

Characterization of Nutritional, Mineral, Heavy Metal, Phytochemical, and Antioxidant Profiles of *Eucheuma spinosum* from Gerupuk Waters, Central Lombok

Mohammad Sayuti^{1✉}, Aghitia Maulani², Siti Zachro Nurbani³, Bagus Hadiwinata MS⁴, Niken Dharmayanti⁵, Nur Hidayah⁶, Yudi Prasetyo Handoko⁷, Rufnia Ayu Afifah⁸, Fardha Awallya⁹

¹⁻⁹ Teknologi Pengolahan Hasil Perikanan, Politeknik Ahli Usaha Perikanan, Indonesia

✉ Corresponding Author : Mohammad Sayuti (e-mail: mohsayut@gmail.com)

Article Information	ABSTRACT
Article History Received : August 19, 2026 Revised : September 15, 2026 Published : October 04, 2026	<i>Eucheuma spinosum</i> is a promising marine resource for food, hydrocolloid, and bioactive compound applications, although its nutritional and safety characteristics may vary with geographical origin. This study characterized <i>E. spinosum</i> from Gerupuk Waters, Central Lombok, focusing on raw material quality, nutritional composition, mineral and heavy metal contents, phytochemical profile, and antioxidant activity. Samples were dried and extracted using ultrasound-assisted extraction (UAE) with methanol. Analyses included organoleptic assessment, clean anhydrous weed (CAW), proximate composition, mineral analysis by ICP-OES, heavy metal analysis by ICP-MS, qualitative phytochemical screening, and DPPH radical-scavenging activity. The raw material complied with SNI 2690:2023, with an organoleptic score of 8 and CAW content of 50.20%, while the methanolic extract yield was 1.36%. The seaweed was characterized by high ash (35.88%), carbohydrate (32.01%), and crude fiber (15.41%) contents, with potassium as the predominant mineral (18,221.22 mg/100 g). Hg, Cd, and Pb concentrations were within SNI limits; however, total arsenic reached 7.12 mg/kg, exceeding the applicable maximum limit. Phytochemical screening revealed the presence of alkaloids, flavonoids, phenolics, saponins, and steroids, while the methanolic extract showed strong DPPH radical-scavenging activity (IC ₅₀ = 70.81 ppm). Overall, <i>E. spinosum</i> from Gerupuk Waters exhibited favorable raw material quality and considerable nutritional and antioxidant potential. However, the elevated total arsenic content represents an important food-safety concern, and arsenic speciation and further toxicological assessment are required before its suitability for direct food or functional-food applications can be established.
Keywords: <i>Antioxidant Activity;</i> <i>Eucheuma Spinosum;</i> <i>Heavy Metals;</i> <i>Phytochemicals;</i> <i>Proximate.</i>	

INTRODUCTION

Seaweed is an important marine biological resource with considerable ecological and economic value and substantial potential as a raw material for food, hydrocolloid, nutraceutical, pharmaceutical, and cosmetic applications. As an archipelagic country, Indonesia possesses extensive coastal waters that provide favorable conditions for the cultivation and development of diverse seaweed commodities, making seaweed one of the most promising fisheries commodities for supporting coastal livelihoods. National seaweed production has shown an increasing trend,

reaching 9,234,268 tonnes in 2022, 9,753,411 tonnes in 2023, and 9,853,606 tonnes in 2024, while West Nusa Tenggara (NTB) contributed approximately 691,574 tonnes in 2024 (KKP, 2025). This production trend highlights the importance of not only increasing seaweed production but also gaining a comprehensive understanding of raw material quality, nutritional composition, bioactive constituents, and safety characteristics to support sustainable downstream utilization (Nugraha et al., 2022); (Saputra et al., 2021); (Putriarti et al., 2023). These production data and the increasing importance of seaweed as a source of industrial raw materials provide the broader context for the present study.

Among economically important red seaweeds, *Eucheuma spinosum* (Rhodophyta), which is taxonomically and commercially associated with *Eucheuma denticulatum*, is of particular interest because of its potential for value-added utilization. This species is recognized as an important source of carrageenan and is valued for its hydrocolloid properties, including thickening, stabilizing, and structure-forming capabilities in various food systems. Beyond its hydrocolloid functionality, *E. spinosum* contains nutritional constituents and secondary metabolites that may provide additional value as a functional food ingredient. Previous studies have reported the presence of phenolic and flavonoid compounds and demonstrated free-radical-scavenging activity in *E. spinosum*, indicating that the species has potential not only as a carrageenan-producing biomass but also as a source of naturally occurring bioactive compounds (Hradaya & Husni, 2021); (Podungge et al., 2018). Methanolic extracts of *E. spinosum* have also been reported to exhibit antioxidant activity based on the DPPH assay, with some extract fractions demonstrating strong radical-scavenging capacity (Podungge et al., 2018); (Lantah et al., 2017).

Gerupuk waters in Central Lombok, West Nusa Tenggara, represent one of the areas with potential for seaweed cultivation, including *E. spinosum*. The environmental conditions and habitat characteristics of the area support seaweed growth and have been utilized by local communities for cultivation activities. Previous research in Gerupuk Bay demonstrated that *E. spinosum* can be cultivated and contributes to nutrient uptake within an integrated multitrophic aquaculture (IMTA) system, while other cultivation studies have shown that planting depth can influence the growth performance of *E. spinosum*. Thus, Gerupuk is relevant not only as a seaweed production area but also as an important location for investigating the quality characteristics and utilization potential of *E. spinosum* produced under local environmental conditions (Yuniarsih et al., 2014); (Farnani et al., 2011).

The occurrence and cultivation of *E. spinosum* in Gerupuk are particularly important because the species has been developed by local communities and represents a potentially valuable economic commodity. Studies on *E. spinosum* cultivation at Muluk Gerupuk Beach have identified the species as one of the red seaweeds cultivated by local communities, while research conducted in the broader Gerupuk area has documented diverse macroalgal resources associated with local environmental conditions and coastal habitat characteristics. These conditions indicate that increasing the value of *E. spinosum* requires location-specific information on raw material quality because the chemical and bioactive characteristics of seaweeds can vary according to species, geographical location, environmental conditions, season, harvesting age, and post-harvest handling practices (Cokrowati et al., 2024); (Holdt & Kraan, 2011); (Stengel & Connan, 2015).

Previous research on *E. spinosum* has primarily focused on antioxidant activity, extraction conditions, phytochemical constituents, growth performance, and its utilization as a carrageenan source. For example, Hradaya & Husni, (2021) demonstrated that extraction temperature influenced the antioxidant activity of methanolic *E. spinosum* extracts, whereas Podungge et al., (2018) reported the presence of several phytochemical groups in *E. spinosum* extracts and demonstrated antioxidant activity using the DPPH assay. Other studies have further investigated antioxidant constituents in *E. spinosum* and highlighted its potential as a source of functional food ingredients. Collectively, these findings support the bioactive potential of *E. spinosum*; however, its bioactive characteristics should be evaluated specifically in relation to the geographical origin and physicochemical characteristics of the raw material under investigation (Hradaya & Husni, 2021); (Podungge et al., 2018); (Lantah et al., 2017).

In addition to secondary metabolites, the nutritional composition and raw material characteristics of *E. spinosum* are important determinants of its potential applications. Seaweeds generally contain appreciable levels of minerals, dietary fiber, structural polysaccharides and hydrocolloids, together with varying proportions of proteins and lipids. These components are strongly influenced by biological and environmental factors, including species, harvesting age, season, salinity, temperature, light intensity, and nutrient availability (Holdt & Kraan, 2011); (Circuncisão et al., 2018). Accordingly, proximate and crude fiber characterization of *E. spinosum* from a specific geographical location is necessary to establish an evidence-based profile of its actual raw material quality and potential suitability for food and hydrocolloid applications.

Raw material quality must also be considered together with food safety because seaweeds can accumulate minerals and certain elements from the surrounding aquatic environment. Functional groups present in cell-wall polysaccharides can interact with various ions and contribute to the accumulation of environmental elements. Such accumulation may become a safety concern when seaweed is intended for food applications, particularly with respect to potentially toxic elements such as arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb). In the present study, *E. spinosum* from Gerupuk waters contained Hg, Cd, and Pb at concentrations below the maximum limits specified by SNI 2690:2023 (BSN, 2023), whereas total arsenic reached 7.12 mg/kg, exceeding the stipulated limit of 3.0 mg/kg. This finding is particularly relevant because total arsenic concentration alone does not directly characterize toxicological risk without information on arsenic speciation, especially the proportion of inorganic arsenic, which is considered more toxicologically relevant (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2009); (Taylor & Jackson, 2016).

At the same time, the antioxidant potential of *E. spinosum* should be interpreted in conjunction with its secondary metabolite profile. Phenolic compounds, flavonoids, alkaloids, saponins, steroids, and other metabolite classes may contribute to the biological activities of seaweeds, although their occurrence and concentrations are strongly influenced by environmental conditions and extraction procedures. Previous studies have demonstrated that *E. spinosum* contains phenolic and flavonoid compounds and exhibits antioxidant activity in DPPH assays. Moreover, differences in solvent type and extraction conditions have been shown to influence the antioxidant activity of *E. spinosum* extracts, indicating that findings obtained from a particular location or extraction procedure cannot necessarily be generalized to raw materials originating from different environments (Podungge et al., 2018); (Hradaya & Husni, 2021).

Despite the growing body of research on *E. spinosum* addressing antioxidant activity, phytochemical constituents, carrageenan characteristics, and cultivation, there remains limited integrated information combining raw material quality, proximate composition, crude fiber, secondary metabolites, minerals, heavy metals, and antioxidant activity in *E. spinosum* originating from Gerupuk waters, Central Lombok. Previous studies conducted in Gerupuk have largely emphasized cultivation, growth performance, planting depth, nutrient uptake, and environmental utilization, whereas comprehensive information concerning the quality and safety of *E. spinosum* as a potential food and industrial raw material remains limited (Yuniarsih et al., 2014); (Farnani et al., 2011); (Cokrowati et al., 2024). Consequently, a comprehensive assessment is needed that integrates physicochemical characteristics, nutritional value, secondary metabolite profiles, antioxidant capacity, mineral composition, and heavy metal contamination in *E. spinosum* obtained from a defined production area. Addressing this research gap is important because the chemical and bioactive characteristics of seaweeds are highly dynamic and can be influenced by geographical and environmental factors. Therefore, data obtained from *E. spinosum* cultivated or harvested in other regions may not adequately represent the characteristics of biomass produced in Gerupuk.

The novelty of this study lies in providing an integrated, location-specific characterization of *Eucheuma spinosum* from Gerupuk Waters, Central Lombok, encompassing raw material quality, nutritional composition, phytochemical profile, mineral and heavy metal contents, and antioxidant activity. Unlike previous studies that mainly examined cultivation, carrageenan, phytochemicals, or antioxidant activity separately, this study integrates these attributes and

identifies total arsenic exceeding the SNI limit, providing important new evidence on the quality, bioactive potential, and food-safety considerations of locally produced *E. spinosum*.

Accordingly, this study aimed to characterize *Eucheuma spinosum* from Gerupuk waters, Central Lombok, with respect to raw material quality, yield, proximate composition, crude fiber content, secondary metabolite profile, mineral composition, heavy metal concentrations (Hg, Pb, Cd, and As), and the antioxidant activity of its methanolic extract based on the DPPH assay (IC₅₀). The study was designed to provide an integrated assessment of the suitability, safety, and bioactive potential of locally produced *E. spinosum*. Scientifically and practically, the findings are expected to expand the location-specific physicochemical database of *E. spinosum* and provide a basis for evaluating raw material quality, safety, and utilization efficiency. Ultimately, this information may support the development of value-added applications, including functional food ingredients and hydrocolloid-based products, while contributing to sustainable utilization and increased economic value for local coastal communities.

RESEARCH METHODS

Sample Collection

Eucheuma spinosum were collected from Gerupuk Waters, Central Lombok, West Nusa Tenggara, Indonesia. Fresh seaweeds were washed thoroughly with running water to remove adhering sand, epiphytes, and other impurities. Sampling was conducted three times in January 2026, with 5 kg of fresh seaweed collected per sampling. The samples were initially air-dried under shade during transportation and subsequently dried in a hot-air oven at 50°C for 5 h until constant weight. The dried samples were ground into powder using a laboratory grinder and sieved to obtain homogeneous seaweed flour for subsequent analyses.

Sensory Evaluation

The sensory quality of dried seaweed was evaluated according to SNI 2690:2023 (BSN, 2023) using six trained panelists. Appearance and texture were assessed using the standard score sheet with three independent observations for each sample.

Mineral and Heavy Metal Determination

Macro-minerals (K, Ca, and Mg) were determined using Inductively Coupled Plasma–Optical Emission Spectrometry (ICP-OES) after microwave-assisted acid digestion. Heavy metals (Hg, Pb, Cd, and As) were determined using Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) following SNI 2354.5:2011 (Pb and Cd), SNI 2354.6:2016 (Hg), SNI 2354.15:2017 (As), and AOAC Official Method 999.11 (AOAC, 2023). Analyses were conducted at the accredited laboratory of PT Saraswanti Indo Genetech, Bogor, Indonesia.

Extraction Procedure

Methanolic extracts were prepared using ultrasound-assisted extraction (UAE) following the method of Nufus et al., (2017) with slight modifications. Fifty grams of seaweed powder were extracted with 200 mL of 98% methanol (1:4, w/v) using an ultrasonic bath operating at 60 kHz for 30 min (Santoso et al., 2022). The extract was filtered and concentrated under reduced pressure using a rotary evaporator at 40°C to obtain crude extract, which was stored in amber bottles at 4°C until analysis.

Physicochemical Analysis

Moisture, ash, crude fat, and crude protein contents were determined according to the Indonesian National Standards (SNI), namely SNI 2354.2:2015 (moisture) (BSN, 2015a), SNI 2354.1:2010 (ash) (BSN, 2010), SNI 2354.3:2017 (fat) (BSN, 2017), and SNI 01-2354.4:2006 (protein) (BSN, 2006). Carbohydrate content was calculated by difference. Crude fiber was analyzed according to the AOAC Official Method 962.09 (AOAC, 2019), while Clean Anhydrous Weed (CAW) was determined according to SNI 8168:2015 (BSN, 2015b) for dried seaweed quality assessment. All analyses were conducted in triplicate.

Phytochemical Screening

Qualitative phytochemical screening was carried out following the procedures described by (Harborne, 1998) and (Yainahu et al., 2023). Methanolic extracts were analyzed for alkaloids,

flavonoids, phenolics, tannins, saponins, steroids, and triterpenoids based on characteristic color reactions and precipitate formation using specific reagents. All analyses were performed in triplicate. The criteria for positive (+) and negative (–) results are presented in **Table 1**.

Table 1. Criteria for Interpretation of Phytochemical Test Results

No.	Compound Tested	Reagent	Positive Result (+)	Negative Result (–)
1	Flavonoids	Concentrated H ₂ SO ₄	Development of a red color	No development of a red color
2	Alkaloids	Mayer's reagent	Formation of a white precipitate	No formation of a white precipitate
		Wagner's reagent	Formation of a brown precipitate	No formation of a brown precipitate
		Dragendorff's reagent	Formation of a reddish-orange precipitate	No formation of a reddish-orange precipitate
3	Phenols	5% FeCl ₃	Development of a green or bluish-green color	No development of a green or bluish-green color
4	Tannins	FeCl ₃	Development of a dark blue or blackish-green color	No development of the specified color
5	Saponins	Distilled water + 2 N HCl	Formation of stable foam persisting for 30 min	No foam formation or unstable foam
6	Steroids	Liebermann–Burchard reagent	Development of a blue or green color	No development of a blue or green color
7	Triterpenoids	Liebermann–Burchard reagent	Development of a pink or purple color	No development of a pink or purple color

Antioxidant Activity

Radical scavenging activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay according to SNI 8623:2018 with slight modifications based on (Syafuddin et al., 2025). Extracts were prepared at concentrations of 10–50 µg/mL and reacted with DPPH solution for 30 min under dark conditions. Absorbance was measured at 517 nm using a UV–Visible spectrophotometer. Vitamin C served as the positive control. The percentage of radical scavenging activity and IC₅₀ values were calculated from the inhibition curves. All measurements were performed in triplicate. The percentage inhibition of free radicals was determined using the following equation:

$$\% \text{ Inhibition} = \frac{(C-D-(A-B))}{(C-D)} \times 100\%$$

Note:

A = absorbance value of the sample solution or positive control;

B = absorbance value of the sample control solution;

C = absorbance value of the negative control solution;

D = absorbance value of the blank solution.

Data Analysis

All experimental data were expressed as mean ± standard deviation (SD). The data obtained from the raw material quality assessment, proximate composition, mineral and heavy metal analysis, and phytochemical evaluation were analyzed descriptively to characterize the quality and chemical composition of *E. spinosum*. The analytical results were compared with the applicable Indonesian National Standards (SNI), where relevant, to determine compliance with the specified quality and safety requirements. For the antioxidant assay, the percentage of DPPH radical-scavenging activity was calculated based on the decrease in absorbance of the DPPH solution following treatment with different concentrations of the methanolic *E. spinosum* extract.

The IC₅₀ value, defined as the extract concentration required to inhibit 50% of the DPPH radicals, was determined from the concentration–response relationship. A lower IC₅₀ value indicated stronger radical-scavenging activity. All analyses were performed in replicates, and the results were reported as mean ± SD.

RESULTS AND DISCUSSION

Raw Material Quality

The quality of the *Eucheuma spinosum* raw material was initially evaluated to ensure its suitability for subsequent processing and extraction. The assessment included organoleptic characteristics, clean anhydrous weed (CAW) content, dried seaweed yield, and methanolic extract yield. The organoleptic characteristics and CAW content were compared with the requirements specified in SNI 2690:2023, while the dried seaweed and methanolic extract yields were determined to characterize the recovery of the raw material during the drying and extraction processes. The results of the raw material quality assessment are presented in **Table 2**.

Table 2. Raw Material Quality of *E. spinosum*

Raw Material Quality Parameter	Result	Remarks
Organoleptic score	8	Complies with SNI 2690:2023
Clean Anhydrous Weed (CAW) (%)	50.20 ± 0.46	Complies with SNI 2690:2023
Dried seaweed yield (%)	15.67 ± 0.24	–
Methanolic extract yield (%)	1.36 ± 0.13	–

Note: SNI = Indonesian National Standard. Values are presented as mean ± standard deviation.

The raw material quality assessment of *Eucheuma spinosum* is presented in **Table 2**. Overall, the seaweed met the quality requirements specified in SNI 2690:2023, as indicated by its organoleptic score and clean anhydrous weed (CAW) content. The organoleptic score was 8, indicating that the raw material exhibited acceptable sensory characteristics and complied with the Indonesian National Standard. The CAW content was 50.20 ± 0.46%, demonstrating that approximately half of the raw material consisted of clean, anhydrous seaweed and fulfilled the applicable quality requirement. The organoleptic scores obtained were comparable to those reported by (Abidin et al., 2022) and higher than those reported by Saraswati et al., (2022), indicating that the drying method employed was effective in preserving the quality of the raw material.

Following the drying process, the seaweed exhibited a dried seaweed yield of 15.67 ± 0.24%. This value represents the proportion of dried seaweed recovered from the initial raw material after moisture removal. Furthermore, methanolic extraction produced an extract yield of 1.36 ± 0.13%. The relatively low extract yield may reflect the selective solubility of methanol-extractable compounds in *E. spinosum*, including low-molecular-weight phenolic and other bioactive constituents. The results indicate that the raw material was of suitable quality and adequately prepared for subsequent processing and extraction. Yield is influenced by the initial moisture content, structural polysaccharide composition, harvesting age, thallus morphology, and environmental conditions at the seaweed growing site (Abidin et al., 2022); (Prita et al., 2021). In addition, yield is an important indicator for evaluating the efficiency of the drying process and the quality of raw materials intended for subsequent processing (Saputra et al., 2021).

Proximate Composition Result

Proximate analysis was conducted to characterize the basic nutritional and chemical composition of *Eucheuma spinosum* and to provide an initial assessment of its potential as a source of functional components. The analysis included moisture, ash, fat, protein, carbohydrate, and crude fiber contents. These parameters provide important information regarding the major constituents of the seaweed and can also serve as a basis for evaluating its suitability for further processing and utilization. The results of the proximate composition analysis of *E. spinosum* are presented in **Table 3**.

Table 3. Proximate Composition of *E. spinosum*

Parameter	Result (%)
Moisture content	28.31 ± 2.84
Ash content	35.88 ± 0.76
Fat content	0.28 ± 0.28
Protein content	3.52 ± 0.19
Carbohydrate content	32.01 ± 0.91
Crude fiber content	15.41 ± 0.69

Values are presented as mean ± standard deviation (SD).

The proximate composition of *Eucheuma spinosum* is presented in **Table 3**. The results indicate that the seaweed exhibited a relatively high ash content, with a value of 35.88 ± 0.76%, suggesting a substantial contribution of mineral components to its overall composition. The carbohydrate content was 32.01 ± 0.91%, indicating that carbohydrates constituted one of the major proximate components of *E. spinosum*. This finding is consistent with the general composition of seaweeds, in which structural and storage polysaccharides commonly represent a considerable proportion of the dry matter.

The moisture content was 28.31 ± 2.84%, indicating that a considerable amount of water remained in the analyzed raw material. The crude fiber content reached 15.41 ± 0.69%, further indicating the presence of substantial structural polysaccharide components and other fiber-associated constituents. In contrast, the protein content was relatively low at 3.52 ± 0.19%, while the fat content was the lowest proximate component, at 0.28 ± 0.28%. Overall, the proximate profile demonstrates that *E. spinosum* is characterized by high ash and carbohydrate contents, accompanied by relatively low levels of protein and lipid, supporting its potential as a source of minerals and polysaccharide-rich functional ingredients. The relatively high carbohydrate content is also associated with the presence of structural polysaccharides and hydrocolloids, which constitute important compositional characteristics of red seaweeds (Holdt & Kraan, 2011); (Circuncisão et al., 2018). Accordingly, the proximate composition of *E. spinosum* indicates that this species possesses a combination of nutritional components and polysaccharides that may support its further development as a raw material for food and industrial applications. Discrepancies between these findings and those of previous studies may be attributed to variations in species, age and harvest time, environmental and habitat conditions, nutrient availability, as well as sample handling, drying, and analytical methods. Regarding carbohydrates specifically, differences are also influenced by moisture, ash, protein, and fat contents, as they are determined using the *by-difference* method. Seaweed-derived dietary fiber can provide added value in the development of functional foods because it contributes to the physiological and textural properties of food matrices and may support gastrointestinal function and metabolic regulation (Cherry et al., 2019). Therefore, the relatively high fiber content further supports the potential of *E. spinosum* as a marine-derived source of functional food ingredients.

Mineral and Heavy Metal Content Result

The mineral and heavy metal profiles of *E. spinosum* were evaluated to characterize its nutritional composition and assess potential safety concerns associated with inorganic contaminants. Mineral analysis focused on essential elements, including potassium (K), calcium (Ca), and magnesium (Mg), whereas heavy metal analysis included arsenic (As), mercury (Hg), cadmium (Cd), and lead (Pb). The concentrations obtained were compared with the applicable Indonesian National Standards (SNI) to determine compliance with established safety requirements. The results of the mineral and heavy metal analyses are presented in **Table 4**.

Table 4. Mineral and Heavy Metal Content of *E. spinosum*

Characteristic Group	Parameter	Result	Remarks
Minerals (mg/100 g)	Potassium (K)	18,221.22	–
	Calcium (Ca)	507.41	–
	Magnesium (Mg)	722.59	–
Heavy metals (mg/kg)	Arsenic (As)	7.12	Exceeds SNI limit
	Mercury (Hg)	0.02	Complies with SNI
	Cadmium (Cd)	0.57	Complies with SNI
	Lead (Pb)	0.26	Complies with SNI

Note: SNI = Indonesian National Standard. Values are expressed on the basis indicated in the respective units.

The mineral and heavy metal composition of *E. spinosum* is presented in **Table 4**. The seaweed contained substantial amounts of essential minerals, with potassium (K) showing the highest concentration at 18,221.22 mg/100 g, followed by magnesium (Mg) at 722.59 mg/100 g and calcium (Ca) at 507.41 mg/100 g. These findings indicate that *E. spinosum* contains appreciable levels of mineral elements, particularly potassium, which represents the predominant mineral among those analyzed. Differences in mineral content compared with previous studies may be attributed to variations in species, mineral absorption and accumulation capacities, aquatic environmental conditions, salinity, and mineral availability in the growth habitat. The physiological characteristics of individual seaweed species can also lead to distinct mineral absorption and retention capacities, resulting in variations in K, Ca, and Mg compositions across locations and studies.

The concentrations of Hg, Cd, and Pb in *E. spinosum* remained below the maximum permissible limits specified by SNI 2690:2023, whereas the total arsenic concentration of dried *Eucheuma spinosum* sample reached 7.12 mg/kg as determined by ICP-MS. However, this value cannot be directly compared with the Indonesian regulatory limit of 3.0 mg/kg, which is specified for inorganic arsenic in seaweed. However, total arsenic concentration does not directly reflect toxicological risk because arsenic toxicity is highly dependent on its chemical speciation, particularly the proportion of inorganic arsenic relative to organic forms such as arsenosugars (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2009); (Taylor & Jackson, 2016). Therefore, arsenic speciation is required to determine the concentration of inorganic arsenic and to assess the suitability of the seaweed for food applications. Differences in the results compared with previous studies may be attributed to variations in species, absorption and accumulation capacities, aquatic environmental conditions and salinity, mineral availability, as well as the extent of pollutant exposure and sediment conditions.

Phytochemical Screening and antioxidant activity *E. spinosum* Extract

The methanolic extract of *E. spinosum* was subjected to qualitative phytochemical screening to identify the major classes of secondary metabolites potentially responsible for its biological activity. The analysis included alkaloids, flavonoids, phenolics, saponins, steroids, tannins, and triterpenoids using specific qualitative reagents. In addition, the antioxidant activity of the extract was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging assay and expressed as the half-maximal inhibitory concentration (IC₅₀). The results of the phytochemical screening and antioxidant activity assessment are presented in **Table 5**.

Table 5. Phytochemical Screening of Methanolic *E. spinosum* Extract

Secondary Metabolite	Result	Remarks
Alkaloids (Mayer's test)	+	Detected
Alkaloids (Dragendorff's test)	+	Detected
Flavonoids	+	Detected
Phenolics	+	Detected
Saponins	+	Detected
Steroids	+	Detected

Secondary Metabolite	Result	Remarks
Tannins	–	Not detected
Triterpenoids	–	Not detected
Alkaloids (Wagner's test)	–	Not detected
IC ₅₀ of DPPH assay (ppm)	70.81 ± 0.76	Strong antioxidant activity

Note: (+) = detected; (–) = not detected. Values are presented as mean ± standard deviation (SD). IC₅₀ = concentration required to inhibit 50% of DPPH radicals.

The phytochemical profile and antioxidant activity of the methanolic extract of *E. spinosum* are presented in **Table 5**. Qualitative phytochemical screening revealed the presence of several secondary metabolites, including alkaloids, flavonoids, phenolics, saponins, and steroids. Alkaloids were detected using both Mayer's and Dragendorff's reagents, whereas the Wagner test gave a negative result. In addition, flavonoids, phenolics, saponins, and steroids were detected in the methanolic extract. In contrast, tannins and triterpenoids were not detected. The variation in the detection of alkaloids among the different qualitative tests may be associated with differences in the chemical sensitivity and specificity of the reagents used.

The presence of phenolic and flavonoid compounds is particularly relevant to the antioxidant potential of *E. spinosum*, as these classes of secondary metabolites have been reported to contribute to radical-scavenging activity in seaweed extracts. Previous studies have also demonstrated that methanolic extracts of *E. spinosum* can contain phenolic and flavonoid compounds and exhibit DPPH radical-scavenging activity, although the activity can vary substantially depending on extraction conditions. Phenolic and flavonoid compounds are well recognized for their ability to act as electron or hydrogen donors in free-radical scavenging reactions, while their chemical structures facilitate radical stabilization through resonance and the chelation of certain metal ions (Jomova et al., 2025). Previous studies have also demonstrated that *E. spinosum* extracts contain phenolic and flavonoid compounds that contribute to their antioxidant activity, highlighting the potential of this species as a source of natural antioxidants (Hradaya & Husni, 2021).

The DPPH assay showed an IC₅₀ value of 70.81 ± 0.76 ppm, indicating strong antioxidant activity according to the classification applied in this study. An IC₅₀ value in the range of 50–100 ppm is commonly categorized as strong antioxidant activity, with lower IC₅₀ values indicating greater radical-scavenging effectiveness (Molyneux, 2004). The relatively low IC₅₀ value observed in the present study suggests that the methanolic extract of *E. spinosum* possesses appreciable DPPH radical-scavenging capacity. This activity may be associated, at least in part, with the phenolic and flavonoid constituents detected during phytochemical screening. However, because the phytochemical screening was qualitative, further quantitative determination of total phenolic and flavonoid contents, together with chromatographic identification of individual compounds, would be required to establish a more direct relationship between specific bioactive constituents and the observed antioxidant activity. In another study, *Eucheuma spinosum* exhibited an IC₅₀ value of 42.10 ppm on (Syafuruddin et al., 2025). These differences are presumably influenced by the bioactive compound profile, sampling location and season, drying process, solvent type, extraction method, and DPPH assay conditions. This value falls within the category of strong antioxidant activity.

CONCLUSION

Eucheuma spinosum from Gerupuk Waters, Central Lombok, met SNI 2690:2023 quality requirements and exhibited high ash (35.88%), carbohydrate (32.01%), crude fiber (15.41%), and potassium (18,221.22 mg/100 g) contents. Although Hg, Cd, and Pb complied with safety limits, total arsenic (7.12 mg/kg) exceeded the applicable limit, highlighting the need for arsenic speciation before food application. The methanolic extract contained alkaloids, flavonoids, phenolics, saponins, and steroids and showed strong antioxidant activity (IC₅₀ = 70.81 ppm).

Overall, *E. spinosum* shows promising potential for functional food and hydrocolloid applications, subject to appropriate safety assessment, although further safety evaluation is required, particularly regarding arsenic levels, which still exceed permissible limits.

REFERENCES

- AOAC. (2023). *Official Methods of Analysis of AOAC International* (G. W. Latimer Jr., Ed.; 22nd Edition). AOAC Publications.
- BSN. (2010). *SNI 2354.1:2010 Cara uji kimia – Bagian 1: Penentuan kadar abu dan abu tak larut dalam asam pada produk perikanan*. Badan Standardisasi Nasional (BSN).
- BSN. (2006). *SNI-01-23544-2006 Cara uji kimia - Bagian 4: Penentuan kadar protein dengan metode total nitrogen pada produk perikanan*. Badan Standarisasi Nasional (BSN).
- BSN. (2015a). *SNI 2354.2:2015 Cara uji kimia-Bagian 2: Pengujian kadar air pada produk perikanan*. Badan Standarisasi Nasional (BSN).
- BSN. (2015b). *SNI 8168: 2015 Penentuan Clean Anhydrous Weed (CAW) pada rumput laut kering*. Badan Standarisasi Nasional (BSN).
- BSN. (2017). *SNI 2354-3:2017 Cara uji kimia – Bagian 3: Penentuan kadar lemak total pada produk perikanan*. Badan Standarisasi Nasional (BSN).
- BSN. (2023). *SNI 2690:2023 Rumput laut kering - Syarat mutu dan pengolahan*. Badan Standarisasi Nasional (BSN).
- Cherry, P., O'Hara, C., Magee, P. J., McSorley, E. M., & Allsopp, P. J. (2019). Risks and benefits of consuming edible seaweeds. *Nutrition Reviews*, 77(5), 307–329. <https://doi.org/10.1093/nutrit/nuy066>
- Circuncisão, A. R., Catarino, M. D., Cardoso, S. M., & Silva, A. M. S. (2018). Minerals from Macroalgae Origin: Health Benefits and Risks for Consumers. *Marine Drugs*, 16(11), 400. <https://doi.org/10.3390/md16110400>
- Cokrowati, N., Lumbessy, S. Y., Wahyuningsih, E., & Faris, M. (2024). Budidaya rumput laut *Eucheuma spinosum* di pantai muluk Gerupuk Kabupaten Lombok Tengah. *Jurnal Pengabdian Magister Pendidikan IPA*, 7(3), 788–792. <https://doi.org/10.29303/jpmipi.v7i3.8999>
- EFSA Panel on Contaminants in the Food Chain (CONTAM). (2009). Scientific Opinion on Arsenic in Food. *EFSA Journal*, 7(10), 1351. <https://doi.org/10.2903/j.efsa.2009.1351>
- Farnani, Y. H., Cokrowati, N., & Farida, N. (2011). Pengaruh Kedalaman Tanam Terhadap Pertumbuhan *Eucheuma spinosum* Pada Budidaya dengan Metode Rawai. *Jurnal Kelautan*, 4(2), 176–186.
- Harborne, J. B. (1998). *Phytochemical Methods. A Guide to Modern Techniques of Plant Analysis* (3th Edition). Chapman and Hall Ltd.
- 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>
- Hradaya, K. P. T., & Husni, A. (2021). Pengaruh Suhu Ekstraksi terhadap Aktivitas Antioksidan Ekstrak Metanolik *Eucheuma spinosum*. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 24(1), 1–10. <https://doi.org/10.17844/jphpi.v24i1.34193>
- Jomova, K., Alomar, S. Y., Valko, R., Liska, J., Nepovimova, E., Kuca, K., & Valko, M. (2025). Flavonoids and their role in oxidative stress, inflammation, and human diseases. *Chemico-Biological Interactions*, 413, 111489. <https://doi.org/10.1016/j.cbi.2025.111489>
- KKP. (2025). *Volume produksi perikanan Indonesia* (diakses 22 Juli 2026)

- Lantah, P. L., Montolalu, L. A. D. Y., & Reo, A. R. (2017). Kandungan fitokimia dan aktivitas antioksidan ekstrak metanol rumput laut *Kappaphycus alvarezii*. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 167–173. <https://doi.org/10.35800/mthp.5.3.2017.16785>
- Molyneux, P. (2004). The Use of the Stable Free Radical Diphenylpicryl-hydrazyl (DPPH) for Estimating Antioxidant Activity. *Songklanakarin Journal of Science and Technology*, 26(December 2003), 211–219. <https://doi.org/10.1287/isre.6.2.144>
- Nugraha, S., Humairani, Huriyah, S. B., & Kurniawati, E. (2022). Karakteristik kandungan kimia dan komponen bioaktif rumput laut. *Jurnal Fishtech*, 11(2), 89–98. <https://doi.org/10.36706/fishtech.v11i2.18029>
- Podungge, A., Damongilala, L., & Mewenghkang, H. (2018). Kandungan antioksidan pada rumput laut *Eucheuma spinosum* yang diekstrak dengan metanol dan etanol. *Jurnal Media Teknologi Hasil Perikanan*, 6(1), 1–5. <https://doi.org/https://doi.org/10.35800/mthp.6.1.2018.16859>
- Putriarti, D., Winarsih, & Rachmadiarti, F. (2023). Keanekaragaman rumput laut dan pemanfaatannya oleh masyarakat di pantai Kecamatan Palang Kabupaten Tuban. *Barkalah Ilmiah Biologi*, 12(3), 248–257.
- Saputra, S. A., Yulian, M., & Nisahi, K. (2021). Karakteristik dan kualitas mutu karaginan rumput laut di Indonesia. *Lantanida Journal*, 9(1), 1–13. <https://doi.org/https://doi.org/10.22373/lj.v9i1.9189>
- Stengel, D. B., & Connan, S. (2015). *Natural Products From Marine Algae Methods and Protocols* (Vol. 1308). Humana Press, Springer . <https://doi.org/10.1007/978-1-4939-2684-8>
- Syafruddin, Masri, A., Rukman, W. Y., Nurjannah, S., & Guntur, M. (2025). Uji Aktivitas Antioksidan Ekstrak Rumput Laut Merah (*Eucheuma spinosum*) menggunakan metode DPPH (1,1-Diphenyl-2-Picryl Hydrazil). *Fito Medicine: Journal Pharmacy and Sciences*, 16(2), 54–58.
- Taylor, V. F., & Jackson, B. P. (2016). Concentrations and speciation of arsenic in New England seaweed species harvested for food and agriculture. *Chemosphere*, 163, 6–13. <https://doi.org/10.1016/j.chemosphere.2016.08.004>
- Yuniarsih, E., Nirmala, K., & Radiarta, I. N. (2014). Tingkat penyerapan nitrogen dan fosfor pada budidaya rumput laut berbasis imta (Integrated Multi-Trophic Aquaculture) di Teluk Gerupuk, Lombok Tengah, Nusa Tenggara Barat. *Jurnal Riset Akuakultur*, 9(3), 487–500.