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The potential of seaweed extracts from Suli Beach, Central Maluku: Antioxidant and photoprotective activities for natural cosmetic applications

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Abstract

Excessive ultraviolet (UV) radiation exposure is one of the main causes of premature aging, sunburn, and an increased risk of skin cancer. Many commercial sunscreens contain synthetic ingredients such as oxybenzone and octinoxate, which are reported to act as endocrine disruptors and harm coral reef ecosystems. Therefore, natural and eco-friendly alternatives are needed. This study aimed to evaluate the antioxidant activity, total phenolic content (TPC), and sun protection factor (SPF) of methanolic extracts of seaweeds from Suli Beach, Central Maluku. Antioxidant activity was determined using the DPPH method, TPC was measured by the Folin–Ciocalteu assay, and SPF values were calculated *in vitro* using UV–Vis spectrophotometry. The results showed that *Turbinaria sp*. extract exhibited higher antioxidant activity (112.47 ± 2.13 mg AEAC/g) than *Sargassum* sp. (100.69 ± 2.29 mg AEAC/g). However, *Sargassum* sp. contained higher TPC (18.71 mg GAE/g) compared to *Turbinaria sp*. (9.69 mg GAE/g). The SPF values increased with concentration, with the highest protection at 200 ppm (12.45 for *Turbinaria sp*. and 10.22 for *Sargassum* sp.). Phytochemical screening confirmed the presence of flavonoids, steroids, saponins, and tannins in both extracts, while alkaloids were detected only in *Sargassum* sp. Thin layer chromatography revealed distinct metabolite profiles, suggesting species-specific differences. These findings identify seaweed extracts, particularly *Turbinaria sp*., as promising candidates for the development of eco-friendly cosmetic ingredients with antioxidant and photoprotective properties.

Keywords: *Turbinaria* sp.*; Sargassum* sp.; Antioxidant Activity; Phlorotannins; Photoprotective Activity; Total Phenolic Content

1. Introduction

Excessive ultraviolet (UV) exposure has long been recognized as one of the major causes of skin damage, ranging from premature aging (photoaging), sunburn, hyperpigmentation, to an increased risk of skin cancer [12]. Sunscreens are considered one of the most effective measures to protect the skin from the harmful effects of UV radiation. However, the use of chemical-based sunscreens has raised growing concerns. Several commonly used active ingredients, such as oxybenzone and octinoxate, have been reported to act as endocrine disruptors and contribute to coral reef degradation [4]. This situation emphasizes the urgent need for alternative sunscreens derived from natural sources that are safe for human health and environmentally friendly.

Indonesia, as the largest archipelagic country in the world, possesses exceptionally high marine biodiversity, including various seaweed species that serve as potential sources of bioactive compounds. Seaweeds have long been utilized in food, pharmaceuticals, and cosmetics, but their application as photoprotective active ingredients remains underdeveloped. One of the promising areas is Suli Beach in Central Maluku, which hosts abundant brown algae such

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as *Turbinaria sp*. and *Sargassum* sp. [15]. These species thrive in tropical waters with high adaptability, making them sustainable biomass resources for exploration and development.

Brown seaweeds are particularly rich in bioactive compounds, especially phenolics with unique forms known as phlorotannins. Phlorotannins are polyphenols exclusively found in brown algae, exhibiting strong antioxidant activity as well as UV absorption capacity [18]. These properties not only provide ecological advantages for seaweeds in protecting themselves against solar radiation and oxidative stress but also make them promising candidates for natural skin protection. In addition to phlorotannins, brown algae are also reported to contain flavonoids, carotenoids, xanthophylls, and vitamins that may synergistically enhance their antioxidant and photoprotective effects. Therefore, brown seaweeds hold significant potential for development as raw materials for natural sunscreens and anti-aging cosmetics.

Previous studies have highlighted the bioactive potential of *Turbinaria* and *Sargassum* genera in various biological activities, including antioxidant, antimicrobial, and UV-protective effects [8,16]. However, comprehensive studies that simultaneously integrate antioxidant activity, total phenolic content (TPC), and Sun Protection Factor (SPF) analysis of seaweed species from Central Maluku waters remain very limited. Furthermore, the phytochemical profiles and secondary metabolite diversity of algae from Suli Beach have not yet been systematically evaluated. Therefore, this study aimed to analyze antioxidant activity, total phenolic content, SPF values, and phytochemical profiles of methanolic extracts of *Turbinaria sp*. and *Sargassum* sp. The findings are expected to provide scientific evidence supporting the utilization of Indonesian marine biodiversity as sustainable raw materials for natural cosmetic applications.

2. Material and methods

Seaweed samples (*Turbinaria sp*. and *Sargassum* sp.) were collected on October 23, 2023, at Suli Beach, Central Maluku, at coordinates 3°37'32.02"S 128°18'10.56"E. Samples were subsequently identified and prepared at the Marine Science Laboratory, Diponegoro University. Extraction, evaporation, and all chemical analyses (phytochemical screening, DPPH antioxidant assay, total phenolic content, and SPF determination) were conducted at the Chemical Oceanography Laboratory and Microbiology Laboratory, Faculty of Fisheries and Marine Science, Diponegoro University.

The seaweed samples were washed with seawater and freshwater to remove debris and epiphytes, then oven-dried at 40 °C until a constant weight was achieved. The dried samples were ground into powder. A total of 100 grams of powder from each species was extracted with analytical grade methanol using the maceration method for 3 × 24 hours. The resulting filtrates were concentrated using a rotary evaporator at 40 °C until a thick extract was obtained. The concentrated extracts were stored in dark vials and used for all subsequent analyses.

Antioxidant activity was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method following a modified procedure from Aryanti et al. (2021). A total of 1 mg of DPPH was dissolved in 25 mL of methanol to prepare a 0.1 mM stock solution. Sample extracts were dissolved in methanol to prepare a series of concentrations (12.5, 25, 50, 100, and 200 ppm). One milliliter of each sample solution was mixed with 1 mL of the DPPH solution, incubated in the dark for 30 minutes, and the absorbance was measured at 517 nm using a UV-Vis spectrophotometer

The total phenolic content was determined using the Folin–Ciocalteu method. A total of 0.1 mL extract (1 mg/mL) was added to 0.5 mL Folin–Ciocalteu reagent (1:10) and allowed to stand for 5 minutes. Then, 1 mL of 7.5% Na_2CO_3 solution was added, and the mixture was incubated in the dark for 60 minutes. The absorbance was measured at 770 nm. Total phenolics were expressed as milligrams of gallic acid equivalents per gram of extract (mg GAE/g) based on a gallic acid calibration curve (0–100 µg/mL). Total phlorotannins were measured using the same method and expressed as milligrams of phloroglucinol equivalents per gram of extract (mg Floroglucinol/g).

SPF values were determined *in vitro* using UV-Vis spectrophotometry according to Yanuarti et al. (2021). Extracts were dissolved in methanol at various concentrations (12.5–200 ppm). The absorbance of each solution was recorded at wavelengths of 290–320 nm at 5 nm intervals.

Qualitative phytochemical screening was performed to detect alkaloids (Dragendorff's reagent), flavonoids (Shinoda test), tannins ($FeCl_3$), steroids (Liebermann–Burchard test), and saponins (frothing test). Thin-layer chromatography (TLC) was conducted using silica gel GF254 plates and a solvent system of n-hexane:ethyl acetate (1:1). Spots were visualized under UV light at 254 nm and 356 nm, and after spraying with $FeCl_3$ reagent.

All experiments were carried out in triplicate (n = 3). Data obtained were analyzed descriptively and presented as mean ± standard deviation (SD).

3. Results and discussion

The antioxidant activity of *Turbinaria sp*. and *Sargassum* sp. extracts is presented in Table 1. The extract of *Turbinaria sp*. exhibited significantly higher percentage inhibition and AEAC values compared to *Sargassum* sp., indicating a stronger ability to neutralize DPPH free radicals.

Table 1 Antioxidant Activity of *Turbinaria sp*. and *Sargassum* sp. Extracts

Sample	% Inhibisi (Mean ± SD)	AEAC (µg/mL)
Turbinaria	59.7 ± 0,4	94.2
Sargassum	50.4 ± 0.4	78.0
DPPH Control	0.742	

The measurements of TPC and total phlorotannins revealed a trend that differed from the antioxidant activity. As presented in Table 2, *Sargassum* sp. exhibited nearly twice the total phenolic content (gallic acid equivalent) and phlorotannin content (phloroglucinol equivalent) compared to *Turbinaria sp*.

Table 2 Total phenolic content (TPC) of three seaweed species measured as gallic acid and phloroglucinol equivalents. Values represent the concentration of standard equivalents and the calculated TPC per gram of extract

Sample	Gallic Acid (µg/mL)	TPC (mg GAE/g)	Phloroglucinol (µg/mL)	TPC (mg Phloroglucinol/g)
Turbinaria sp.	38.738	7.748	51.899	10.380
Sargassum sp.	74.849	14.970	97.859	19.572

The SPF values of both extracts showed a linear relationship with increasing concentrations (Figure 1). At all concentration levels, the extract of *Turbinaria sp*. consistently exhibited higher SPF values than *Sargassum* sp. At a concentration of 200 ppm, *Turbinaria sp*. reached an SPF value of 12.45, which falls into the medium protection category, while *Sargassum* sp. reached 10.22.

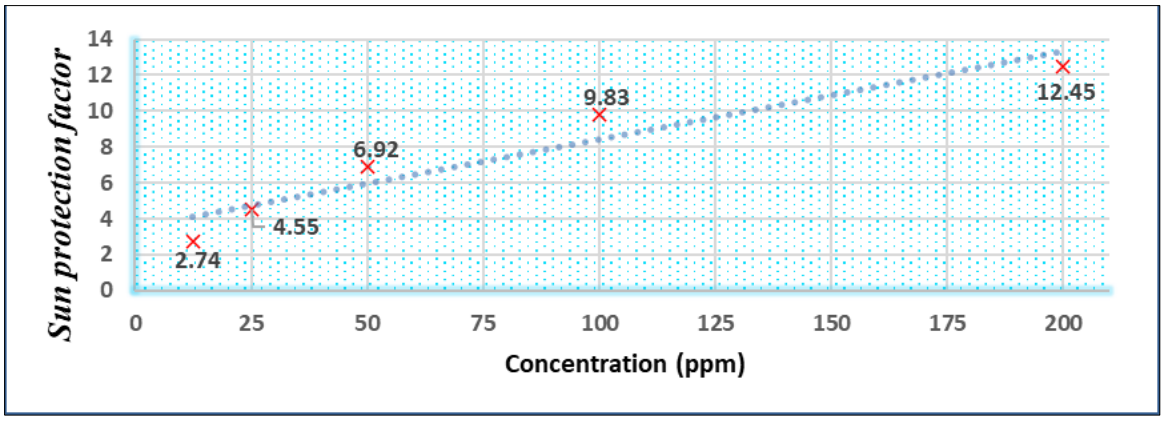

Figure 1 Concentration and Sun Protection Factor (SPF) of Ethanol Extract of *Turbinaria sp*

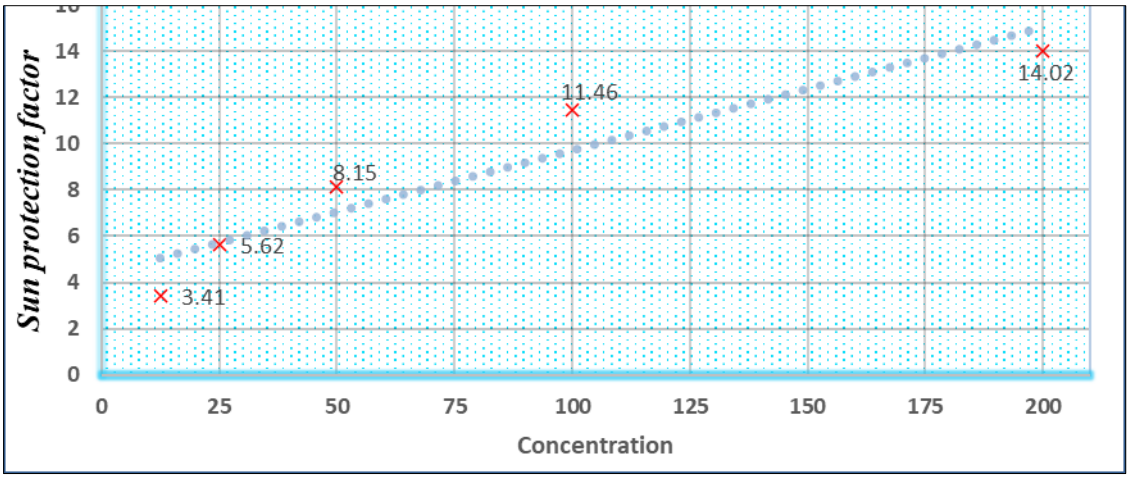

Figure 2 Concentration and Sun Protection Factor (SPF) of Ethanol Extract of *Sargassum* s

The results of the qualitative phytochemical screening (Table 3) showed that both extracts contained flavonoids, steroids, saponins, and tannins. Alkaloids were detected only in *Sargassum* sp. TLC analysis under UV light at 254 nm and 356 nm, as well as after spraying with $FeCl_3$ reagent, confirmed the presence of several polar and non-polar compounds in both extracts, with distinct spot patterns indicating diverse secondary metabolite profiles.

Table 3 Thin-layer chromatography (TLC) profiles of *Sargassum* sp. and *Turbinaria* sp. extracts. The table shows the number of spots, their approximate positions on the TLC plate, the observed colors, and the calculated Rf values, indicating differences in secondary metabolite composition between the two brown algae species

Sample	Spot No.	Position (cm)	Spot Color	Rf
Sargassum	1	~2.4	Light brownish yellow	0.28
	2	~3.1	Light brown / pale yellow	0.42
	3	~4.4	Dark reddish brown	0.68
Turbinaria	1	~2.7	Faint brownish yellow	0.34
	2	~3.6	Dark yellowish-orange	0.52
	3	~5.0	Dark reddish brown	0.80

This study highlights the complex dynamics between phenolic compound content and biological activity in two brown algae species, namely *Turbinaria sp*. and *Sargassum* sp. In general, *Turbinaria sp*. extracts exhibited higher antioxidant activity (112.47 ± 2.13 mg AEAC/g) compared to *Sargassum* sp. (100.69 ± 2.29 mg AEAC/g), although the total phenolic content of *Sargassum* sp. was nearly twice as high (18.71 mg GAE/g vs 9.69 mg GAE/g). This disparity indicates that biological effectiveness is not solely determined by phenolic quantity, but also by the quality, chemical structure, and specific types of bioactive compounds present [11,6]. In other words, the quantitative TPC value only reflects the total amount, but does not represent the diversity and reactivity of the molecules themselves.

Thin Layer Chromatography (TLC) analysis further supports these findings by revealing differences in metabolite profiles between the two species. *Turbinaria* sp. produced three spots at Rf 0.34, 0.52, and 0.80, whereas *Sargassum* sp. showed three spots at Rf 0.28, 0.42, and 0.68. The different elution patterns indicate variations in polar and non-polar compounds present. Polar compounds, such as flavonoid glycosides and hydrolyzable tannins, tend to appear at low Rf values, while less polar compounds, such as flavonoid aglycones, terpenoids, or steroids, tend to appear at high Rf values [7]. The fact that both species produced the same number of spots but with different Rf values and intensities suggests that each has a distinct secondary metabolite "fingerprint." These variations are likely influenced by environmental factors such as light intensity, nutrient availability, salinity, and the physiological condition of the organisms [2].

Although *Sargassum* sp. has a higher TPC, the higher antioxidant activity of *Turbinaria* sp. can be explained by the presence of certain phlorotannins that are more reactive in electron donation. Phlorotannins are polymers of phloroglucinol units found exclusively in brown algae, with structural variations affecting antioxidant capacity [20].

Low molecular weight phlorotannins, for example, interact more readily with free radicals and exhibit higher scavenging activity [18]. Therefore, *Turbinaria* sp. likely produces phlorotannins with specific spatial configurations or molecular weights that are more effective than those in *Sargassum* sp. Additionally, the contribution of non-phenolic compounds such as carotenoids, fucoxanthin, xanthophylls, as well as vitamins C and E may further enhance antioxidant activity through synergistic mechanisms [12,13].

This relationship is also evident in SPF testing, where *Turbinaria* sp. consistently provided higher SPF values than *Sargassum* sp. at all concentrations. At 200 ppm, *Turbinaria* sp. reached an SPF of 12.45, which falls under moderate protection, while *Sargassum* sp. only reached 10.22. This protective mechanism works synergistically through two pathways: first, physically by absorbing UV radiation at wavelengths of 290–320 nm; second, chemically by neutralizing free radicals generated by UV exposure [9,19]. Previous studies have also reported that combining phenolic compounds with other pigments in algal extracts can improve photoprotective effectiveness, meaning that SPF values not only reflect the absorptive capacity of compounds but also their antioxidant protection [14,5]. However, in vitro SPF values remain indicative, as the final effectiveness of sunscreens is highly influenced by formulation systems, emulsion types, photochemical stability, and interactions of the extract with the cosmetic matrix [3].

The practical implications of these findings are significant. From a cosmetic perspective, *Turbinaria* sp. extracts can serve dual functions as anti-aging agents through their antioxidant activity and as UV protectants through their SPF values. This offers a competitive advantage over synthetic sunscreens, which generally only act as UV filters without additional benefits [10]. Furthermore, the use of brown algae extracts as natural active cosmetic ingredients aligns with the global trend towards “green beauty” products that emphasize safety, sustainability, and environmental friendliness [17].

Beyond dermatological implications, these findings also have socio-economic significance. *Turbinaria* sp. from Suli Beach, Central Maluku, which was previously underutilized commercially, has the potential to become a new flagship commodity for coastal communities. Utilization through sustainable aquaculture systems can create job opportunities, reduce dependence on imported raw materials, and help conserve marine ecosystems [15]. This highlights that developing a bioindustry based on *Turbinaria* sp. is not only beneficial for the cosmetic industry but also aligns with sustainable development and blue economy agendas.

Another important finding is the presence of alkaloids detected exclusively in *Sargassum* sp. Marine alkaloids are known to possess a wide range of biological activities, including antimicrobial, anti-inflammatory, and even anticancer effects [3]. This opens opportunities for further research to explore the pharmacological potential of *Sargassum* sp. beyond its role as a photoprotectant. For both species, the next crucial research steps are the isolation and characterization of pure compounds contributing to antioxidant activity and SPF, followed by toxicity and in vivo efficacy tests. Consequently, these findings can serve as a foundation for developing safe, effective, and environmentally friendly brown algae-based photoprotective cosmetic products in Indonesia.

4. Conclusion

Based on the results of this study, it can be concluded that the methanol extract of *Turbinaria sp*. from Suli Beach, Central Maluku exhibits greater potential as a natural cosmetic active ingredient compared to *Sargassum* sp. This is evidenced by its higher antioxidant activity (AEAC value of 112.47 ± 2.13 mg/g) and superior Sun Protection Factor (SPF) value (12.45 at a concentration of 200 ppm). Although *Sargassum* sp. showed a higher total phenolic content (18.71 mg GAE/g), these findings indicate that biological activity is not solely dependent on the quantity of total phenolic compounds, but rather on the quality, type, and specific structure of the bioactive constituents. Thin Layer Chromatography (TLC) analysis revealed distinct secondary metabolite profiles between the two species, with *Turbinaria sp*. displaying less polar compounds that are presumed to contribute to its superior biological activity. Phytochemical screening confirmed the presence of flavonoids, steroids, saponins, and tannins in both species, with alkaloids detected exclusively in *Sargassum* sp. Overall, this study identifies *Turbinaria sp*. as a promising candidate for the development of natural photoprotective and anti-aging cosmetic products.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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