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AN APPRAISAL ON ANTIMICROBIAL APPLICABILITY OF MARINE MACROALGAE

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Abstract - *Algae are a very diverse group of autotrophic organisms that exist as unicellular as well as multicellular forms. The most complex marine plants are called seaweeds. Seaweeds are known for their various therapeutic properties. The term seaweeds refer only to macro or large marine algae, found as wild and cultivated, growing in saltwater. Seaweed produces metabolites that help in the protection against different biotic and abiotic stresses. These compounds show antiviral, antiprotozoal, antifungal, and antibacterial properties. Secondary metabolites from natural resources are a potential source of antimicrobial leads and drugs can be exploited to combat antimicrobial resistance in microorganisms. Seaweeds are a valuable medicinal source with a broad spectrum of biological activities. The substances isolated from Chlorophyta, Phaeophyta, and Rhodophyta show potent antimicrobial activity mainly belong to polysaccharides, fatty acids, phlorotannins, pigments, lectins, alkaloids, terpenoids, and halogenated compounds. In recent years, biological activities, potential health benefits, and the nutraceutical value of marine algae have been in great interest. Marine algae derivatives have shown potent sources for the novel, antibacterial drug discovery. This review, however, focuses specifically on the antimicrobial aspects of marine algae.*

Key Words: Macroalgae, Antimicrobial, Phycocompounds, Antibacterial, Seaweed

1.INTRODUCTION

Algae are one of the primary producers and it is the division of lower plants that contain chlorophyll in plant cell organelle chloroplast. They can be divided broadly into two different types: macro-algae (macroscopic) and microalgae (microscopic).[1] Marine algae is a broad term of marine life in which, together with cyanobacteria, it forms the main primary producers at the base of the ocean food chain. Marine algae include invisible and unicellular microalgae, which together with cyanobacteria from the ocean phytoplankton, as well as, more visible and complex multicellular macroalgae commonly called seaweed. Seaweeds are found along with coastal areas, living on the floor of continental shelves and washed up in intertidal zones. The term seaweed refers to the macrophytic marine algae that grow exclusively in the shallow waters. They provide shelter and food for many different sea animals, lend beauty to the underwater landscape, and are a direct source of food and feed. It has been reported that seaweeds serve as an important source of bioactive natural substances.[2]Many metabolites isolated from marine algae are found to be bioactive.[3]They absorb the nutrients from the surrounding water and don't need roots or any complex conducting tissues. Some large seaweed such as the kelps have root-like parts called holdfasts, not for conduction of water but to attach them to the rock. Most seaweed has to be attached to something to survive, and only a few will grow while drifting loose in the sea.[4]Three types of seaweeds are recognized, according to their pigments that absorb light of particular wavelengths and give them their characteristic colors of green (Chlorophyta), brown (Phaeophyta),or red (Rhodophyta). Because they need light to survive, seaweeds are found only in the relatively shallow parts of the oceans, which means around the shores.

The seaweeds are distributed horizontally in different zonations viz. supratidal (supralittoral), intertidal (littoral), and subtidal (sublittoral) regions of the seas and oceans.[5]Seaweeds found in the intertidal, shallow, and deep waters of the sea up, to 180 m depth and in estuaries and backwaters. They grow on substrates like rocks, corals, stones, pebbles, and also as epiphytes on sea grasses. Many species of

macroalgae with their large quantities occur along the Southern Tamil Nadu Coast from Rameswaram to Kanyakumari covering 21 islands of the Gulf of Mannar. On the Gujarat coast, seaweeds occur in abundance in Okha, Dwarka, Porbandar, Veraval, Diu, and Gopnath areas. Rich seaweed beds are present in Mumbai, Goa, Karwar, Varkala, Ratnagiri, Vizhinjam, Visakhapatnam, and coastal lakes of Pulicat and Chilka. Seaweeds also occur in abundance in Lakshadweep, Andaman and Nicobar Islands. Around more than 10,000 species of marine algae have been reported all over the world. In India, about 740 species of marine algae were recorded, 60 species of them are of economic value.[6]

Seaweeds were used as human food, eaten as a salad, curry, soup, or jam. [7-10] Seaweeds are the richest source of proteins, lipids, carbohydrates, minerals, vitamins (A, B, C, and Niacin) and antioxidants and are considered as a valuable food supplement for humans of 21st century and serve as a low-calorie food. [11]

In many countries, raw (fresh) or processed seaweeds are regularly fed to animals like cows, goats, horses, etc. A complex polysaccharide called phycocolloids is present in the cell wall of many types of seaweed. Among the various phycocolloids, Agar, Algin, and Carrageenan are most important. The seaweeds are used as biofertilizers because of their benefits as soil conditioners and green manure.[12] The potential of seaweeds is known not only for the macronutrients such as Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulphur but also for its trace elements like Zn, Cu, and Mn, and plant growth regulators namely Auxins, Gibberellins, and Cytokinins. The most powerful water-soluble antioxidants found in algae are polyphenols, phycobiliproteins, and vitamins.[13]

Marine organisms produce variety pharmacologically important compounds having activities, that include anticancer, antimicrobial, antifungal, antiviral, antiinflammatory and others, and are potential sources of new therapeutic agents. Marine organisms can survive in a competitive and hostile environment. They produce complex secondary metabolites in response to ecological pressure, such as competition for space, predation, and tide variations. Some of these compounds have an antimicrobial tendency that inhibits or limits the development and growth of other competitive microorganisms. Marine sessile organisms, such as algae, sponges, and corals, have developed physiological adaptations, including the synthesis of bioactive which confer defense against grazers and/or the installation of epiphytes and fouling organisms.[14-16] Metabolites isolated from three different types of algae may be useful for inhibiting bacteria, viruses, fungi, and other epibionts (e.g., cytostatic, antiviral, anthelmintic, antibacterial, antifungal activity).

Microorganisms have developed new strategies to evade the action of antibiotics, leading to multiple drug-resistant bacterial strains. With increasing resistance of pathogens to antibiotics, there is a public health priority for exploring and developing cheaper and effective natural antimicrobial agents with better potential, fewer side effects than antibiotics, good bioavailability, and minimal toxicity.[17] It is also worthwhile to test the marine antimicrobials for possible synergism with existing drugs.[18]

Based on published studies, Vatsos and Rebours reviewed the antimicrobial properties of seaweed extracts related to aquaculture.[19]Eom *et al.* reviewed the antimicrobial effects of phlorotannins from brown algae, concerning the food and pharmaceutical industries.[20] Abu-Ghannam and Rajauria reviewed the algal antimicrobials with potential food applications.[21] The studies on the genus *Cystoseira* were overviewed which show biological activities of extracts from native and some non-native Brazilian seaweed and the research progress concerning the isolation and structural elucidation of the secondary metabolites from *Cystoseira.*[22,23,24] The objective of this work is to collect the information published in recent years on the antimicrobial properties of compounds from seaweed, their extraction, and their major applications.

James J. Sims et al (1975) screened marine algae for the antimicrobial activity that showed three out of five compounds exhibited potent activity against bacteria *Staphylococcus aureus* and *Salmonella choleraesuis.*[25] M. Kausalya and G.M. Narasimha Rao (2015) found *Sargassum polycystum* revealed the strongest antibacterial activity.[26] Wan Razarinah (2018) screened antimicrobial activity of green algae on microbial pathogens like Gram-positive bacteria, Gram-negative bacteria, yeast, and mold. He found *Halimeda sp*. showed better antibacterial activity against *Bacillus subpilis*, *S.aureus,* and *Bacillus cereus* at different concentrations.[27] T. Vimala and T.V. Poonghuzhali (2017) reported maximum antimicrobial activity of different extracts of *Hydroclathrus clathratus* against human bacterial and fungal pathogen by vitro studies.[28] Shimaa M. El Shafay et al. (2015) evaluated the antimicrobial activity of different seaweeds such as

Ceramium rubrum (Rhodophyta), *Sargassum vulgare*, *Sargassum fusiforme* and *Padina pavonia* (Phaeophyta) collected from Red sea against multidrug-resistant bacteria.[29] Sung-Hwan Eom, young-Mogkim and Se-Kwon Kim (2012) reviewed the importance of brown algae-derived phlorotannins for antimicrobial activity against foodborne pathogenic bacteria, [30] Other researchers reported different biological activities such antiviral, antifungal, antiprotozoal and antibacterial properties of seaweed-derived bioactive compounds like polysaccharides, fatty acids, phlorotannins, pigments, lectins, alkaloids, terpenoids, and halogenated compound, etc.[31] Yong Li et al. (2018) suggested highest antibacterial activity of *U. prolifera*, *G. lemaneiformis,* and *S. fusiforme* in ethanolic extract.[32] Review studies of different marine algae for antimicrobial perspectives reported in table no. 1.

2. DISCUSSION

Macroalgae is found to contain numerous metabolites and bioactive compounds that have been proved to be unique in therapeutics. Many of the substances obtained from seaweed, such as alginates, carrageenan, and agar have been used for decades in traditional medicine, pharmacology, and food. Other compounds have bacteriostatic or antibacterial, antiviral, antitumor, anti-inflammatory, and antifouling activities. Therefore, seaweed could provide promising bioactive that can be used in the treatment of human diseases, or new antimicrobial agents to replace synthetic antibacterial agents used in agriculture and the food industry.

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Table: 1 Review study on Antimicrobial activities of different macroalgae

NO.	POTENTIAL MARINE ALGAE	SOLVENT USED FOR EXTRACT PREPARATION	EFFECT	TEST ORGANISM	REFERENCES
1.	*Padina tetrastromatica*	Methanol(DMSO)	Antibacterial effect Antioxidant activity	*Vibrio cholera Shigella flexneri*	[33]
2.	*Enteromorpha flexuosa*	Ethanol	Antibacterial effect	*E. coli*	[34]
3.	*Pterocladiella capillacea Osmundaria obtusiloba*		BCB Beta carotene bleaching activity, Antioxidant activity		[35]
4.	Brown algae *Fucus virsoides*	Water> Ethanol	Antibacterial activity	*Aeromonas salmonicida sub sp. Salmonicida, Photobacterium damselae*	[36]
5.	*Undaria pinatifida*	Polysaccharide	Antibacterial	*V. harveyi* Multiresistant *P. aeruginosa*	[36]
6.	*Ulva lactuca*	Ethyl acetate	Antifungal activity	*C. parapsilosis* fungi	[37]
7.	*Sargassum tenerrimum*	Methanol> Ethanol>Chloroform> Water	Antibacterial and Antifungal activity	*P. Vulgaris K. Pneumoniae A niger R. stolonifer*	[38]
8.	*Cystoseira crinite Cystoseira sedoides*	Chloroform & Ethyl acetate	Antifungal activity	4 Candida strains	[39]
9.	*Cystoseira crinite Cystoseira sedoides*	Petroleum ether	Antibacterial activity	*E. coli*	[39]
10.	*S. swartzii*	Methanol	Antibacterial activity	*E. faecalis S. pyogenes*	[40]
11.	*Ceramium nitens*	Lipid soluble extract	Antibacterial activity	*B. subtilis*	[41]
12.	*Ceramium nitens*	Chloroform: Methanol(2:1)	Antibacterial activity	*M. luteus*	[41]
13.	*Ulva fasciata*	Methanol> Ethanol> Acetone	Antibacterial activity	*E. coli*	[42]
14.	*Chaetomorpha aerea*	Methanol> Ethanol> Acetone	Antibacterial activity	*S. aureus*	[42]
15.	*Sargassum latifolium* B	Acetone	Antibacterial activity	*Salmonella sp.*	[43]
16.	*Cladophora socialis*	Methanolic extract	Antibacterial activity	*MRSA*	[43]
17.	*Dictyota linearis*	Methanol	Antifungal activity	*A. niger F. solani*	[44]
18.	*Dictyota dichotoma*	Methanol	Antifungal activity	*Aspergillus flavus Candida utilis, Penicillium sp.*	[44]