

Update Review: Utilization, Chemical Content, and Pharmacological Activity of Macroalgae for Development and Empowerment of Natural Resources in South Garut, Indonesia

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ARTICLE HISTORY

| Received: 12 May 2025

| Revised: 10 December 2025

| Accepted: 16 December 2025

Abstract

Macroalgae are autotrophic organisms that lack organs typically found in plants, such as roots, stems, and leaves. Macroalgae are grouped based on shape, size, and color. One of the coastal areas with abundant natural resources is the Garut Regency, Indonesia. This review aims to provide an updated assessment of the utilization, chemical composition, and pharmacological activities of macroalgae, to develop macroalgae as a natural resource. An updated review of macroalgae's utilization, chemical content, and pharmacological activities for developing and empowering macroalgae as natural resources in South Garut, Indonesia. This article was written by reviewing scientific articles published in the last 10 years on the utilization, chemical content, and pharmacological activities of macroalgae. In the coastal areas of Garut Regency, 44 species of macroalgae are found, comprising three divisions: *Chlorophyta*, *Phaeophyta*, and *Rhodophyta*. Macroalgae have benefited from an ecological and economic perspective. The chemical content of macroalgae can also be utilized as raw materials or additional ingredients in various industries, including the food, supplement, pharmaceutical, agricultural, and cosmetics industries. The bioactive compound content of each type of macroalgae can vary. *Sargassum sp.* contains bioactive compounds such as alkaloids, flavonoids, tannins, terpenoids, phenolics, saponins, steroids, glycosides, and chlorophyll. *Glacilaria sp.* contains bioactive compounds such as phenolic compounds, triterpenoids, flavonoids, and fatty acids. *Ulva lactuca* contains flavonoids, alkaloids, tannins, triterpenoids, saponins, catechins, quercetin, rutin, campherol, caffeic acid, ellagic acid, and chlorogenic acid. The influence of seasons and variations in harvest will influence the chemical content in macroalgae. Macroalgae possess several pharmacological properties, including antioxidant, antibacterial, anti-inflammatory, and anticancer effects. Various industries can utilize Macroalgae in the coastal waters of South Garut because they are rich in phytochemical content and pharmacological

activity, making them suitable for the development and sustainable use of natural resources essential for human life.

Keywords: glacialaria, macroalgae, natural resources, sargassum, ulva lactuca

Introduction

Indonesia boasts a high biodiversity, including flora, fauna, and marine biodiversity. Marine organisms commonly found in almost all coastal waters in Indonesia are macroalgae. Macroalgae are autotrophic organisms that lack organs typically found in plants, such as roots, stems, and leaves. Therefore, algae are classified as thallus plants.¹ Macroalgae are included in eukaryotic organisms and the Plantae kingdom. Macroalgae are divided into three divisions, namely *Chlorophyta*, *Phaeophyceae*, and *Rhodophyta*.²

Macroalgae can live in habitats such as reef flats, coral rubble, muddy coral, dead coral, muddy sand, and along shallow water, macroalgae are shaped like colorful plants (green, yellow, red, or brown). Typically, lay people call it seaweed. Indonesia's marine biodiversity has made it the second-largest country in the world, with the largest seaweed production. This is because Indonesian waters have enormous potential for natural resources.³ One coastal area with abundant natural resources is the Garut Regency, Indonesia. The coastal area in Garut Regency spans approximately 306,519 Hectares, with a length of the south coast area of around 72 km. South Garut Beach also faces the Indian Ocean. The South Garut Beach area boasts an abundance of marine resources, especially macroalgae at Sayang Heulang Beach and Karapyak Beach.⁴

Macroalgae have great potential for development because they play a crucial role from an ecological and economic perspective. However, macroalgae are also organisms vulnerable to environmental changes that can affect their existence. Macroalgae in the sea can provide a habitat for other biota to live and can maintain marine ecosystems.⁵ Apart from that, macroalgae also have other benefits: they can act as a medium for absorbing blue carbon to reduce greenhouse gases and absorb CO₂.³ However, farmers and macroalgae collectors in the coastal waters of South Garut still need to care about the sustainable use of the various types of seaweed because macroalgae have many benefits, namely as a cosmetic and food ingredient. Our review aims to investigate the updated utilization, chemical composition, and pharmacological activities of macroalgae as natural resources in South Garut, Indonesia.

Method

This article was written by collecting and reviewing scientific articles on the utilization, chemical composition, and pharmacological activity of macroalgae to develop and empower natural resources in South Garut, Indonesia. This article was published in the last 10 years. Articles presented in PubMed, Science Direct, Google Scholar, Springer, and Elsevier also have a DOI.

Result

Table 1. Utilization of Macroalgae

Macroalgae Species	Utilization	References
<i>Sargassum</i>	Fish feed	(19)
	Antidengue	(20)
	Alginate source	(15)
	Edible film	(21)
	Poultry feed	(22)
	supplements	(22)
<i>Glacilaria</i>	Fish feed	(19)
	Antioxidant	(23)
	Nori	(24)
	Poultry feed	(22)
	supplements	(22)
<i>Ulva lactuca</i>	Food source	(25)
	Cracker ingredients	(26)
	Edible film	(27)
	Biodiesel production	(28)
	Bioethanol and bio- oil production	(29)
	Syngas and hydrochar production	(30)
	Bioethanol production	(31)

Discussion

Macroalgae Diversity in South Garut Coastal Waters, Indonesia

Coastal areas have abundant natural resources that residents can utilize to meet their living needs. One of Indonesia's coastal areas with natural resources and abundant marine organisms is the Garut Regency. Garut Regency is one of the regions in West Java that boasts a diverse array of marine organisms, including macroalgae. In the coastal waters of South Garut, there are 44 species of macroalgae comprising the *Chlorophyta* division, which consists of 13 species and seven genera; the *Phaeophyta* division, which consists of 9 species and four genera; and the *Rhodophyta* division, which consists of 22 species and ten genera. The macroalgae most commonly found in South Garut coastal waters are *Glacilaria* (six species) and *Sargassum* (four species).

Several factors can influence the distribution of macroalgae species in coastal waters, namely substrate, geographical conditions, coastal topography, and season.⁶

Macroalgae are a group of eukaryotic organisms that are multicellular, macroscopic, and photoautotrophic. Algae cannot be distinguished between roots, stems, and leaves, so the algae's body shape is characterized as a thallus.⁷ Based on the color of pigmentation, macroalgae are divided into *Chlorophyta*, *Phaeophyta*, and *Rhodophyta*. In macroalgae, chlorophyll a and b pigments are the main pigments. Green algae (*Chlorophyta*) contain the pigments chlorophyll a and b, as well as carotenoids, xanthophylls, violaxanthin, and lutein. The most dominant of which are chlorophyll a and b, which cause the green color of macroalgae. Brown algae (*Phaeophyta*) have the pigments chlorophyll a, carotene, xanthophyll, and fucoxanthin. This fucoxanthin masks other colors, causing the algae to turn brown. Red algae (*Rhodophyta*) have chlorophyll a pigments, carotenoids, and phycoerythrin. Phycoerythrin is the most dominant pigment responsible for the red macroalgae.^{8,9}

Macroalgae can carry out photosynthesis because they have chlorophyll a and b.¹⁰ Several environmental factors can influence the spread of macroalgae, such as tidal activity, substrate, nutrients, salinity, pH, temperature, and light quality.¹¹ Macroalgae have an important role in marine ecosystems. Macroalgae can act as the primary food producer in the sea and as a shelter for other marine organisms, thereby supporting the life of different organisms. Substrate factors, season, geographical conditions, and coastal topography can determine the existence and diversity of macroalgae types found in coastal waters.¹² Basic information, such as the state of environmental factors, species diversity, and density of organisms, is crucial information for aquaculture because marine organisms have different growth and living conditions.¹³

Utilization of Macroalgae

Macroalgae have great potential for development because they play a crucial role in both ecological and economic aspects, as they are important from both environmental and financial perspectives (Table 1). Apart from that, macroalgae also have advantages in terms of chemical content, making them a superior commodity for development. Macroalgae can be utilized as a source of food and medicine for various industries, including gelatin and carrageenan production, food, chemicals, pharmaceuticals, supplements, and agricultural industries. Macroalgae produce a source of alginate, which is utilized by the chemical and pharmaceutical industries. This alginate can be used as an emulsifier, gelling agent, suspending agent, dispersing agent, and stabilizer. In the food industry, it is used to make milk, butter, and ice cream. In the cosmetics industry, it is used as an ingredient in cosmetics, serving as a preservative, excipient, and thickening agent.^{11,13-16} The bioactive compound content of macroalgae can easily be absorbed into the skin. It can reduce blemishes and redness, hydrate the skin, tighten, and protect against UV rays, making it suitable for cosmetic products.¹ In the agricultural industry, macroalgae can be used to improve plants and increase the productivity of various plants because they contain growth regulators such as cytokinins, auxins, gibberellins, minerals, vitamins, amino acids, and fertilizers. Macroalgae can also serve as an indicator of water quality.^{17,18}

In Table 1, Utilization of Macroalgae, the addition of *Sargassum* sp. and *Glacilaria* sp., in Asian bass fish to feed against hypoxic stress. Fish fed a mixture of *Sargassum* sp., and *Glacilaria* sp., can reduce cortisol, glucose, and lactic acid levels in response to hypoxic stress, making it beneficial in fish food.¹⁹ Derived from *Sargassum*, exophytic bacterial proteins have potential activity as anti-dengue effects on Vero cells.^{20,27} The isolation of alginate from *Sargassum* extracts from Lima Island contains different levels of guluronic acid and mannuronic acid, making the structure stiff and less flexible compared to other locations.¹⁵

The edible film made from Sodium Alginate with the addition of carrageenan, CaCl_2 , and glycerol can increase the plastic properties and tensile strength of the film, resulting in a stiffer edible film.²¹ The evaluation of *Sargassum sp.* and *Glacilaria sp.*, which are used as a poultry feed supplement, has a fiber content of 0.15–17.20%, protein of 9.07–63.63%, and fat of 0.152–2.11%.²²

Glacilaria sp., extract has antioxidant activity with an IC_{50} value of 982.25 ppm.²³ *Glacilaria sp.*, also using for making nori with the addition of pectin, chitosan and gelatin. Nori with the addition of gelatin has almost the same quality and characteristics as commercial nori.²⁴ Red algae (*Gracilaria sp.*), brown algae (*Sargassum sp.*), and green algae (*Ulva sp.*) are used as food ingredients because they contain vitamins, proteins, carbohydrates and minerals.²⁵

Ulva lactuca is also used as a flour substitute for the development of functional crackers. Crackers made from *Ulva lactuca* have a higher protein content and better nutritional value.²⁶ *Ulva lactuca* also being developed for use in making edible film. Combining *Ulva lactuca* with edible cellulose film yields promising results, including increased film thickness, enhanced water solubility, increased water vapor permeability, and antioxidant activity. This combination can be developed for food product packaging, as it can increase the shelf life of food.²⁷ *Ulva lactuca* can be used as a raw material for biodiesel, which is produced through transesterification with a base catalyst, yielding a biodiesel yield of 88.77%.²⁸

Ulva lactuca can be utilized for bioethanol fermentation and bio-oil production, with various parameters, including method, time, and temperature, to produce optimal results. The sonication method with a duration of 5 days and a temperature of 240°C produces the maximum bioethanol and bio-oil production.²⁹ *Ulva lactuca* can be used for syngas and hydrochar production. By using the subcritical water gasification method, as the temperature increases, the H_2 content also increases. However, increasing the concentration of raw materials can reduce H_2 . Hydrochar produced at a temperature of 400°C has a higher heating value (HHV), making it a viable fuel source.³⁰ The fermentation and hydrolysis process for bioethanol production with various parameters. The fermentation and hydrolysis processes can maximize bioethanol production, making it a valuable resource for developing environmentally friendly and economical factories.³¹

In the Pameungpeuk coastal area of South Garut, macroalgae are primarily used to make paper, and as a traditional food in the area. The macroalgae most commonly found in South Garut coastal waters are *Sargassum sp.*, *Glacilaria sp.*, and *Ulva lactuca*.³ Therefore, from several studies conducted regarding the use of macroalgae, apart from being used in the gelatin industry, food industry, chemical industry, pharmaceutical industry and agricultural industry, macroalgae can also be used in other countries as fish feed, edible film, poultry feed supplements, bioethanol production, functional food, cracker ingredients, biodiesel production, bioethanol and bio-oil production, syngas and hydrochar production, and bioethanol production. The use of macroalgae can serve as a reference for developing strategies that utilize macroalgae in the coastal waters of South Garut, enabling the natural resources to be utilized more effectively and for better, more sustainable use for human life.

Chemical Content of Macroalgae

In macroalgae, the genus, species, phylum (*Chlorophyta*, *Phaeophyta*, and *Rhodophyta*), as well as seasonal and harvest variations, can influence the chemical compound content and nutritional value. The *Chlorophyta* division has higher protein compared to the *Phaeophyta* division and the *Rhodophyta* division. However, the *Phaeophyta* division contains higher levels of minerals and polyphenols. The nutritional content of macroalgae, including protein, minerals, carbohydrates, and polyphenols, is also influenced by seasonal changes. In spring or summer, macroalgae can produce

proteins and minerals in the highest concentrations, while in autumn or summer, macroalgae can produce carbohydrates and polyphenols in the highest concentrations. The nutritional content and bioactive compounds of macroalgae can be influenced by various factors, including seasonal variations, location, and environmental conditions.³² Consumable macroalgae are rich in different nutrients that are beneficial for human health. In the food industry, macroalgae are used as a primary ingredient for functional food products because they contain high levels of polysaccharides. Apart from polysaccharides, macroalgae also contain protein, vitamins, amino acids, potassium, calcium, niacin, phosphorus, iron, magnesium, unsaturated fatty acids, iodine, and minerals, as well as dietary fiber. Flour made from macroalgae has low calories and can be used as a substitute for regular flour.^{9,33-35}

Macroalgae contain various kinds of bioactive compounds. These bioactive compounds can be isolated from macroalgae. The brown algae division (*Sargassum* sp.) includes a range of bioactive compounds such as alkaloids, flavonoids, tannins, terpenoids, phenolics, saponins, steroids, glycosides, and chlorophyll.^{36,37} Red algae (*Glacilaria* sp.) contain bioactive compounds such as triterpenoids, flavonoids, phenolic acids, and fatty acids such as Phosphatidylcholine, Lysophosphatidylcholine, Phosphatidylethanolamine, Phosphatidylglycerol, Lysophosphatidylglycerol, Phosphatidylinositol, Phosphatidic acid, and Inositolphosphoceramide.³⁸ Green algae (*Ulva lactuca*) contain flavonoids, alkaloids, tannins, triterpenoids, saponins, catechins, quercetin, rutin, campherol, caffeic acid, ellagic acid, and chlorogenic acid.^{23,39}

Pharmacological Activity of Macroalgae

Based on the results of various studies, macroalgae have been found to contain bioactive compounds that are useful for therapeutic purposes. These bioactive compounds are extracted from *Sargassum* sp., *Glacilaria* sp., and *Ulva lactuca*. Macroalgae exhibits pharmacological activities, including antioxidant, antibacterial, anti-inflammatory, and anticancer.

Antioxidant Activity

The acetone extract of *Sargassum* exhibited measurable antioxidant capacity in the DPPH assay, recording a value of 2.684. In contrast, the ethanol extract demonstrated higher activity in the FRAP test with a reading of 9.09.⁴⁰ Moreover, fermentation of *Sargassum* water extract with *Lactobacillus acidophilus* notably increased antioxidant performance, producing values of 43,498.33 at the initiation and 39,940.67 at the end of fermentation, as determined by the DPPH method.⁴¹ Another study employing the same assay reported an antioxidant activity value of 7.67 for fermented *Sargassum* water extract.⁴² Additionally, when processed into dry tea and analyzed through the FRAP method, *Sargassum* exhibited a strong antioxidant potential, achieving an activity level of 56.01.⁴³

The antioxidant potential of *Sargassum* also varied depending on solvent and analytical method. Using the Phosphomolybdenum method, the methanol extract collected before the rainy season showed an activity of 7.07. At the same time, the amount after the rainy season decreased slightly to 6.95.⁴⁴ In comparison, the water extract tested with the DPPH method exhibited an antioxidant activity of 12.3%.⁴⁵ Application of several assays revealed diverse antioxidant values, including 80.86 (ABTS), 91.28 (FRAP), 252.22 (OH-RSA), and 96.90 (RPA). Furthermore, the freeze-dried *Sargassum* extract obtained through the DPPH assay displayed an activity of 47.66, whereas the ethanol extract analyzed by the same method recorded a value of 33.65.^{46,47}

The methanol extract of *Glacilaria* exhibited antioxidant activity of 982.25 ppm based on the DPPH assay.²³ Meanwhile, *Ulva lactuca* extracts prepared in different

solvents demonstrated varying antioxidant efficiencies under the same method. The 70% ethanol extract at a concentration of 2.5 g/100 mL obtained through cold maceration presented the highest activity with a Trolox equivalent of 0.285 nmol per 10 μ L sample.⁴⁸ Among the solvent fractions, methanol extract recorded the strongest radical scavenging effect (11.26%), followed by chloroform (7.67%), benzene (4.85%), ethyl acetate (3.85%), ethanol (2.97%), and petroleum ether (2.21%), which showed the weakest activity.⁴⁹ Furthermore, *Ulva lactuca* copper nanoparticle extract exhibited a dose-dependent increase in scavenging capacity. In contrast, the methanol extract at 1000 μ g/mL concentration achieved a high antioxidant potential of $54.46 \pm 0.39\%$, indicating that both the extraction solvent and concentration significantly influence antioxidant performance.^{50,51}

In addition, these findings are consistent with the rich secondary metabolite profile of *Ulva lactuca* including phenolics, flavonoids, carotenoids, polysaccharides, vitamins C and E, polyphenols, chlorophylls, ascorbic acid, and specific peptides which act as potent antioxidants that scavenge free radicals, reduce oxidative stress, and support potential applications in nutraceutical, cosmetic, and pharmaceutical products targeting oxidative damage related conditions such as cardiovascular disease.⁵²

Antibacterial Activity

The methanol or water extract of *Sargassum sp.* demonstrated significant antibacterial activity, as evaluated using the microdilution and well diffusion methods. The results revealed that the extract inhibited the growth of both Gram-negative bacteria (*E. coli* and *K. pneumoniae*) and Gram-positive bacteria (*S. aureus* and *S. epidermidis*), producing inhibition zones of approximately 10.67 ± 0.58 mm. Notably, *S. aureus* (methicillin-sensitive strains) exhibited the highest susceptibility, with a much wider inhibition zone of 44.67 ± 1.15 mm.⁵³ Furthermore, the antibacterial screening of *Sargassum sp.* extracts prepared using different solvents indicated that the n-hexane extract was particularly active against *S. typhi* and *A. hydrophila*, showing inhibition diameters of 25.67 mm and 18.2 mm, respectively. In contrast, the methanol extract effectively suppressed the growth of *V. harveyi*, producing a clear zone of 18.04 mm.⁵⁴ A formulation study using liquid soap containing 25% *Sargassum* methanol extract combined with 75% *Eucheuma sp.* extract also showed strong antibacterial effects, yielding an inhibition zone of 28.30 ± 9.62 mm.⁵⁵

In a separate study, combining *Glacilaria sp.* extract with clarithromycin using the microdilution technique enhanced the inhibitory effect against *E. coli* compared to the antibiotic alone.⁵⁶ The antibacterial evaluation of the methanol extract of *Glacilaria sp.* through agar diffusion further confirmed its bioactivity, exhibiting inhibition zones of 15.3 ± 0.5 mm against *B. subtilis*, 24 ± 0.0 mm against *V. cholera*, and 11.7 ± 1.7 mm against *E. coli*. These findings indicate that various seaweed extracts, particularly from *Sargassum* and *Glacilaria* species, possess promising antibacterial potential against multiple pathogenic bacteria.⁵⁷

The methanol extract of *Ulva lactuca* exhibited marked antibacterial effects, particularly against *S. epidermidis* and *S. aureus*, as observed from the disc diffusion results.⁵⁸ When synthesized into iron nanoparticles, the *Ulva lactuca* extract demonstrated enhanced antibacterial potency, producing inhibition zones of 24 ± 1 mm for *S. aureus*, 29 ± 1 mm for *E. coli*, and 31 ± 2 mm for *S. typhimurium*, outperforming the methanol extract.⁵⁹ Evaluations using in vitro inhibition assays revealed that the ethanol extract of *Ulva lactuca* effectively inhibited *Vibrio anguillarum*, *Photobacterium damsela* subsp. *piscicida*, and *Tenacibaculum maritimum*.⁶⁰ Furthermore, comparative studies employing the well diffusion method found that the ethanol extract had the most pronounced antibacterial response, producing inhibition zones between 10 ± 1.24 mm and 22 ± 1.24 mm across all tested isolates. Meanwhile, the chloroform extract exhibited

weaker bacteriostatic properties, forming inhibition zones of only 10 ± 0.816 mm to 13.16 ± 1.027 mm against multidrug-resistant and beta-lactamase-producing foodborne bacteria.⁶¹

Additional investigations reported a moderate antibacterial action of the aqueous *Ulva lactuca* extract, particularly against Gram-positive species such as *S. mutans*, *S. aureus*, *E. faecalis*, and *Lactobacillus sp.*, as determined by agar diffusion assays.⁶² Solvent variation experiments showed that the butanol fraction produced inhibition zones approximately twice as large against Gram-negative bacteria (*P. aeruginosa* and *E. coli*) compared with those formed by the ethyl acetate fraction against *S. aureus*.⁶³ In another analysis using the well-cut diffusion technique, ulvan polysaccharides isolated from *Ulva lactuca* also demonstrated antimicrobial effectiveness against a broad spectrum, including *C. albicans*, *B. subtilis*, *S. epidermidis*, *A. hydrophila*, *P. fluorescens*, *P. aeruginosa*, *E. coli*, and *K. pneumoniae*.⁶⁴ Moreover, combining the methanol extract of *Ulva lactuca* with several antibiotics via agar diffusion produced synergistic inhibition, notably against *K. pneumoniae*, where an additive effect was recorded upon mixing 2.5 mg/mL of the extract with gentamicin (4 µg/mL).⁶⁵

Moreover, the rich content of secondary metabolites in *Ulva lactuca*, including alkaloids, flavonoids, phenolics, terpenoids, steroids, and fatty acids, exhibits potent antibacterial activity through mechanisms such as disrupting bacterial cell membranes, inhibiting protein and nucleic acid synthesis, chelating essential metal ions, and suppressing quorum-sensing pathways. These mechanisms enhance its defensive role against pathogenic microbes and highlight its potential as a source of novel antibiotics and antifouling agents; however, variations in metabolite composition and bioactivity may occur due to environmental and seasonal influences.⁶⁵

Anti-inflammatory Activity

An ethanol extract cream from *Gracilaria sp.*, applied at 5% and 10% concentrations in a UVB-irradiated mouse model, provided protection from epidermal damage; however, the results differed significantly from the control.³⁹ Meanwhile, *Ulva lactuca* methanol extract demonstrated strong anti-inflammatory effects in the BSA denaturation assay, achieving peak inhibition of 51.65% at 150 µg/mL, with an IC_{50} of 107.94 µg/mL.⁶⁶

These activities are associated with secondary metabolites such as phenolics and flavonoids that scavenge free radicals and inhibit nitric oxide production. Additionally, ulvan polysaccharides with anti-edematous and immunomodulatory effects, carotenoids like beta-carotene that protect against oxidative damage, and triterpenoids and saponins that support wound healing through their antibacterial and anti-inflammatory actions.⁶⁷

Anti-cancer Activity

Ethanol extract of *Sargassum sp.* evaluated by the MTT assay on HeLa cervical cancer cells exhibited cytotoxic effects, with an IC_{50} of 1915 µg/mL.⁶⁸ The ethanol extract of *Ulva lactuca* tested on MOLT-3 leukemia cells induced cytotoxic responses ranging from mild to severe after 24 h of exposure.⁶⁹ In studies using MCF-7 breast cancer and HCT-116 colon cancer cell lines, *Ulva lactuca* extracts in different solvents showed that the n-hexane fraction possessed the most prominent anticancer effect, with an IC_{50} of 45.1 µg/mL, whereas the ethanol, chloroform, and ethyl acetate fractions were less potent against HCT-116 cells, displaying IC_{50} values between 100 and 300 µg/mL.⁷⁰

The anticancer effects of *Ulva lactuca* are attributed to bioactive constituents such as sulfated polysaccharides (ulvans) and secondary metabolites like terpenoids and flavonoids. These compounds induce apoptosis through p53 activation, increase ROS generation, and regulate key signaling pathways including Bcl-2 and JNK, thereby demonstrating strong natural antitumor potential.⁶⁷

Conclusion

Various industries can utilize Macroalgae in the coastal waters of South Garut because they are rich in phytochemical content and pharmacological activity, making them suitable for the development and sustainable use of natural resources essential for human life. Macroalgae contain a variety of chemical compounds, including polysaccharides, proteins, vitamins (A, B1, B2, B6, C, D, E), amino acids, polyunsaturated fatty acids, calcium, magnesium, potassium, phosphorus, iodine, iron, minerals, and dietary fiber. Based on its nutritional content, consuming macroalgae can contribute to overall health. Macroalgae contain various bioactive compounds, also known as secondary metabolites, that are beneficial for therapeutic purposes. These secondary metabolites are phenolics, flavonoids, tannins, alkaloids, steroids, saponins, terpenoids, glycosides, and chlorophyll. The bioactive compound content of each type of macroalgae can vary. Brown algae (*Sargassum* sp.) contain bioactive compounds including alkaloids, flavonoids, tannins, terpenoids, phenolics, saponins, steroids, glycosides, and chlorophyll. Red algae (*Glacilaria* sp.) contain bioactive compounds, including phenolic compounds, triterpenoids, flavonoids, and fatty acids. Green algae (*Ulva lactuca*) contain flavonoids, alkaloids, tannins, triterpenoids, saponins, catechins, quercetin, rutin, campherol, caffeic acid, ellagic acid, and chlorogenic acid. Seasonal influences and variations in harvest will affect the chemical composition of macroalgae. Green algae (*Chlorophyta*) have higher protein content than brown algae (*Phaeophyta*) and red algae (*Rhodophyta*). Brown algae (*Phaeophyta*) contain higher levels of minerals and polyphenols. Bioactive compounds are extracted from macroalgae samples using appropriate solvents. Macroalgae possess several pharmacological properties, including antioxidant, antibacterial, anti-inflammatory, and anticancer.

Acknowledgment

The author would like to respect the facilities of the Department of Pharmaceutical Biology, Department of Pharmacology-Clinical Pharmacy, Department of Pharmaceutical Technology, Faculty of Mathematics and Natural Sciences, University of Garut; Department of Pharmacy, Faculty of Mathematics and Natural Sciences, University of Bengkulu; Department of Pharmaceutical Biology, Faculty of Health Sciences, Karawang Singaperbangsa University.

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