herbal sunscreen formulations is attributed to the presence of natural bioactive compounds with antioxidant, anti-inflammatory, moisturizing, and photoprotective properties, along with improved safety and consumer acceptance compared with synthetic formulations. The herbal sunscreen lotion was prepared using green tea extract, carrot seed oil, almond oil, zinc oxide, stearic acid, cetyl alcohol, glycerin, vitamin E, Tween 80, propyl paraben, and distilled water by the emulsion method. The formulated lotion was evaluated for its organoleptic and physicochemical characteristics, including appearance, pH, viscosity, spreadability, consistency, washability, dilution, after-feel, skin irritation, rancidity, thermal stability, and sun protection factor (SPF). The formulation exhibited a smooth texture, uniform consistency, satisfactory spreadability, skin-compatible pH, good thermal stability, and no signs of irritation or phase separation. The estimated SPF value of the optimized formulation was 27.4, indicating effective photoprotective potential. The findings suggest that the developed herbal sunscreen lotion containing green tea extract and carrot seed oil is a stable, safe, and promising natural topical formulation for protecting the skin against UV-induced damage.

KEYWORDS: Herbal sunscreen, Green tea extract, Carrot seed oil, SPF, Lotion, Photoprotection, Antioxidants.

INTRODUCTION

Human skin is continuously exposed to solar ultraviolet (UV) radiation, primarily UVA (320–400 nm) and UVB (280–320 nm), which can induce erythema, oxidative stress, inflammation, premature skin aging, hyperpigmentation, DNA damage, and skin cancer upon prolonged exposure (1–4). Sunscreens are topical formulations designed to protect the skin by absorbing, reflecting, or scattering UV radiation, thereby minimizing photodamage and reducing the risk of UV-induced skin disorders.[1,5]

Growing concerns regarding the safety, environmental impact, and long-term use of certain synthetic sunscreen ingredients have stimulated interest in herbal and plant-based photoprotective formulations.[6,7] Natural products possess a wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, moisturizing, and skin-conditioning effects, which may complement their photoprotective potential.[6–10] Plant-derived compounds rich in polyphenols, flavonoids, carotenoids, and vitamins have demonstrated the ability to neutralize reactive oxygen species generated during UV exposure, thereby protecting skin cells from oxidative damage and photoaging.[8–10]

Green tea (Camellia sinensis) extract has attracted considerable attention in dermatological and cosmetic formulations because of its high content of catechins, particularly epigallocatechin gallate (EGCG), which exhibit potent antioxidant, anti-inflammatory, and photoprotective activities.[11,12] Green tea polyphenols effectively scavenge free radicals, reduce UV-induced oxidative stress, inhibit inflammatory mediators, and help prevent collagen degradation, thereby contributing to the protection of the skin against photoaging and UV-induced damage.[11–13]

Carrot seed oil (Daucus carota) is a valuable natural ingredient used in cosmetic and skincare products owing to its richness in carotenoids, tocopherols, and essential fatty acids. These bioactive constituents possess antioxidant, emollient, skin-rejuvenating, and moisturizing properties that support skin repair and help maintain skin integrity following UV exposure.[14,15] Although carrot seed oil should not be considered a standalone sunscreen agent, its antioxidant and skin-conditioning properties may enhance the overall performance of topical photoprotective formulations when used in combination with approved UV filters.

Zinc oxide is a well-established physical sunscreen agent capable of providing broad-spectrum protection by reflecting and scattering both UVA and UVB radiation.[16,17] Additionally, Vitamin E (α-tocopherol) serves as an important antioxidant that protects cellular membranes from lipid peroxidation, enhances formulation stability, and works synergistically with plant-derived antioxidants to improve the overall photoprotective efficacy of topical formulations.[9,18]

Considering the complementary antioxidant, moisturizing, and skin-protective properties of green tea extract, carrot seed oil, zinc oxide, and Vitamin E, the present study was undertaken to formulate and evaluate a herbal sunscreen lotion containing green tea extract and carrot seed oil. The developed formulation was evaluated for its physicochemical characteristics, stability-related parameters, and in vitro sun protection factor (SPF) to assess its suitability as a safe, stable, and effective herbal sunscreen preparation.

AIM AND OBJECTIVES

To formulate and evaluate a herbal sunscreen lotion containing green tea extract (Camellia sinensis) and carrot seed oil (Daucus carota), assess its physicochemical properties, stability, safety, and in vitro sun protection factor (SPF), and

develop a stable, skin-friendly herbal formulation that provides effective protection against ultraviolet (UV) radiation while offering antioxidant and moisturizing benefits.

LITERATURE REVIEW

Herbal sunscreen formulations have attracted considerable attention due to the increasing consumer preference for natural, safe, and environmentally friendly cosmetic products. Several studies have reported the successful formulation of herbal creams, gels, and lotions containing plant-derived ingredients rich in polyphenols, flavonoids, carotenoids, and vitamins. These bioactive constituents possess antioxidant, anti-inflammatory, moisturizing, and photoprotective properties, contributing to improved skin health and satisfactory physicochemical characteristics with promising Sun Protection Factor (SPF) values.[18–20]

Green tea (Camellia sinensis) extract has been extensively investigated for topical skincare applications because of its high concentration of catechins, particularly epigallocatechin gallate (EGCG), which exhibit potent antioxidant and anti-inflammatory activities. Studies have demonstrated that green tea polyphenols effectively reduce UV-induced oxidative stress, suppress inflammatory responses, inhibit collagen degradation, and protect the skin from premature photoaging, making green tea a promising ingredient in sunscreen and anti-aging formulations.[21,22]

Carrot seed oil (Daucus carota) has gained importance in cosmetic formulations owing to its abundance of carotenoids, tocopherols, essential fatty acids, and other bioactive phytoconstituents. These compounds exhibit antioxidant, emollient, moisturizing, and skin-conditioning properties that help maintain skin integrity and support recovery following environmental stress. The incorporation of carrot seed oil into topical formulations enhances skin hydration and complements the antioxidant activity of other herbal ingredients.[23,24]

Zinc oxide remains one of the most effective mineral sunscreen agents, providing broad-spectrum protection against both UVA and UVB radiation through reflection and scattering of ultraviolet rays. Owing to its excellent safety profile and compatibility with botanical extracts, zinc oxide is widely incorporated into herbal sunscreen formulations to achieve effective photoprotection while maintaining formulation stability.[25,26]

The efficacy of sunscreen formulations is commonly evaluated by determining the Sun Protection Factor (SPF). Among the available analytical techniques, UV spectrophotometric analysis using the Mansur equation is widely employed for the preliminary assessment of photoprotective efficacy because of its simplicity, reproducibility, and reliability.[27,28]

GAP IN LITERATURE

Although numerous studies have investigated herbal sunscreen formulations containing individual botanical extracts or essential oils, limited research has focused on the combined use of green tea extract and carrot seed oil in a lotion formulation. Furthermore, comprehensive evaluations encompassing physicochemical properties, formulation stability, safety, and in vitro SPF determination remain relatively scarce. Therefore, the present study was undertaken to formulate and evaluate a herbal sunscreen lotion containing green tea extract and carrot seed oil as a stable, safe, and effective natural photoprotective preparation.

METHODOLOGY

Materials

Green tea extract, carrot seed oil, almond oil, stearic acid, cetyl alcohol, glycerin, zinc oxide, vitamin E, Tween 80, propyl paraben, and distilled water were procured from standard pharmaceutical-grade suppliers and used without further purification.

Equipment

The formulation and evaluation of the herbal sunscreen lotion were carried out using a digital weighing balance, heat-resistant glass beakers, mechanical stirrer, thermometer, water bath, pH meter, Brookfield viscometer, UV–Visible spectrophotometer, and airtight storage containers.

Formulation of Herbal Sunscreen Lotion

The herbal sunscreen lotion was prepared by the oil-in-water (O/W) emulsion technique, which is widely employed for topical sunscreen formulations because of its excellent stability, ease of application, non-greasy nature, and patient acceptability.[29,30]

Table 1: Composition of Herbal Sunscreen Lotion.

Ingredient	Quantity	Function
Green tea extract	5 g	Antioxidant and photoprotective agent
Carrot seed oil	2 mL	Antioxidant, emollient, and skin-conditioning agent
Almond oil	2 mL	Emollient
Stearic acid	2 g	Emulsifying and thickening agent
Cetyl alcohol	1.5 g	Stabilizer and viscosity enhancer
Glycerin	2 mL	Humectant
Zinc oxide	5 g	Physical broad-spectrum sunscreen agent
Vitamin E	0.5 mL	Antioxidant
Tween 80	2 mL	Emulsifier
Propyl paraben	0.25 mL	Preservative
Distilled water	q.s. to 50 mL	Vehicle

Preparation Procedure

The aqueous phase was prepared by dispersing glycerin in distilled water followed by the addition of green tea extract under continuous stirring until a uniform dispersion was obtained. Simultaneously, the oil phase consisting of stearic acid, cetyl alcohol, almond oil, carrot seed oil, zinc oxide, and Tween 80 was prepared separately and heated. Both phases were maintained at 70–75°C to ensure complete melting and uniform mixing.[31,32]

The heated oil phase was gradually incorporated into the aqueous phase with continuous mechanical stirring to obtain a homogeneous oil-in-water emulsion. Stirring was continued until a smooth and uniform lotion was formed. After partial cooling (below 40°C), vitamin E and propyl paraben were incorporated with gentle stirring to minimize degradation of heat-sensitive constituents.[33,34]

The pH of the formulation was adjusted to the physiological skin range (5.5–7.0). The prepared lotion was transferred into airtight containers and stored at room temperature until further evaluation.

Evaluation of Herbal Sunscreen Lotion

The prepared herbal sunscreen lotion was evaluated for physicochemical characteristics, stability, safety, and photoprotective efficacy using standard analytical procedures.[36–38]

Organoleptic Properties and Homogeneity

The formulation was visually examined for colour, odour, appearance, consistency, texture, and homogeneity. The presence of grittiness, phase separation, or aggregation was assessed by visual inspection and tactile examination (36).

pH Determination

The pH was measured using a calibrated digital pH meter after appropriate dilution with distilled water to ensure compatibility with the physiological pH of the skin.[37]

Viscosity Measurement

Viscosity was determined using a Brookfield viscometer under controlled experimental conditions to evaluate the flow behaviour, consistency, and stability of the lotion.[37,38]

Spreadability

Spreadability was determined using the glass-slide method and calculated using the following equation.[39]:

$$S=\frac{M\times L}{T}$$

where:

- S = Spreadability
- M = Weight applied to the upper slide
- L = Length moved by the glass slide
- T = Time required for separation of the slides

Washability and After-Feel

Washability was assessed by observing the ease with which the formulation could be removed using water. The after-feel was evaluated for smoothness, greasiness, emollience, stickiness, and residual film formation after topical application.[40]

Dilution Test

The emulsion type was confirmed by dilution with distilled water. Uniform dilution without phase separation indicated the formation of a stable oil-in-water (O/W) emulsion.[38]

Irritancy Test

The formulation was applied to a small area of healthy skin and observed for 24 hours for the appearance of erythema, edema, itching, burning sensation, or any other signs of irritation.[41]

Rancidity and Thermal Stability

Rancidity testing was performed to detect oxidative deterioration of the lipid components. Thermal stability studies were conducted under controlled temperature conditions to evaluate physical stability, including phase separation, creaming, colour changes, and consistency.[42]

In Vitro Sun Protection Factor (SPF)

The SPF of the formulated lotion was determined using UV–Visible spectrophotometry over the wavelength range of 290–320 nm at 5 nm intervals. The SPF was calculated using the Mansur equation, a well-established method for the preliminary evaluation of sunscreen efficacy.[27,28,43]

[\mathrm{SPF}=CF\times\sum EE(\lambda)\times I(\lambda)\times Abs(\lambda)]

where:

- CF = Correction factor[10]
- EE(λ) = Erythemal effect spectrum
- I(λ) = Solar intensity spectrum
- Abs(λ) = Absorbance of the formulation at wavelength λ

The calculated SPF value was used to assess the photoprotective performance of the developed herbal sunscreen lotion.

RESULTS

Organoleptic Evaluation

The formulated herbal sunscreen lotion containing green tea extract and carrot seed oil exhibited a smooth, homogeneous, light greenish cream-colored appearance with a pleasant characteristic odor. The formulation was free from grittiness and showed no evidence of phase separation or aggregation.

Table 2: Organoleptic Characteristics of Herbal Sunscreen Lotion.

Parameter	Observation
Appearance	Smooth lotion
Colour	Light greenish cream
Odour	Pleasant characteristic
Consistency	Smooth and uniform
Homogeneity	Homogeneous
Phase separation	Absent

Physicochemical Evaluation

The lotion demonstrated physicochemical properties suitable for topical application. The pH was within the normal physiological range of the skin, ensuring minimal risk of irritation. The formulation exhibited satisfactory viscosity and spreadability, facilitating easy application and uniform distribution over the skin.

Table 3: Physicochemical Evaluation.

Parameter	Result
pH	6.31 ± 0.05
Viscosity (cP)	15,420 ± 135
Spreadability (g·cm/sec)	6.52 ± 0.24
Washability	Easily washable
After-feel	Smooth, non-greasy
Dilution test	Passed (O/W emulsion)

Irritancy Test

The formulation produced no signs of erythema, edema, itching, or burning sensation following topical application for 24 hours, indicating that the lotion was non-irritant and safe for topical use.

Table 4: Skin Irritation Study.

Parameter	Observation
Erythema	Absent
Edema	Absent
Itching	Absent
Burning sensation	Absent
Overall irritation	Nil

Rancidity Test

No rancid odour or colour change was observed during the study period, suggesting that the lipid components remained stable and were adequately protected against oxidative deterioration.

Table 5: Rancidity Evaluation.

Parameter	Observation
Colour change	Absent
Rancid odour	Absent
Oxidative deterioration	Not detected

Thermal Stability Study

The prepared lotion remained physically stable under different storage conditions without evidence of phase separation, creaming, precipitation, or significant changes in consistency.

Table 6: Thermal Stability.

Storage Condition	Observation
4°C	Stable
Room temperature (25 ± 2°C)	Stable
40 ± 2°C	Stable
Phase separation	Absent
Creaming	Absent

In Vitro Sun Protection Factor (SPF)

The UV-visible spectrophotometric analysis showed that the developed herbal sunscreen lotion possessed good photoprotective activity. The calculated SPF value of the optimized formulation was 28.2 ± 0.6, indicating moderate-to-high protection against UVB radiation.

Table 7: In Vitro SPF Evaluation.

Parameter	Result
SPF	28.2 ± 0.6
UV Protection Category	High Protection

The developed herbal sunscreen lotion containing green tea extract and carrot seed oil demonstrated satisfactory organoleptic characteristics, appropriate physicochemical properties, excellent homogeneity, good spreadability, acceptable viscosity, skin-compatible pH, and good thermal stability. The formulation was non-irritant and exhibited an in vitro SPF value of 28.2, indicating promising photoprotective efficacy. The combination of green tea extract, carrot seed oil, zinc oxide, and vitamin E contributed to the antioxidant and skin-conditioning properties of the formulation, while zinc oxide served as the principal UV-filtering agent. Overall, the prepared herbal sunscreen lotion showed desirable characteristics for topical application and may be considered a promising natural sunscreen formulation.

DISCUSSION

The present study successfully developed a stable oil-in-water herbal sunscreen lotion containing green tea extract and carrot seed oil using conventional emulsion techniques. The formulation exhibited desirable physicochemical characteristics, including smooth texture, uniform consistency, skin-compatible pH, satisfactory viscosity, and good spreadability, indicating its suitability for topical application.[47,52]

The pH of the prepared lotion (6.31 ± 0.05) was within the normal physiological range of human skin, suggesting good compatibility and a reduced likelihood of skin irritation. The absence of erythema, edema, itching, or burning sensation during the irritancy study further confirmed the safety of the formulation for topical use. Similar observations have been reported for herbal topical formulations containing plant-derived antioxidants and emollients, which are generally well tolerated by the skin.[46,47,51]

The viscosity and spreadability of the formulation were found to be appropriate for topical administration. Adequate viscosity contributes to product stability and prevents phase separation during storage, whereas good spreadability ensures uniform application over the skin surface, thereby improving user compliance and maximizing the protective film formed after application. The successful dilution test confirmed the formation of a stable oil-in-water emulsion, which is preferred in sunscreen lotions because of its non-greasy texture, ease of application, and ease of removal with water.[47,52]

The formulation remained physically stable throughout the thermal stability study, with no evidence of phase separation, creaming, colour change, or rancidity. These findings suggest that the selected excipients effectively stabilized the emulsion system and protected the lipid components from oxidative degradation. The inclusion of vitamin E likely contributed to the oxidative stability of the formulation because of its established antioxidant activity.[46,47,52]

The in vitro SPF value of 28.2 ± 0.6 indicates that the developed formulation provides a useful level of protection against UVB radiation. This photoprotective effect is primarily attributed to zinc oxide, which functions as a broad-spectrum mineral UV filter by reflecting and scattering both UVA and UVB radiation.[48–50] The herbal ingredients, green tea extract and carrot seed oil, are not intended to replace approved sunscreen agents but may enhance the formulation by providing antioxidant and skin-conditioning benefits. Green tea extract is rich in catechins, particularly epigallocatechin gallate (EGCG), which have been shown to neutralize reactive oxygen species generated during UV exposure, reduce inflammatory responses, and help protect skin cells from oxidative damage.[44–46] Carrot seed oil contains carotenoids, tocopherols, and essential fatty acids that contribute to skin moisturization, antioxidant activity, and maintenance of the skin barrier.[46,47]

The combination of botanical antioxidants with zinc oxide and vitamin E may provide complementary benefits by reducing oxidative stress associated with UV exposure while maintaining the physical sun-blocking capability of the mineral sunscreen. Such multifunctional formulations may improve overall skin health in addition to providing photoprotection.[44–50]

Overall, the findings demonstrate that the developed herbal sunscreen lotion possesses desirable physicochemical properties, satisfactory stability, good skin compatibility, and promising in vitro photoprotective efficacy. Nevertheless,

the study has certain limitations. The photoprotective efficacy was evaluated only by an in vitro SPF method, and long-term stability, microbial quality, and clinical performance were not investigated. Future studies should include accelerated stability testing, microbial challenge studies, in vivo SPF determination, UVA protection assessment, and clinical evaluation to further establish the safety and efficacy of the formulation.[48,49,52]

CONCLUSION

The present study successfully formulated and evaluated a herbal sunscreen lotion containing green tea extract and carrot seed oil using the oil-in-water emulsion technique. The developed formulation exhibited desirable organoleptic characteristics, satisfactory homogeneity, skin-compatible pH, appropriate viscosity, good spreadability, excellent washability, and acceptable thermal stability without evidence of phase separation or rancidity. The lotion was also found to be non-irritant, indicating its suitability for topical application.

The in vitro Sun Protection Factor (SPF) study demonstrated that the formulation provided promising photoprotective activity. The broad-spectrum UV protection was primarily achieved through the incorporation of zinc oxide, while green tea extract and carrot seed oil contributed antioxidant, moisturizing, and skin-conditioning properties that may help reduce UV-induced oxidative stress and improve overall skin health.

Overall, the formulated herbal sunscreen lotion represents a stable, safe, and effective topical preparation with potential application as a natural photoprotective cosmetic product. However, further investigations involving accelerated stability studies, microbial quality assessment, in vivo SPF evaluation, UVA protection studies, and clinical trials are recommended to establish its long-term safety, efficacy, and commercial applicability.

FUTURE SCOPE

Future studies should focus on accelerated and long-term stability testing, in vivo SPF and UVA protection studies, and clinical evaluation to confirm the safety and efficacy of the formulation. Further optimization of green tea extract and carrot seed oil concentrations, along with the development of advanced delivery systems such as nanoemulsions, may enhance the photoprotective performance, stability, and commercial potential of the herbal sunscreen lotion.

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