GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

Check for updates

Phytochemical screening and bio-functional assessment of seaweed extract in topical cream formulations

ABDULRAHMAN NURUDEEN ABDULHAFEEZ [1], OYEWOLE OYEWUMI NATHER [1] and FALODUN AYODEJI EMMANUEL [2,*]

[1] *Department of Science Technology Chemistry Unit, Federal Polytechnic, Ado-Ekiti, Ekiti State Nigeria.*
[2] *Department of Science Technology, Central Research Laboratory, Federal Polytechnic, Ado Ekiti, Ekiti State, Nigeria.*

GSC Biological and Pharmaceutical Sciences, 2025, 32(01), 152-159

Publication history: Received on 31 May 2025; revised on 05 July 2025; accepted on 08 July 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.32.1.0255

Abstract

This study evaluated the phytochemical composition, physicochemical properties, antimicrobial activity, irritation potential, and antioxidant capacity of cosmetic creams formulated with varying concentrations of seaweed extract (F1–F4). Phytochemical screening revealed the presence of key secondary metabolites, with flavonoids being most abundant (7.6 mg/g), indicating strong antimicrobial and anti-inflammatory potential. Physicochemical evaluation showed all formulations met standard cosmetic criteria, with increasing seaweed concentration leading to higher moisture content and viscosity, and slightly reduced but acceptable spread ability. Antimicrobial testing revealed no activity in the base cream (F1), while F4 (7.5% seaweed inclusion) demonstrated significant zones of inhibition, particularly against *Staphylococcus aureus* (8.1 mm), closely matching the standard antibiotic. HET-CAM skin irritation testing confirmed all formulations were non-irritant, including F4 with the highest extract concentration, whereas the positive control (SLS) produced a severe reaction. Antioxidant assays showed concentration-dependent radical scavenging activity, with F4 achieving 25.0%, supported by increased vitamin E content (1.00 mg/g), though still below the ascorbic acid standard. These results indicate that seaweed extract enhances the bifunctional properties of cream formulations without compromising safety, supporting its potential use in natural skincare products.

Keywords: Seaweed Extract; Phytochemicals; Cosmetic Formulation; Antimicrobial Activity; Antioxidant Properties

1 Introduction

The demand for natural, safe, and environmentally friendly cosmetic products has grown significantly in recent years. This shift is largely attributed to increased consumer awareness of the potential health risks and ecological impact associated with synthetic ingredients commonly found in personal care products. Compounds such as parabens, sulfates, phthalates, and synthetic fragrances, while effective in enhancing product performance, have been implicated in adverse effects including skin irritation, hormonal disruption, and long-term environmental degradation (Draelos, 2021; European Commission, 2022). In response to these concerns, the cosmetics industry is increasingly turning toward plant-based and marine-derived ingredients that offer safer and more sustainable alternatives.

Among these natural resources, marine algae—particularly seaweeds have emerged as promising candidates for cosmetic formulation. Seaweed is an abundant and renewable source of diverse bioactive compounds including phlorotannin's, flavonoids, saponins, alkaloids, sterols, and polysaccharides such as alginates and carrageenan's. These phytochemicals are known to possess antioxidant, anti-inflammatory, antimicrobial, moisturizing, and UV-protective properties, making them highly suitable for skincare applications targeting dryness, irritation, aging, and microbial imbalance (Holdt & Kraan, 2011; Rangaswami et al., 2020).

* Corresponding author: FALODUN A. E

In addition to their functional efficacy, seaweed-derived ingredients offer several advantages over synthetic counterparts. They are biocompatible and biodegradable, posing minimal risk of skin irritation or long-term environmental harm. Furthermore, seaweed cultivation does not rely on freshwater, arable land, or synthetic fertilizers, and contributes positively to marine ecosystems through carbon sequestration and nutrient uptake. These qualities align well with the principles of green chemistry and the global movement toward sustainable product development (Falodun et al., 2024).

This study evaluated the potential of seaweed extracts in the development of cosmetic creams. It focused on assessing the phytochemical composition of seaweed relevant to topical applications, investigating its functional properties, including antioxidant and antimicrobial activities, and determining its physicochemical compatibility and skin safety. Furthermore, the study compared the performance of seaweed-based formulations with established cosmetic standards to assess their viability as alternatives to synthetic ingredients. This approach aimed to contribute to the growing body of evidence supporting the use of marine-derived bioactives in the formulation of modern, multifunctional, and environmentally responsible skincare products.

2 Materials and Methods

2.1 Collection and Preparation of Seaweed Extract

Seaweed **(*Sargassum spa*)** *was* collected from Ese Odo, Ondo State, Nigeria and thoroughly rinsed with tap water to remove all epiphytes and sand particles. The cleaned samples were shade-dried at room temperature for 5–7 days and ground into a fine powder using a laboratory grinder. Extraction was performed using aqueous maceration. The mixture was filtered, and the filtrate was concentrated using a rotary evaporator at 40–45 °C. The extract was stored at 4 °C in an airtight container until use in formulation.

2.2 Phytochemical Screening

Qualitative phytochemical analysis of the seaweed extract was carried out to detect the presence of key bioactive constituents such as flavonoids, phlorotannin's, alkaloids, sterols, saponins, and tannins using standard procedures described by Harborne (1998)

2.3 Formulation of Seaweed-Based Creams

A base cream formulation was prepared using standard emulsifying agents (stearic acid, acetyl alcohol), humectants (glycerin), emollients (liquid paraffin), preservatives, and distilled water. Seaweed extract was incorporated into the cream at concentrations of 0%, 2.5%, 5.0%, and 7.5%, labelled as F1 (control), F2, F3, and F4 respectively. All creams were homogenized at 3000 rpm for 10 minutes and stored in sterile containers for further analysis.

2.4 Physicochemical Evaluation

2.4.1 Evaluation of Formulated Creams

The formulated seaweed-based creams were subjected to a series of physicochemical evaluations to determine their quality, functional performance, and topical suitability.

- **pH Determination**

The pH of the creams was determined using a calibrated digital pH meter (Model: [insert model, manufacturer]), following the procedure described by Aulton and Taylor (2013). Approximately 1 g of each cream formulation was dispersed in 10 mL of distilled water and stirred thoroughly to obtain a uniform mixture. The electrode was then immersed in the dispersion, and the pH was recorded after stabilization. All measurements were performed in triplicate.

- **Moisture Content**

The moisture content was evaluated using the gravimetric drying method as outlined in the British Pharmacopoeia (2020). A known weight of each cream sample was placed in a pre-weighed crucible and dried in a hot air oven at 105 °C until a constant weight was achieved. The difference in weight before and after drying was used to estimate the moisture content.

- **Viscosity Measurement**

Viscosity was measured using a Brookfield digital viscometer (Model: [insert model, manufacturer]) according to the procedure described by Tadros (2010). Approximately 50 g of cream was placed in a beaker, and the appropriate spindle was immersed in the sample. The measurement was carried out at 25 °C with a fixed spindle speed, and the viscosity values were recorded in centipoise (cP). Each measurement was conducted in triplicate.

- **Spreadability**

Spreadability of the formulations was assessed using the slip-and-drag technique described by Das and Das (2013). A fixed amount of cream (1 g) was placed between two glass slides, and a standardized weight (100 g) was applied on the upper slide for a fixed duration (5 minutes). The distance the cream spread between the slides was used to estimate the spreadability of the formulation.

- **Stability Test**

The stability of the cream formulations was assessed by observing physical changes over a one-month period at ambient room temperature (25 ± 2 °C), following the ICH (2003) guidelines. Parameters such as color, odor, phase separation, and consistency were monitored weekly. All observations were documented and compared over time to evaluate the formulations' physical stability.

All measurements were performed in triplicate and compared with established cosmetic standards (Lambers et al., 2006; Draelos, 2021).

2.5 Antioxidant Activity (DPPH Assay)

The antioxidant potential of the cream formulations was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method as described by Liu *et al*.,(2014). A 1 mL aliquot of each formulation was mixed with 2 mL of DPPH solution (0.1 mM in ethanol) and incubated in the dark for 30 minutes. Absorbance was measured at 517 nm using a UV–Vi's spectrophotometer. Ascorbic acid and vitamin E were used as reference antioxidants.

2.6 Antimicrobial Assay

The antimicrobial activity of the creams was evaluated using the agar well diffusion method against selected bacterial and fungal strains: *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans according to* Nishio et al., (2016). Wells were filled with 100 µL of each formulation, and inhibition zones were measured after 24 hours of incubation at 37 °C. A standard antibiotic (e.g., ciprofloxacin) was used as the positive control.

2.7 Skin Irritation Test (HET-CAM Assay)

The Hen's Egg Test on the Chorioallantois Membrane (HET-CAM) was employed to evaluate the irritation potential of the formulations. Fertile chicken eggs were incubated at 37 °C for 10 days. On Day 10, the shell was carefully removed to expose the CAM, and 0.3 mL of each formulation was applied. The membrane was observed for hemorrhage, lysis, and coagulation within 5 minutes. Irritation scores were calculated and interpreted according to guidelines as described OECD , (2011).

2.8 Statistical Analysis

All data were presented as mean ± standard deviation (SD). Statistical significance was determined using one-way ANOVA followed by Tukey's post hoc test. A p-value of <0.05 was considered statistically significant.

3 Results

3.1 Phytochemical analyses of seaweeds

The table 1 shows that flavonoids had the highest concentration (7.6 mg/g), indicating their dominance in the seaweed extract. All tested secondary metabolites were present (+vet), suggesting broad pharmacological potential. The phlorotannin's and tannins shared equal values (1.6 mg/g), both linked to antibacterial properties. Sterols and Alkaloid had the lowest concentration (1.1 mg/g) but still contributed with skin permeability and antimicrobial roles

3.2 Selected Physicochemical Properties of Seaweed Cream Formulations Compared to Cosmetic Standards

The table 2 indicates that all four seaweed cream formulations (F1–F4) fall within acceptable cosmetic standards for pH, viscosity, spread ability, and stability. pH levels slightly decreased as seaweed concentration increased, but remained within the safe range (4.5–7.0). Moisture content increased progressively with higher seaweed concentration, potentially enhancing skin hydration. Viscosity also rose with increasing concentration, improving cream consistency. Spread ability decreased slightly but remained within the acceptable range, indicating good application potential.

3.3 Antimicrobial Activity of Seaweed Cream Formulations (Zone of Inhibition in mm)

The figure 1 shows a concentration-dependent antimicrobial activity of the seaweed formulations. F1 (0%) had no inhibitory effect, confirming that the base cream lacked antimicrobial agents. F4 (7.5%) exhibited the highest activity across all organisms tested, with inhibition zones approaching those of the standard antibiotic, particularly against *S. aureus* (8.1 mm vs. 8.2 mm).

3.4 HET-CAM Skin Irritation Test Results of Seaweed Cream Formulations

The table 3 HET-CAM test results reveal that all seaweed cream formulations (F1 to F4) scored well below the irritation threshold, indicating they are non-irritant and safe for topical application. Even the highest concentration (F4, 7.5%) showed only a slight increase in irritation score (0.15), which is still negligible. The positive control, sodium lauryl sulfate (SLS), produced a severe irritation score of 6.10, validating the sensitivity of the test.

3.5 Antioxidant Activity of Seaweed Cream Formulations (DPPH Radical Scavenging Assay and Vitamin E Content)

The table 4 results reveal that Antioxidant activity and vitamin E content increased progressively with higher seaweed concentrations. F4 (7.5%) showed the highest scavenging activity (25.0 ± 0.3%) and vitamin E level (1.00 ± 0.01), indicating strong dose-dependent enhancement.

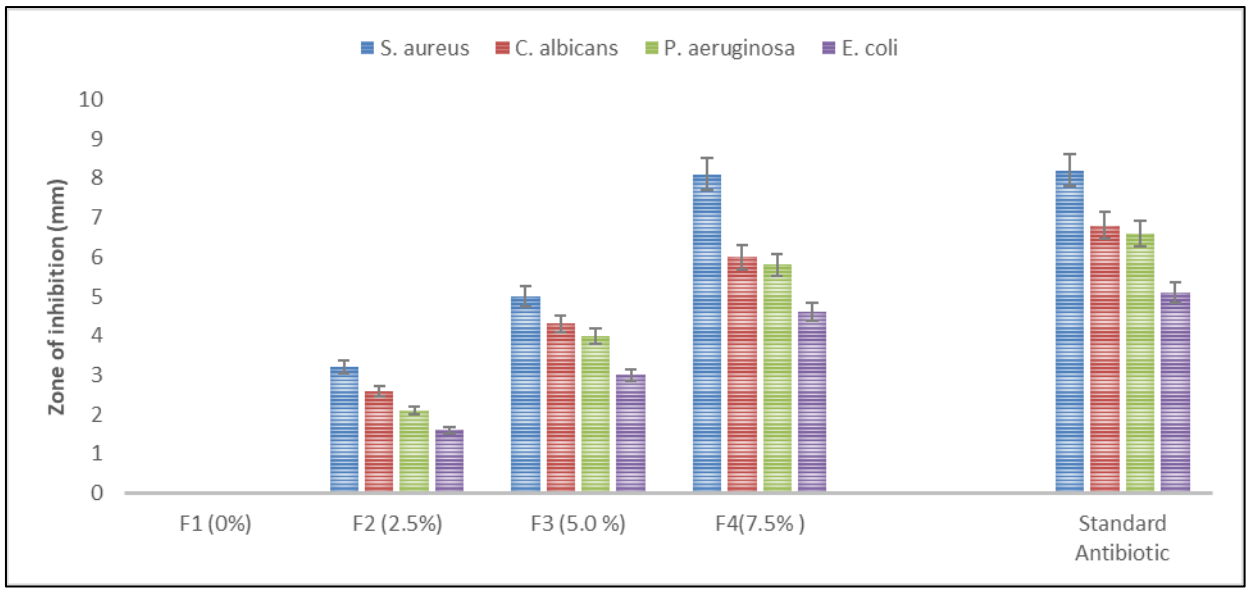
Table 1 Phytochemical Composition and Pharmacological Importance of Seaweed Extract

Secondary metabolites	Inference	Values (mg/g)	Pharmacological importance
Phlorotannin's	+VE	1.6±0.01	Antibacterial, antioxidant
Flavonoids	+VE	7.6 ±0.03	Anti-inflammatory, antimicrobial
Alkaloids	+VE	1.1 ±0.02	Antifungal, antibacterial
Sterols	+VE	1.1±0.01	Skin permeability enhancer, antimicrobial
Saponins	+VE	1.4±0.01	Antifungal, foaming agent
Tannins	+VE	1.6±0.01	Antibacterial, astringent

Table 2 Selected Physicochemical Properties of Seaweed Cream Formulations Compared to Cosmetic Standards

Parameter	F1 (0%)	F2 (2.5%)	F3 (5.0%)	F4 (7.5%)	Cosmetic Standard Range
pH	6.5	6.4	6.3	6.2	4.5–7.0
Moisture Contents (%)	56.2± 0.03	59.0± 0.00	62.1± 0.05	64.0± 0.06	-
Viscosity (cp)	2300± 0.03	2400± 0.10	2600± 0.08	2800± 0.06	2000–5000
Spread ability (gm./sec)	14.2± 0.06	13.6± 0.05	13.0± 0.05	12.4± 0.06	10–16
Cream Stability (1 month @ RT)	Stable	Stable	Stable	Stable	Must be stable

Formulation key: where F1 = Base cream only, F2 = Base cream + 2.5% of seaweed cream inclusion F3 = Base cream + 5.0% of seaweed cream inclusion F4 = Base cream + 7.5% of seaweed cream inclusion



Formulation key: where F1 = Base cream only, F2 = Base cream + 2.5% of seaweed cream inclusion F3 = Base cream + 5.0% of seaweed cream inclusion F4 = Base cream + 7.5% of seaweed cream inclusion

Figure 1 Antimicrobial Activity of Seaweed Cream Formulations (Zone of Inhibition in mm)

Table 3 HET-CAM Skin Irritation Test Results of Seaweed Cream Formulations

Sample	Irritation Score (IS)	inference
PBS (Negative control)	0.00	Non-irritant
F1 (0%)	0.0±0.00	Non-irritant
F2 (2.5%)	0.07±0.00	Non-irritant
F3 (5.0%)	0.10±0.01	Non-irritant
F4 (7.5%)	0.15±0.02	Non-irritant
SLS (Positive control)	6.10±0.01	Severe irritant

Formulation key: where F1 = Base cream only, F2 = Base cream + 2.5% of seaweed cream inclusion F3 = Base cream + 5.0% of seaweed cream inclusion F4 = Base cream + 7.5% of seaweed cream inclusion

Table 4 Antioxidant Activity of Seaweed Cream Formulations (DPPH Radical Scavenging Assay and Vitamin E Content)

Sample	% Scavenging Activity (± SD)	Vitamin E
F1 (0%)	3.1 ± 0.4	0.14± 0.00
F2 (2.5%)	6.4 ± 0.6	0.44± 0.03
F3 (5.0%)	14.8 ± 0.5	0.84± 0.03
F4 (7.5%)	25.0 ± 0.3	1.00± 0.01
Ascorbic Acid (Standard)	65.2 ± 0.2	

Formulation key: where F1 = Base cream only, F2 = Base cream + 2.5% of seaweed cream inclusion F3 = Base cream + 5.0% of seaweed cream inclusion F4 = Base cream + 7.5% of seaweed cream inclusion

4 Discussion

As consumer preferences increasingly shift toward natural and sustainable personal care products, the search for safe, effective, and eco-friendly cosmetic ingredients has intensified. This study highlights the potential of seaweed extracts as a valuable alternative to synthetic compounds in cosmetic formulations. Seaweed, a rich source of bioactive compounds such as phlorotannin's, flavonoids, alkaloids, sterols, saponins, and tannins, offers multiple benefits that align with the core requirements of modern skincare efficacy, safety, and environmental sustainability. Many synthetic ingredients traditionally used in cosmetics such as parabens (preservatives), phthalates (solubilizers), and synthetic fragrances are now under scrutiny due to their potential for skin irritation, hormonal disruption, and environmental persistence (khan *et al.,* 2022; European Commission, 2022). In contrast, seaweed extracts provide multifunctional properties naturally (Falodun *et al*., 2024). Their plant-derived origin appeals to health-conscious consumers and minimizes adverse reactions often associated with synthetic chemicals (Plaza et al., 2020).

Table 3.1 outlines the wide range of bioactive in seaweed. The seaweed extract contained key secondary metabolites including flavonoids (7.6 mg/g), phlorotannin's (1.6 mg/g), tannins (1.6 mg/g), alkaloids (1.1 mg/g), sterols (1.1 mg/g), and saponins (1.4 mg/g). Flavonoids, being the most abundant, contribute to antimicrobial and anti-inflammatory activity, consistent with the findings of Holdt and Kraan (2011), who reported similar functions in marine algae. Phlorotannin's and tannins, known for their antioxidant and antibacterial roles, support earlier observations by Li et al. (2009) regarding their effectiveness in oxidative stress reduction. The presence of alkaloids and sterols, both at 1.1 mg/g, indicates potential antifungal action and enhancement of skin permeability, in line with Manilal et al. (2010). Saponins at 1.4 mg/g also suggest antifungal and emulsifying benefits, as previously documented by Plaza et al. (2008). These constituents highlight the multifunctional properties of the seaweed extract for use in skin-care formulations.

Seaweed-enriched creams in this study maintained acceptable pH values (6.2–6.5), aligning with international cosmetic guidelines (Lambers et al., 2006). Maintaining pH near the skin's natural level (~5.5) is critical to prevent irritation and preserve the skin's acid mantle. Additionally, seaweed addition improved moisture content and viscosity while maintaining spread ability, which are essential attributes for consumer satisfaction and formulation performance (Baumgartner et al., 2020). The creams remained stable for one month at room temperature, suggesting that the natural polysaccharides and antioxidants present in seaweed contribute to both physical and microbial stability.

The antimicrobial evaluation showed that higher concentrations of seaweed extract significantly inhibited the growth of *S. aureus*, *C. albicans*, and *P. aeruginosa*, pathogens commonly associated with skin infections and acne. This aligns with studies reporting that seaweed polysaccharides such as fucoidan possess strong antimicrobial activity (Xu, et al., 2023). Compared to synthetic preservatives, which can trigger allergic responses in sensitive users, seaweed offers a gentler alternative that still ensures product hygiene.

Antioxidant testing revealed a dose-dependent increase in DPPH radical scavenging activity. While not as powerful as vitamin C (ascorbic acid), the 7.5% seaweed formulation showed a 25% scavenging rate, confirming the presence of effective antioxidant compounds. This is important in reducing skin damage from UV exposure, pollution, and stress, all of which accelerate skin aging (Saha *et al.,* 2020; Haja *et al.,* 2021). In contrast to synthetic antioxidants like BHT and BHA, which face safety concerns, seaweed-derived antioxidants are naturally occurring and biocompatible.

Results from the HET-CAM test indicated that all seaweed-based formulations, even at higher concentrations, had very low irritation scores. This suggests excellent skin compatibility, which is critical for cosmetic products, especially those targeting sensitive skin. Compared to known irritants like Sodium Lauryl Sulfate (SLS), seaweed formulations showed almost no irritation (irritancy index < 0.2), supporting their suitability for everyday use (OECD , 2011).

The integration of seaweed extracts into cosmetic products also aligns with the rising demand for eco-conscious beauty solutions. Seaweed is renewable, fast-growing, and requires no fertilizers or freshwater for cultivation, making it a sustainable alternative to synthetic and even some plant-based ingredients with higher environmental footprints (Falodun et al., 2024). By replacing synthetic ingredients with seaweed, brands can reduce their ecological impact and appeal to the green cosmetics market, which is projected to reach over $30 billion globally by 2030.

5 Conclusion

The study demonstrated that seaweed extracts possess valuable cosmetic properties, as evidenced by the presence of beneficial phytochemicals, favorable physicochemical characteristics, effective antioxidant activity, low skin irritation potential, and antimicrobial efficacy at higher concentrations. All tested formulations (F1 to F4) fell within acceptable

cosmetic standards for pH, viscosity, spread ability, and stability. The increasing concentration of seaweed extracts improved moisture content and antioxidant properties without causing irritation, confirming its suitability for topical applications. Based on these findings, seaweed extracts are recommended as safe, natural alternatives to synthetic ingredients in cosmetic formulations. Further research should focus on optimizing extraction methods, evaluating long-term skin benefits, and exploring different seaweed species to broaden their application in skincare and personal care products.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares that there is no conflict of interest

References

[1] Aulton, M. E., & Taylor, K. (2013). Aulton's pharmaceutics: The design and manufacture of medicines (4th ed.). Churchill Livingstone..

[2] Bafakeeh, O. T., Alharbi, M. H., Alharbi, S. A., Alharbi, A. H., & Alshahrani, M. Y. (2022). Evaluation of antibacterial properties of alkaloid-rich plant extracts for acne treatment. Journal of Herbal Medicine, 32, 100565. https://doi.org/10.1016/j.hermed.2022.100565

[3] Baumgartner, S., Luber, M., & Flammer, M. (2020). Rheological properties of creams: Viscosity and spreadability analysis in formulation development. International Journal of Cosmetic Science, 42(1), 56–64. https://doi.org/10.1111/ics.12543

[4] British Pharmacopoeia. (2020). Vol. I–IV. The Stationery Office on behalf of the Medicines and Healthcare Products Regulatory Agency (MHRA), UK

[5] Draelos, Z. D. (2021). Cosmetic Dermatology: Products and Procedures (3rd ed.). Elsevier.

[6] Das, M. K., & Das, S. K. (2013). Formulation and evaluation of herbal creams for improvement of skin texture. International Journal of Pharmaceutical Sciences and Research, 4(1), 325–331.

[7] European Commission. (2022). Cosmetics Regulation (EC) No 1223/2009. Retrieved from https://health.ec.europa.eu

[8] Falodun A.E., Oyewole O. N., And Idowu K. S (2024): Mitigating effects of Nigeria seaweed phytonutrients on biochemical and physiological conditions of Lycopersicon esculentum under heavy metal-induced abiotic stress. GSC Biological and Pharmaceutical Sciences, 2024, 29(01), 078–086 DOI: https://doi.org/10.30574/gscbps.2024.29.1.0343

[9] Godoy-Gallardo, M., Ek, P. K., & Wagner, D. (2020). Formulation stability in cosmetic emulsions: Role of antioxidants and preservatives. Cosmetics, 7(4), 98. https://doi.org/10.3390/cosmetics7040098

[10] Hajal, C., Aslam, M., & El-Said, R. (2021). Multifunctional properties of marine seaweeds in dermatological and cosmetic applications. Journal of Applied Phycology, 33(4), 2041–2056. https://doi.org/10.1007/s10811-021-02461-9

[11] Holdt, S. L., & Kraan, S. (2011). Bioactive compounds in seaweed: Functional food applications and legislation. Journal of Applied Phycology, 23(3), 543–597. https://doi.org/10.1007/s10811-010-9632-5

[12] Harborne, J. B. (1998). Phytochemical methods: A guide to modern techniques of plant analysis (3rd ed.). Springer.

[13] ICH. (2003). Stability testing of new drug substances and products Q1A(R2). International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use.

[14] Kim, M. M., Rajapakse, N., & Kim, S. K. (2017). Seaweed-derived polysaccharides for skin moisturizing in cosmetic creams. Biotechnology and Bioprocess Engineering, 22(3), 301–310. https://doi.org/10.1007/s12257-016-0430-2

[15] Kumar, V., Yadav, S., & Singh, S. (2022). Concentration-dependent antimicrobial efficacy of herbal and marine extracts. Journal of Cosmetic Dermatology, 21(9), 3731–3738. https://doi.org/10.1111/jocd.14309

[16] Lambers, H., Piessens, S., Bloem, A., Pronk, H., & Finkel, P. (2006). Natural skin surface pH is on average below 5, which is beneficial for its resident flora. International Journal of Cosmetic Science, 28(5), 359–370. https://doi.org/10.1111/j.1467-2494.2006.00344.x

[17] Liu, S., Dong, Y., Xu, L., and Kong, J. (2014). Effects of foliar applications of nitric oxide and salicylic acid on salt-induced changes in photosynthesis and antioxidative metabolism of cotton seedlings. Plant Growth Regul. 73, 67–78.

[18] Manilal, A., Sujith, S., Kiran, G. S., Selvin, J., Shakir, C., & Gandhimathi, R. (2010). Biopotentials of seaweeds collected from southwest coast of India. Journal of Marine Science and Technology, 18(4), 658–665. https://doi.org/10.1007/s00773-010-0093-5

[19] Nishio E.K, Ribeiro JM, Oliveira AG, Andrade CGTJ, Proni EA, Kobayashi RKT (2016). Antibacterial synergic effect of honey from two stingless bees: Scaptotrigona bipunctata Lepeletier, 1836, and S. postica Latreille, 1807. Sci Rep 6:1–8

[20] OECD. (2011). Peer Review Report of Validation of the Skin Irritation Test Using LabCyte EPI-MODEL24. Environment, Health and Safety Publications, Series on Testing and Assessment (No. 155.), Organisation for Economic Cooperation and Development, Paris.

[21] Plaza, M., Herrero, M., & Cifuentes, A. (2020). Seaweed-derived ingredients in skin health and cosmeceutical development. Current Opinion in Food Science, 33, 1–7. https://doi.org/10.1016/j.cofs.2020.03.005

[22] Saha, M., Raychaudhuri, U., & Chakraborty, R. (2020). Marine antioxidants in cosmetic applications: A comprehensive review. Trends in Cosmetic Science, 8(2), 45–58.

[23] Tadros, T. F. (2010). Rheology of dispersions: Principles and applications. Wiley-VCH.

[24] Xu, R., Yang, Y., & Li, C. (2023). Tannin-rich formulations in cosmetic science: Benefits, limitations, and applications. Pharmaceuticals, 16(2), 214. https://doi.org/10.3390/ph16020214