

Formulation and Evaluation of a Marine-Based Sunscreen Stick Containing *Kappaphycus alvarezii*

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Abstract: Excessive exposure to ultraviolet (UV) radiation can cause skin damage, premature aging, and skin cancer. This study aimed to formulate and evaluate a marine herbal sunscreen stick using *Kappaphycus alvarezii*, zinc oxide, and natural ingredients such as beeswax, shea butter, coconut oil, carrot seed oil, and vitamin E. The prepared formulations were evaluated for physical appearance, pH, spreadability, antioxidant activity, anti-inflammatory activity, and Sun Protection Factor (SPF). The optimized formulation showed good physical properties, satisfactory spreadability, a skin-friendly pH (6–7), 56% antioxidant activity, 61% anti-inflammatory activity, and an SPF value of 15. The results indicate that the marine herbal sunscreen stick provides effective UV protection and has promising antioxidant and anti-inflammatory properties. Therefore, it may serve as a safe and eco-friendly alternative to conventional sunscreens.

Objective: To formulate and evaluate a marine herbal sunscreen stick containing *Kappaphycus alvarezii* and natural ingredients for photoprotective efficacy.

Keywords: *Kappaphycus alvarezii*, Marine sunscreen, Herbal sunscreen stick, Antioxidant, SPF, Zinc oxide.

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Introduction

Ultraviolet (UV) radiation is one of the major environmental factors responsible for skin damage, photoaging, oxidative stress, inflammation, and skin cancer. Approximately 95% of the ultraviolet radiation reaching the Earth's surface consists of UVA rays, while only 5% is UVB. UVA penetrates deeper into the skin, leading to premature aging, whereas UVB causes erythema, sunburn, and DNA damage. Excessive exposure to UV radiation also generates reactive oxygen species (ROS), resulting in oxidative stress and cellular injury [1,2,3].

Sunscreens protect the skin by absorbing, reflecting, or scattering ultraviolet radiation. However, increasing

concerns regarding the safety of synthetic UV filters and their environmental impact have encouraged the development of natural and eco-friendly sunscreen formulations [4].

Marine algae are rich sources of bioactive compounds with antioxidant and photoprotective properties. Among them, *Kappaphycus alvarezii* contains mycosporine-like amino acids (MAAs), sulfated polysaccharides, and polyphenols that exhibit natural UV-absorbing, antioxidant, and anti-inflammatory activities [5,6,7].

Natural ingredients such as carrot seed oil, coconut oil, beeswax, shea butter, vitamin E, and zinc oxide have also been reported to enhance sunscreen efficacy by providing

antioxidant protection, moisturization, and broad-spectrum UV protection[8] .

Therefore, the present study aimed to formulate and evaluate a marine-based herbal sunscreen stick containing *Kappaphycus alvarezii* [9]for photoprotective, antioxidant, and anti-inflammatory activities

Materials and Methods

The sunscreen stick was prepared using *Kappaphycus alvarezii* powder, zinc oxide, carrot seed oil, coconut oil, beeswax, shea butter, vitamin E oil, and lavender oil following the melting method reported for herbal sunscreen formulations [10-30]

S. No.	Ingredients	Function	F1	F2	F3	F4	F5
1	<i>Kappaphycus alvarezii</i> powder (g)	Natural UV absorber, antioxidant	1.2	1.5	1.8	2.0	2.2
2	Zinc oxide (g)	Physical UV filter	2.8	2.8	3.0	3.0	3.2
3	Carrot seed oil (mL)	Antioxidant, skin nourishing agent	1.0	1.0	1.0	1.0	1.0
4	Shea butter (g)	Emollient, moisturizer	2.5	2.5	2.5	2.5	2.5
5	Beeswax (g)	Stiffening agent, base	5.0	5.0	5.0	5.0	5.0
6	Coconut oil (mL)	Emollient, spreading agent	6.0	5.7	5.3	5.0	4.7
7	Vitamin E oil (mL)	Antioxidant, photostabilizer	0.6	0.6	0.6	0.6	0.6
8	Lavender oil (mL)	Fragrance	0.6	0.6	0.6	0.6	0.6

The marine herbal sunscreen stick was prepared by the fusion (melt-pour) method. Beeswax and shea butter were accurately weighed and melted together in a water bath at 70–75°C. Coconut oil was added to the molten base and mixed thoroughly until a uniform mixture was obtained. Zinc oxide was gradually incorporated into the molten base with continuous stirring to ensure uniform dispersion. Finely powdered *Kappaphycus alvarezii* was then added slowly and mixed thoroughly. Carrot seed oil and vitamin E oil were incorporated into the formulation, and the mixture was allowed to cool to approximately 45–50°C. Finally, lavender oil was added, and the homogeneous mixture was poured into sunscreen stick moulds. The sticks were allowed to cool and solidify at room temperature before being removed from the moulds and stored in airtight containers for further evaluation[31,32,33,34] .

Evaluation of Marine Herbal Sunscreen Stick

Physical Appearance

The prepared sunscreen sticks were evaluated for colour, odour, appearance, texture, homogeneity, pH, and the presence of any cracks or phase separation. The pH was determined using a calibrated digital pH meter [35].

Spreadability

Spreadability was determined by the parallel-plate method. Approximately 1 g of the formulation was placed between two glass plates, and a standard weight was applied. The

diameter of the spread formulation was measured and recorded in centimetres[36] .

Antioxidant Activity (DPPH Assay)

The antioxidant activity of the formulation was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay. The absorbance was measured at 517 nm using a UV–Visible spectrophotometer, and the percentage inhibition was calculated using ascorbic acid as the standard[37,38] .

Anti-inflammatory Activity

The anti-inflammatory activity was determined by the egg albumin denaturation method. Different concentrations of the formulation were incubated with egg albumin and phosphate buffer, followed by heating. The absorbance was measured at 660 nm, and the percentage inhibition of protein denaturation was calculated using diclofenac sodium as the standard [39].

Determination of Sun Protection Factor (SPF)

The in vitro Sun Protection Factor (SPF) of the optimized formulation was determined by the spectrophotometric method described by Mansur et al. The absorbance was recorded in the wavelength range of 290–320 nm, and the SPF value was calculated using the Mansur equation[40,41]

Conclusion

A marine herbal sunscreen stick containing *Kappaphycus alvarezii* was successfully formulated and evaluated. The optimized formulation exhibited good physicochemical characteristics, including smooth texture, satisfactory spreadability, and a skin-compatible pH. It also demonstrated moderate antioxidant activity, significant anti-inflammatory activity, and an SPF value of 15, indicating effective protection against UVB radiation. The combination of marine algae, zinc oxide, and natural oils contributed to the overall stability and performance of the formulation. The findings suggest that the developed marine herbal sunscreen stick has potential as a safe, natural, and eco-friendly alternative to conventional sunscreen products. Further stability studies, skin irritation tests, and in vivo SPF evaluation are recommended to confirm its safety and efficacy before commercial application.

Results

Five formulations (F1–F5) of the marine herbal sunscreen stick were successfully prepared using *Kappaphycus alvarezii* powder, zinc oxide, beeswax, shea butter, coconut oil, carrot seed oil, vitamin E oil, and lavender oil. Among the prepared formulations, the optimized formulation exhibited a smooth and homogeneous appearance with no visible cracks or phase separation. The pH of the formulation ranged from 6.0 to 7.0, indicating good compatibility with the skin. The sunscreen stick showed satisfactory spreadability (5.10–6.43 cm) and was easy to apply.

The optimized formulation demonstrated 56% free radical scavenging activity in the DPPH assay with an IC_{50} value of 73.88 mg/mL, indicating moderate antioxidant activity. In the anti-inflammatory study, the formulation showed 61% inhibition of protein denaturation with an IC_{50} value of 91.69 mg/mL, demonstrating good anti-inflammatory potential. The in vitro Sun Protection Factor (SPF) of the formulation was 15, providing approximately 93% protection against UVB radiation. Overall, the marine herbal sunscreen stick exhibited satisfactory physicochemical properties along with effective antioxidant, anti-inflammatory, and photoprotective activities.

Discussion

The present study successfully formulated a marine herbal sunscreen stick using *Kappaphycus alvarezii*, zinc oxide, and natural ingredients such as beeswax, shea butter, coconut oil, carrot seed oil, vitamin E oil, and lavender oil. The prepared formulation exhibited good physicochemical characteristics, including a smooth texture, uniform appearance, satisfactory spreadability, and a skin-friendly pH, indicating its suitability for topical application.

The antioxidant activity observed in the DPPH assay suggests that the formulation possesses the ability to neutralize free radicals generated by ultraviolet (UV) radiation. This activity may be attributed to the presence of bioactive compounds in *Kappaphycus alvarezii* along with the antioxidant properties of carrot seed oil and vitamin E, which help reduce oxidative stress and protect the skin from photoaging.

The formulation also demonstrated significant anti-inflammatory activity in the egg albumin denaturation assay. This effect may be due to the combined action of the marine algae and natural oils, which are known to reduce protein denaturation and protect the skin against UV-induced inflammation.

The in vitro Sun Protection Factor (SPF) value of 15 indicates that the sunscreen stick provides moderate protection against UVB radiation. Zinc oxide acted as a physical UV filter by reflecting and scattering ultraviolet rays, while the marine algae and natural oils enhanced the overall photoprotective effect through their antioxidant properties.

Overall, the results indicate that the formulated marine herbal sunscreen stick possesses good stability, satisfactory physicochemical properties, antioxidant and anti-inflammatory activities, and effective UV protection. The combination of marine-derived bioactive compounds with natural oils and mineral UV filters offers a promising, safe, and environmentally friendly alternative to conventional sunscreen formulations. Further studies on long-term stability, skin irritation, and in vivo SPF evaluation are recommended to confirm its efficacy and safety for commercial use.

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