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Pharmacological Importance of Seaweeds: A Review

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Abstract: Seas and oceans represent a big store for beneficial algae. It is a real fact that the importance of marine organisms as a source of new substances is growing. With marine species comprising approximately a half of the total global biodiversity, the sea offers an enormous resource for novel compounds and it is classified as the largest remaining reservoir of natural molecules to be evaluated for drug activity. A very different kind of substances have been obtained from marine organisms among other reasons because they are living in a very exigent, competitive and aggressive surrounding very different in many aspects from the terrestrial environment, a situation that demands the production of quite specific and potent active molecules. The present review is focusing on the following topics: Seaweeds in India, nutritional and medicinal values of seaweeds, antimicrobial activity of seaweeds and uses of seaweeds.

Key words: Marine Environment · Seaweeds · Medicinal Value and Antimicrobial Activity

INTRODUCTION

Marine algae are one of the largest producers of biomass in the marine environment [1]. They produce a wide variety of chemically active metabolites in their surroundings, potentially as an aid to protect themselves against the other settling organisms. These active metabolites, also known as biogenic compounds, such as halogenated compounds, alcohols, aldehydes, terpenoids are produced by several species of marine macro and microalgae and have antibacterial, antialgal, antimacrofouling and antifungal properties which are effective in the prevention of biofouling and have other likely uses, as in therapeutics [2].

Seaweeds are the eukaryotic organisms that live in salty water and recognized as a potential source of bioactive natural products. Seaweeds have been used since ancient times as food, fodder, fertilizer and as source of medicine. Today, seaweeds are the raw materials for many industrial productions like agar, algin and carrageenan but they continue to be widely consumed as food in Asian countries [3]. In the sea, 3 types of plants occur and they are phytoplanktons, seaweeds or marine algae and seagrasses. Phytoplanktons are microscopic and free-floating forms; they are the primary producers of the sea. Seaweeds or marine algae are macroscopic, attached or freely floating plants. They form one of the important marine living renewable resources. They are primitive plants without any true root, stem and leaves. They belong to the division of Thallophyta in plant kingdom. Marine algae are classified into four groups namely Chlorophyceae (green algae), Phaeophyceae (brown algae), Rhodophyceae (red algae) and Cyanophyceae (blue-green algae) based on the type of pigments, morphological, anatomical and reproductive structures.

Seaweeds are plant like ocean organisms that are botanically classified as macrophytic marine algae. Edible seaweeds are often called "sea vegetables." Seaweeds come in an amazing variety of beautiful shapes, colors and sizes and found in all of the world's oceans. They are most abundant in shallow rocky coastal areas, especially where they are exposed at low tide. Coastal people around the world have been harvesting and eating sea vegetables since the beginning of time. In the United States and Europe, increasing numbers of people are learning that eating sea vegetables can provide a broad range of health benefits. Seaweeds contribute to primary production of the sea and hence seaweed beds are considered highly productive and dynamic ecosystem.

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Seaweeds vegetation provides an ideal habitat, food and shelter to various marine animals. They act as breeding, nursery and feeding grounds for many epiphytic fauna. The hapteron or holdfast of marine algae binds the sediments together and prevents coastal erosion.

Seaweeds in India: Seaweeds occur in the intertidal, shallow and deep waters of the sea upto 180 m depth and in estuaries and backwaters. They grow on dead corals, rocks, stones, pebbles, other substrates and as epiphytes on seagrasses. Several species of green, brown and red algae with luxuriant growth occur along the Southern Tamil Nadu Coast from Rameswaram to Kanyakumari covering 21 islands of Gulf of Mannar. In Gujarat coast, seaweeds occur abundantly in Okha, Dwarka, Porbandar, Veraval, Diu and Gopnath areas. Rich seaweed beds are present at Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam, Visakhapatnam and coastal lakes of Pulicat and Chilka. Seaweeds also occur abundantly in Lakshadweep andaman and Nicobar Islands. More than 10,000 species of marine algae have been reported all over the world. In India, about 220 genera and 740 species of marine algae were recorded of which 60 species are of economic value. In Mandapam area 180 species of seaweeds are growing, of which about 40 species are economically important.

It is estimated from the seaweed resources, survey conducted so far by the Central Marine Fisheries Research Institute, National Institute of Oceanography and other research organizations at different maritime states of India and Lakshadweep that the total standing crop of seaweeds in the intertidal and shallow waters is 91339 tonnes (wet wt.) consisting of 6000 tons of agar yielding seaweeds, 16000 tons of algin yielding seaweeds, remaining edible and other seaweeds. The standing crop of seaweeds in deep waters (5 to 22 m depths) from Dhanushkodi to Kanyakumari was estimated at 75373 tons (wet wt.) in an area of 1863 km. The biomass of economically important seaweeds of Gulf of Mannar was estimated at 8445 tons (wet wt).

Marine algae are not only the primary and major producers of organic matter in the sea, but they also exert profound effects on the density and distribution of other inhabitants of the marine environment. An understanding of the wide range of behavioral relationships that exist among organisms would provide us with clues to substances of biomedical interest. Marine secondary metabolites are organic compounds produced by microbes, sponges, seaweeds and other marine organisms. The host organisms biosynthesizes these compounds as non-primary or secondary metabolites to protect themselves and to maintain homeostasis in their environment. Some of these secondary metabolites offer avenues for developing cost effective, safe and potent drugs. Nearly 50 lakhs species available in the sea are virtually untapped sources of secondary metabolites. Those compounds already isolated from seaweeds are providing valuable ideas for the development of new drugs against cancer, microbial infections and inflammation [4] apart from their potential ecological/industrial significances such as controlling reproduction, settlement/biofouling and feeding deterrents [5].

Tamil Nadu has a geographical extent of 1, 30,058 m^2. It can be divided into two divisions namely the Eastern coastal plains and hills of North and East, which is endowed with the varied coastal habitat like mangroves, corals, seaweeds, seagrass beds, salt marshes, mud flats, sand dunes etc. The coast of Tamil Nadu bears luxuriant growth of seaweeds. More than two hundred species of seaweeds have found in this area. Indian seaweed industries depend on this coastline for raw materials regarding production of agar and sodium alginate. They are consumed in the form of soups as well as salads. The intake of seaweeds in the diet is said to prevent hair loss in men and women. It is also consumed by pregnant and lactating mothers because of their rich iron content. They are called the medical food of the 21^{st} century [6].

Nutritional and Medicinal Values of Seaweeds: Seaweeds contain large amounts of polysaccharides, notably cell wall structural polysaccharides that are extruded by the hydrocolloid industry: alginate from brown seaweeds and agar from red seaweeds. Other minor polysaccharides are found in the cell wall: fucoidans (from brown seaweeds), xylans (from certain red and green seaweeds) and ulvans in green seaweeds. Seaweeds also contain storage polysaccharides, notably laminarin (β-1,3- glucan) in brown seaweeds and floridean starch (amylopectin like glucan) in red seaweeds. When faced with the human intestinal bacteria, most of these polysaccharides (agars, carrageenans, ulvans and fucoidans), are not digested by humans and therefore can be regarded as dietary fibers [7].

Water-soluble and water insoluble fibers have been associated with different physiological effects. Many viscous soluble polysaccharides (pectins, guar gum, etc.) have been correlated with hypocholesterolemic and hypoglycemic effects, whereas water insoluble polysaccharides (cellulose) are mainly associated with a decrease in digestive tract transit time [8].

Among polysaccharides, fucoidans were particularly studied as they showed interesting biological activities (anti -thrombotic, anti-coagulant, anticancer, anti-proliferative, anti-viral and anti-complementary agent, anti-inflammatory). Seaweeds draw from the sea an incomparable wealth of mineral elements, macro elements and trace elements. The mineral fraction of some seaweeds accounts for up to 36% of dry matter. The brown seaweeds have been traditionally used for treating thyroid goiter [9].

Seaweeds are known as an excellent source of vitamins and minerals, especially sodium and iodine, due to their high polysaccharide content that could also imply a high level of soluble and insoluble dietary fiber [10]. Muthuraman and Ranganathan [11] selected six species of marine macro algae *viz*., *Caulerpa scalpelliformis, Cladophora vagabunda, Enteromorpha compressa, Halimeda macroloba, Ulva fasciata* and *Chaetomorpha antennina* to investigate protein, aminoacids, total sugars and lipid contents. Venkatesalu *et al*. [12] investigated fatty acid composition in *Ulva lactuca, Caulerpa chemnitzia, Padina tetrastromatica, Sargassum longifolium, Acanthophora spicifera* and *Gelidium micropterum* collected from Mandapam coast.

The protein content of brown seaweeds is generally small (average: 5 - 15% of the dry weight), whereas higher protein contents are recorded in green and red seaweeds (on average 10 - 30% of the dry weight). Lipids represent only 1-5% of algal dry matter and show an interesting polyunsaturated fatty acid composition particularly regarding with omega 3 and omega 6 acids which play a role in the prevention of cardiovascular diseases, osteoarthritis and diabetes. The green algae show interesting levels of alpha linolenic acid. The red and brown algae are particularly rich in fatty acids with 20 carbon atoms: eicosapentanoic acid and arachidonic acid.

Seaweeds are potentially good sources of proteins, polysaccharides and fiber [7, 13]. Studies on the biochemical constituents such as protein, carbohydrate and lipid in green and brown marine algae have been carried out from different parts of Indian coast [14, 11]. Much work has been done on algal fatty acids both micro algae as well as on the fatty acid composition of seaweeds. Seaweeds are known as an excellent source of vitamins and minerals, especially sodium and iodine, due to their high polysaccharide content, which could dietary fiber, Muthuraman and Ranganathan [11] selected six species of marine macro algae *viz*., *Caulerpa scalpelliformis, Cladophora vagabunda, Enteromorpha compressa, Halimeda macroloba, Ulva fasciata* and *Chaetomorpha antennina* to investigate protein, amino acids, total sugars and lipid contents. Mineral content are shown to vary according to species, wave exposure, seasonal, annual, environmental and physiological factors and the type of processing and method of mineralization [14-16].

Manivannan *et al*. [17] reported the mineral composition of different groups of seaweeds such as Chlorophyceae (*Ulva lactuca, Enteromorpha intestinalis*) Phaeophyceae (*Turbinaria ornata, Padina gymnospora*) and Rhodophyceae (*Hypnae valentiae, Gracilaria folifera*) from Mandapam coastal regions and they found that *Padina gymnospora* showed the maximum content of mineral composition such as copper, chromium, iron, lead, sulphur, calcium and potassium content than other seaweeds. *Hypnea valentiae* observed the minimum level of mineral content such as cadmium, iron, magnesium and calcium.

Karthikai Devi *et al*. [18] observed the element concentration of various seaweeds such as Chlorophyceae (*Codium tomentosum, Enteromorpha clathrata, Enteromorpha compressa*), Phaeophyceae (*Turbinaria conoides, Colpomenia sinuosa, Sargassum tenerimum, Sargassum wightii*) and Rhodophyceae (*Acanthophora spicifera*) from Gulf of Mannar marine biosphere reserve, Southeast coast of India. The *Sargassum wightii* showed the highest level of element composition such as chromium, copper, manganese, nickel, lead and zinc content than other seaweeds. *Acanthophora spicifera* recorded the lowest level of element content such as chromium, copper, lead and zinc.

Seaweeds offer a wide range of therapeutic possibilities both internally and externally. The term seaweeds refer only to macrophytic marine algae, both wild and cultivated, growing in saltwater. Seaweeds were considered to be of medicinal value in the orient as early as 3000 B.C. Carrageenam may be useful in ulcer therapy. Extracts from *Chondrus criseus* and *Gelidium cartilagium* have been found to be active against influenza B and mumps virus [19]. The iodine rich seaweeds such as *Asparagopsis toxiformis* and *Sarconema* sp. can be used for controlling goiter disease [20]. It is now well established that sea is rich source of biologically active materials. Seaweeds has been a source for the production of a variety of major metabolites such as polysaccharides, lipids, proteins, carotenoids, vitamins, sterols, enzymes, antibiotics and many other fine chemicals [21]. The algal dietary fiber, ranged from 33% to 75% of dry weight, mainly consists of soluble polysaccharides having important functional activities such as antioxidant, anticoagulant, antimutagenic and antitumour activity and have an important role in the modification of lipid metabolism in human body [22].

Substances that currently receive most attention from pharmaceutical companies for use in drug development or from researchers in the field of medicine related research include sulphated polysaccharides as antiviral substances, halogenated furanones from Delisea pulchra as antifouling compounds and kahalalide F from a species of Bryopsis as a possible treatment of lung cancer, tumours and AIDS. Other substances such as macroalgal lectins, fucoidans, kainoids and aplysiatoxins are routinely used in biomedical research and a multitude of other substances have known biological activities. Fucus vesiculosus is brown seaweed that grows on the Northern coasts of the Atlantic and Pacific oceans and the North and Baltic seas. This species is often included in kelp preparations along with other types of seaweed. As an herbal medicine, seaweed has been used for traditional cosmetics, treatments for cough, asthma, haemorrhoid, boils, goiters, stomach ailments and urinary diseases and for reducing the incidence of tumors, ulcers and headaches [23].

Del Val *et al*. [24] studied the production of secondary metabolites with antimicrobial activity of four marine algal species. They also explore the possibility of optimizing the production of biologically active compounds by culturing the seaweeds in bioreactor under different conditions and to test whether this approach could be also applied to seaweeds to obtain bioactive metabolites with pharmacological properties.

Charles Vairappan [25] found that the Red algae genus *Laurencia* are known to produce a wide range of chemically interesting secondary halogenated metabolites. This investigation delves upon extraction, isolation, structural elucidation and antibacterial activity of inherently available secondary metabolites of *Laurencia majuscula* collected from two locations in water of Sabah, Malaysia. Two major halogenated compounds identified as elatol and iso-obtusol. Structures of these compounds were determined from their spectroscopic data such as IR, ^{1}H-NMR, ^{13}C-NMR and optical rotation. Antibacterial bioassay against human pathogenic bacteria was conducted using disc diffusion method. Elatol inhibited six species of bacteria, with significant antibacterial activities against *Staphylococcus epidermidis*, *Klebsiella pneumoniae* and *Salmonella* sp. while iso-obtusol exhibited antibacterial activity against four bacterial species with significant activity against *Klebsiella pneumoniae* and *Salmonella* sp. Elatol showed equal and better antibacterial activity compared with tested commercial antibiotics while iso-obtusol only equaled the potency of commercial antibiotics against *Klebsiella pneumoniae* and *Salmonella* sp.

Sanaa Shanab [26] determined the antioxidant activity by free radical scavenging (DPPH-decolorization method) and inhibition of lipid peroxidation in three species of seaweeds [*Sargassum dentifolium*, *Laurencia papillosa* and *Jania corniculata*]. Extraction of each algal species was carried out by aqueous ethanol or dichloromethane and different concentrations were prepared. Dichloromethane extract of each algal species demonstrated greater antioxidant activities than the ethanol extract using both bioassays. Maximum free radical scavenging activity was exhibited by higher concentration of dichloromethane extract of *Sargassum dentifolium* followed by *Laurencia papillosa* and *Jania corniculata*. Also, higher concentration of dichloromethane extract of *Laurencia papillosa* had the maximum anti-lipid peroxidation activity followed by *Sargassum dentifolium* and *Jania corniculata*. All extracts showed antibiotic activity against four bacterial and two fungal species. Spectrophotometric and chromatographic determination of the active compounds revealed that the antioxidant and antibiotic activities might be attributed to algal content of chlorophylls, carotenoids and free phenols as well as fatty acids.

Jayanta Kumar Patra *et al.* [27] investigated the free radical scavenging potentials (DPPH radical and hydroxyl radical), inhibition of lipid peroxidation and glutathione-S-transferase and antimicrobial properties of *Sargassum* sp. The tested extract exhibited a dose dependent free radical scavenging action against DPPH radical and hydroxyl radical and antimicrobial activity. In addition, inhibition of lipid peroxidation and glutathione-S-transferase activities were also observed. The overall results have established that this seaweed could be used against several diseases and in the food processing industry, to preserve foods.

Luis Villarreal-Gomez *et al*. [28] evaluated the antibacterial and anticancer activities of extracts from the seaweeds like *Egregia menziesii, Codium fragile, Sargassum muticum, Endarachne binghamiae, Centroceras clavulatum* and *Laurencia pacifica*. They obtained the organic extracts from bacteria, free algae and from surface-associated bacteria. Pathogenic strains of *Staphylococcus aureus, Klebsiella pneumoniae, Proteus mirabilis* and *Pseudomonas* *aeruginosa* were used to test antibacterial activity and HCT-116 colon cancer cells for anticancer activity. Thirty five bacterial strains were isolated from the surface of seaweeds and identified as the phyla *Firmicutes*, *Proteobacteria* and *Actinobacteria* by 16S rDNA sequencing. The strains *Centroceras clavulatum, Sargassum muticum* and *Endarachne binghamiae* showed anticancer activity with IC_{50} values of 6.492, 5.531 and 2.843 μg mL^{-1} respectively. Likewise, the extracts from the seaweeds associated bacteria inhibited the growth of the Gram-negative bacterium *Proteus mirabilis.*

Renuka Bai [29] screened the marine red alga, *Gracilaria fergusonii* for preliminary phytochemical analysis (coumerins, phenols, quinones, steroids and tannins). Coumerins, phenols, quinones and steroids were present and tannin was absent in the alga investigated. Different organic solvent extracts *viz*., acetone, chloroform, diethyl ether, ethanol and methanol were evaluated for antibacterial activity, employing Gram negative (*Klebsiella pneumoniae* and *Pseudomonas aeruginosa*) and Gram positive (*Bacillus subtilis* and *Staphylococcus aureus*) bacteria. The ethanol extract of the alga was found to be active against *Pseudomonas aeruginosa* and *Bacillus subtilis*.

Rahila Najam *et al*. [30] studied the pharmacological activity of methanol extracts of *Hypnea musciformis* on rabbit and mice. *Hypnea musciformis* significantly decreased the serum total cholesterol, triglyceride and low-density lipoprotein cholesterol levels of rabbits. The level of glucose was increased after the administration of *Hypnea musciformis*, which could be a transient increase only, through action on glucagon and could also be attributed to the fact that the *Hypnea musciformis* contain many amino acids, which may form glucose. Administration of *Hypnea musciformis* significantly increased the level of dopamine. The possible effect of *Hypnea musciformis* on dopamine and other brain biogenic amines indicate that *Hypnea musciformis* probably have psychotropic and anxiolytic profile.

Premalatha [31] conducted the preliminary phytochemical analysis and concluded the presence of extra phytochemical in *Ulva fasciata* and *Chaetomorpha*. In the DPPH scavenging assay, both the seaweed extracts showed high antioxidant activity. The *Ulva fasciata* samples have more effective antioxidant activity when compared to the *Chaetomorpha antennina* and the percentage of scavenging was found to be about 83.95% for *Ulva fasciata* and 63.77% for *Chaetomorpha antennina* sample. The rapid TLC assay is considered as the rapid test to evaluate the antioxidant activity of natural compounds. The compounds showing the bands at Rf = >10, 25 and 94 of both the seaweed extracts and Rf = 52 in *Ulva* sp. alone were proved to be having antioxidant activity. The results of antimicrobial activity by the well diffusion assay also clearly expressed that *Ulva fasciata* has high concentration of active principles when compared to the *Chaetomorpha antennina*.

Seaweeds have become a recognized potential natural product in pharmaceutical industries. The *Gelidium acerosa* contain large amount of valuable phytochemicals like saponins, flavinoids and alkaloids etc., which are known for its medicinal uses. The preparations of the seaweeds are also useful for the common ailments, includes dysentery, hypertension, urinary tract infection and some other microbial infections among people. The extracts of seaweeds are prepared with three different solvents like ethanol, methanol and acetone and tested against bacteria like *Staphylococcus aureus, Bacillus cereus, Micrococcus luteus, Klebsiella pneumoniae, Pseudomonas aeruginosa,* fungus like *Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus, Candida albicans* and *Candida tropicalis*. In their study, ethanolic extract showed a varying degree of inhibition to the growth of tested organisms, than acetone and methanolic extracts and the presences of phytochemicals in *Gelidium acerosa* was confirmed [32].

Many species of algae have been investigated for antibacterial and antiviral properties in the highly volatile fractions of the genera *Asparagopsis*, *Bonnemaisonia* and *Pcilonia*, belonging to to the family Bonnemaisoniaceae a great variety of halogenated alkanes, saturated and unsaturated ketones, aldehyde, alcohols, epoxides and halogenated derivatives of acetic and acrylic acids have been deducted for antibiotic activity against *Bacillus subtilis, Staphylococcus* sp., *Fusarium* sp. and *Vibrio* sp. was shown for the halogenated heptanones [33].

Antimicrobial Activity of Seaweeds: Selective utilization of marine algae as potential source of pharmaceutical agents has been increasing in recent years. Many of the seaweeds possess bioactive components, which inhibit the growth of some Gram-positive bacteria and Gram-negative bacterial pathogens. The algal extracts were used as a curative and preventive agent for various diseases such as antibiotics, antihelminthics, cough remedies, antihypertensive, antitumour and antidiarrhoea. Recently, many researchers have embarked on the chemical investigation of marine algae with a special accent on their bioactive properties [34].

Seaweeds are considered as such a source of bioactive compounds as they are able to produce a great variety of secondary metabolites characterized by a broad spectrum of biological activities. Compounds with cytostatic, antiviral, antihelmintic, antifungal and antibacterial activities have been detected in green, brown and red algae [35, 36]. There are numerous reports concerning the inhibiting activities from macroalgae against human pathogens, fungi and yeasts, but only few contain data about effects against fish pathogens [37].

Zheng Yi [38] tested the crude extracts of seaweeds for antibacterial and antifungal activities. Among them, the ethanol extract showed the strongest activity against the bacteria and fungi tested. Four species of the Rhodophyta (*Laurencia okamurai*, *Dasya scoparia*, *Grateloupia filicina* and *Plocamium telfairiae*) showed a wide spectrum of antibacterial activity. Every solvent extract from the four species was active against all the bacteria tested. The test bacterium *Pseudomonas solancearum* and the fungus *Penicilium citrinum* were most sensitive to the extracts of marine algae. In general, the extracts of seaweeds inhibited bacteria more strongly than fungi and species of the Rhodophyta showed the greatest activity against the bacteria and fungi tested.

Joseph Selvin and Aaron Premnath Lipton [39] tested the secondary metabolites of seaweeds *Ulva fasciata* and *Hypnea musciformis* for biotoxicity potential. Both species showed potent activity in antibacterial, brine shrimp cytotoxicity, larvicidal, antifouling and ichthyotoxicity assays. The green alga *Ulva fasciata* exhibited broad-spectrum antibacterial activity whereas the red alga *Hypnea musciformis* showed narrow spectrum antibacterial activity. The brine shrimp cytotoxicity profile indicated that the seaweeds were moderately toxic. The overall activity profile indicated that *Ulva fasciata* contained more biological potency than *Hypnea musciformis*.

Oranday [40] screened the biological activity of *Gracilaria tikvahiae, Ulva lactuca, Ulva fasciata* and *Sargassum fluitans.* In a preliminary assessment, polar and non-polar extracts of four species of marine protoctist form were evaluated for antibacterial and antifungal properties against seven microorganisms by the diffusion method, non-polar extracts of *Sargassum fluitans* and polar extracts of *Gracilaria tikvahiae* inhibited the growth of more than four microorganisms. Extracts were separated using chromatography column and fractions were tested against *Staphylococcus aureus* and *Candida albicans*. The eighty fraction of petroleum ether of *Sargassum fluitans* exhibited high activity against *Candida albicans*.

Yolanda Freile-Pelegrin and Juan Luis Morales [41] evaluated the antibacterial activity of ethanolic and lipid-soluble extracts from 21 marine algal species against pathogenic microbes. All species with antibacterial activity were active against the Gram-positive bacteria (*Bacillus subtilis*, *Streptococcus faecalis* and *Micrococcus luteus*) and most of the algal species exhibited activity against *Bacillus subtilis* (89% in ethanolic soluble extracts and 94% in lipid-soluble extracts). The lipid-soluble extract of *Ceramium nitens* exhibited the highest activity among the species tested. The results are significant because no antibacterial activity has been found in previous research on this, or any other, species from this genus. The antimicrobial activities associated with extracts from different thallus regions (apical, basal and stolon) of selected *Caulerpa* species (*Caulerpa ashmeadii*, *Caulerpa paspaloides* and *Caulerpa prolifera*) were also evaluated. Results generally indicated that the stolon of *Caulerpa* has the highest antibacterial activity.

Prakash *et al.* [42] studied the antibacterial activity of 45 extracts of nine algae namely *Sargassum weightii, Chaetomorpha antenna, Ulva fasciata, Amphiroa fragillisima*, *Gracilaria edulis* and *Enteromorpha* sp. against the pathogens. The Otitis media infected bacterial pathogens were isolated from 25 infected patients. The isolated bacterial species were Gram positive and Gram negative such as *Haemophilus influenza, Streptococcus pneumoniae, Streptococcus pyogenes, Staphylococcus aureus* and *Moraxella catarrhalis*. Bioassay was carried out with 45 extracts *Halymedia floresia* crude was found to produce maximum growth inhibition against the bacterial pathogens. Five solvents were used for the extraction of antimicrobial of which butanol showed maximum extraction of antimicrobials.

Choudhury *et al.* [43] screened the organic solvent extracts of three marine algae showed species-specific activity in inhibiting the growth of six virulent strains of bacteria pathogenic to fish *viz*., *Edwardsiella tarda*, *Vibrio alginolyticus*, *Pseudomonas fluorescens*, *Pseudomonas aeruginosa* and *Aeromonas hydrophila*. Three methanol extracts of *Cynometra iripa* were active against all the six pathogens, whereas *Aegiceras corniculatum* and *Aglaia cucullata* were active against four of the pathogens. The chromatographic fractionation of active extracts of *Aegiceras corniculatum*, *Cynometra iripa* and *Gracillaria corticata* resulted in enriched fractions with wide spectrum activity and lowered values of minimum inhibitory concentration.

Unci Ney *et al*. [44] studied the antimicrobial activity of methanol, acetone, diethyl ether and ethanol extracts of 11 seaweed species against *Candida* sp., *Enterococcus faecalis*, *Staphylococcus aureus*, *Streptococcus epidermidis*, *Pseudomonas aeruginosa* and *Escherichia coli* by disc diffusion method. Diethyl ether extracts of fresh *Cystoseira mediterranea*, *Enteromorpha linza*, *Ulva rigida*, *Gracilaria gracilis* and *Ectocarpus siliculosus* showed effective results against all tested organisms. However, diethyl ether extracts of some species, such as *Padina pavonica*, *Colpomenia sniosa*, *Dictyota linearis*, *Dictyopteris membranacea*, *Ceramium rubrum* and *Acanthophora nojadiformis* gave different results. A significant difference in antimicrobial activity was not observed between the acetone and methanol extracts of each algae.

Rossana Aguiar Cordeiro [45] obtained a protein fraction which is rich in lectin, from the red seaweed *Hypnea musciformis* by precipitation with ammonium sulfate (F40/70) was screened for chitinase and β-1,3-glucanase activity and assessed for antifungal potential against the human pathogen yeasts *Candida albicans* and *Candida guilliermondii*. The F40/70 fraction showed chitinase and β -1, 3-glucanase enzymes, with specific activities of 276.43 and 1880.7 Units mg^{-1} protein, respectively. It was capable of inhibiting the growth of *Candida guilliermondii* at the concentrations of 45, 100 and 450 µg protein/ml but it showed only a discrete inhibition against *Candida albicans* irrespective of the tested concentrations. The inhibitory action was shown to be fungistatic and the presence of the glycoprotein fetuin.

Roberta Paulert *et al*. [46] studied the antimicrobial activity of cell-wall polysaccharides and crude extracts from the seaweed *Ulva fasciata* against filamentous fungi, yeast and bacteria. The antibacterial activity was assessed by agar diffusion assay and by means of the broth dilution method estimating the minimum inhibitory concentration (MIC). The following human bacterial and yeast strains were tested: *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus cereus*, *Micrococcus luteus* and *Candida albicans* and two plant pathogens: *Xanthomonas campestris* and *Erwinia carotovora*. MIC was determined for the fungi *Colletotrichum lindemuthianum*, *Trichophyton mentagrophytes* and *Microsporum canis*. Both methanol soluble and methanol insoluble extracts were active against *Pseudomonas aeruginosa*, *Xanthomonas campestris* and *Erwinia carotovora.* The highest activity of extracts was observed against *Erwinia* (MIC 1 mg/ml). The methanol insoluble extract inhibited the growth of *Trichophyton mentagrophytes* at concentration of 2 mg/ml. In contrast, ulvans did not show any *in vitro* activity towards all test organisms.

Wendy Stirk *et al*. [47] collected seven seaweeds, *Caulerpa racemosa* var*. laetevirens, Codium capitatum, Halimeda cuneata, Ulva fasciata, Amphiroa bowerbankii, Amphiroa ephedraea* and *Dictyota humifusa* for testing the antifungal, antibacterial and acetylcholinesterase (AChE) inhibitory activity. No seasonal variation was observed in antifungal activity, with *Dictyota humifusa* extracts being the most active. The seaweed extracts inhibited the growth of the Gram-positive bacteria, with *Bacillus subtilis* being more susceptible than *Staphylococcus aureus*. *Dictyota humifusa* was the only seaweed able to inhibit the Gram-negative *Escherichia coli*. Seasonal variation in antibacterial activity was observed with the extracts generally having no activity in summer and having antibacterial activity in late winter and early spring. *Dictyota humifusa* was the most effective seaweed species, having antibacterial activity throughout the year. All the extracts tested had AChE inhibitory activity, with no seasonal variation in the levels of activity. *Dictyota humifusa* extracts were the most effective at inhibiting AChE activity.

Taskin *et al*. [48] studied the antibacterial activity of methanolic extracts of six marine algae belong to Rhodophyceae (*Corallina officinalis*), Phaeophyceae (*Cystoseira barbata*, *Dictyota dichotoma*, *Halopteris filicina, Cladostephus spongiosus*) and Chlorophyceae (*Ulva rigida*) against pathogenic microbes, 3 Gram positive (*Staphylococcus aureus, Micrococcus luteus* and *Enterococcus faecalis*) and 3 Gram negative bacteria (*Escherichia coli, Enterobacter aerogenes* and *Escherichia coli*). Extracts of all the test marine algae except *Corallina officinalis* showed inhibition against *Staphylococcus aureus*. On the other hand, highest inhibition activity among all the extracts was shown to *Enterococcus aerogens* by *Corallina officinalis*. The extract from *Cystoseira barbata* has shown broader activity spectrum against all the test organisms.

Kandhasamy and Arunachalam [49] studied the antibacterial activities of seaweeds belong to Chlorophyceae (*Caulerpa racemosa* and *Ulva lactuca*), Rhodophyceae (*Gracillaria folifera* and *Hypnea musciformis*) and Phaeophyceae (*Sargassum myricocystum*, *Sargassum tenneerimum* and *Padina tetrastomatica*) against both Gram negative and Gram-positive pathogenic bacteria. Methanolic extract of all seaweed extracts exhibited broad spectrum of antibacterial activity. Chlorophyceae members showed high antibacterial activity than other members of the algae tested in the present investigation. *Escherichia coli* alone resistant to all the seaweed extracts except *Sargassum tenneerimum*.

Chinnadurai Sreenath Kumar *et al*. [50] carried out the antimicrobial screening of 12 different seaweeds extracts namely *Chaetomorpha antennina*, *Dictyota dichotoma*, *Enteromorpha flexuosa*, *Laurencia obtusa*, *Gracilaria corticata*, *Gracilaria verrucosa*, *Grateloupia lithophila*, *Padina boergesenii*, *Sargassum wightii*, *Turbinaria conoides*, *Halimeda tuna* and *Ulva lactuca*. The crude extracts were tested against the phytopathogenic bacterium *Pseudomonas syringae* causing leaf spot disease of the medicinal plant *Gymnema sylvestre*. The methanolic extract of *Sargassum wightii* showed maximum activity followed by ethyl acetate compared to that of other organic solvent extracts. Thus, their investigation throws fresh light on the appropriate usage of solvent extraction method in preparing potent biopesticide.

Santhanam Shanmughapriya [51] collected fourteen seaweeds and tested against ten human pathogen bacteria and one human pathogen fungus using the well diffusion test in the casitone agar medium. In their study, methanol:toluene (3:1) was found to be the best solvent for extracting the antimicrobial principles from fresh algae. However, the ethanolic extract showed no antibacterial activity. *Acrosiphonia orientalis* showed activity against 70% of the tested organisms. *Stocheospermum marginatum* was the only seaweed that showed activity against *Klebsiella pneumoniae*. The extract from *Gracilaria corticata* was highly active against *Proteus mirabilis,* a Gram-negative pathogenic bacterium. Their findings revealed that the tested seaweeds were highly active against Gram-negative bacteria than Gram-positive bacteria. The antimicrobial principle from seaweed was found to be a lipophilic compound. The compound was stable over a wide range of temperature (30 - 60°C). The active principles of highly active seaweeds *Acrosiphonia orientalis* and *Stocheospermum marginatum* were bactericidal.

Srinivasakumar and Rajashekhar [52] tested ten microalgae cultured under controlled condition for their antimicrobial activity against the selective bacterial pathogens incompliance with paper disc method. *Isochrysis galbana* showed overall inhibition of (16.22%) followed by *Chlorella marina* (14.43%), *Nannochloropsis oculata* (14.07%), *Dunaliella salina* (13.91%) and *Pavlova lutheri* (13.17%). These five microalgal strains were investigated to examine concentration dependent microbicidal activity using tube dilution method. Microalgal strains were also investigated with agar well diffusion method to understand the efficacy of antimicrobial principles against various bacterial pathogens. The findings of their study revealed that optimal activity was maintained by butanol extract on Gram positive bacteria; ethanol and petroleum ether extract on both Gram positive and Gram negative bacteria; methanol extract on Gram-negative organisms. Chloroform extract, on the other hand did not show any significant antimicrobial activity.

Aseer Manilal *et al.* [53] examined 15 seaweeds belong to 13 families and 6 orders of the Rhodophyta for *in vitro* antimicrobial activity against six pathogenic *Vibrio* strains isolated from moribund tiger shrimp (*Penaeus monodon*), six type cultures of prominent shrimp *Vibrio* pathogens, 10 multidrug resistant clinical pathogens, four species of *Candida* obtained from pulmonary TB patients and four species of plant pathogenic fungi to evaluate their potency to be used as natural antibiotics in pharmaceutical and agriculture field. Bioactivity was analyzed from crude extract of fresh and dried samples prepared from different polar and non-polar solvents. Of these, four species of red algae (*Asparagopsis taxiformis, Laurencia ceylanica, Laurencia brandenii* and *Hypnea valentiae*) were found to be highly active. Broadest and highest activity was observed in the crude extract of *Asparagopsis taxiformis*. Among the pathogens tested, shrimp pathogenic *Vibrios* were the most susceptible organisms while phytopathogens were found to be little resistant.

Saeidnia *et al*. [54] evaluated the cytotoxic, antibacterial and antifungal activity of two red algae, *Gracilaria salicornia* and *Hypnea flagelliformis*. Ethyl acetate extracts of both algae showed a potent cytotoxic effect against *Artemia salina* nauplii (LC_{50} = 3 and 4 µg mL^{-1}, respectively). Aqueous methanol (50%) extracts were also effective. None of the methanol and aqueous methanol extracts of the algae showed antifungal and antibacterial activity against *Staphylococcus aureus, Escherichia coli, Candida albicans* and *Aspergillus niger* by the broth dilution method. Only the ethyl acetate extract exhibited antibacterial activity (MIC = 2 µg mL^{-1}) on *Staphylococcus aureus*.

Rajasulochana *et al*. [55] determined the antibacterial activities of marine seaweeds against different types of bacteria using disc diffusion method. Methanol was used for inhibition of different bacterial isolates such as

Pseudomonas fluorescence, *Staphylococcus aureus*, *Vibrio cholerae* and *Proteus mirabilis* in the case of red algae. In their study, they observed that the kappaphycus exhibited maximum activity against *Pseudomonas fluorescence*, *Staphylococcus aureus* and less inhibition on *Vibrio cholerae* and *Proteus mirabilis*. Benzene, n-hexane, ethyl acetate, methanol, chloroform: methanol solvents were used for inhibition of *Staphylococcus aureus* and *Escherichia coli*. It was noted that chloroform: methonol was the best solution for extracting the effective antibacterial materials from the brown algae species. The chloroform: methanol solvent further used for antibacterial activity against eleven pathogenic bacterial isolates. It was observed from the experiments that the extract residues of algae recorded maximum activity against *Staphylococcus aureus* with an inhibition zone compared to other bacterial isolates. The extract residues of brown algae did not show any effect on the growth of *Proteus vulgaris* and *Pseudomonas aeruginosa*.

Vallinayagam *et al.* [56] screened the antibacterial activities of four important seaweeds namely *Ulva lactuca*, *Padina gymnospora*, *Sargassum wightii* and *Gracilaria edulis* against human bacterial pathogens *Staphylococcus aureus, Vibrio cholerae, Shigella dysentriae, Shigella boydii, Salmonella paratyphi, Pseudomonas aeruginosa* and *Klebsiella pneumoniae.* The maximum activity was recorded from the extract of *Gracilaria edulis* against *Staphylococcus aureus* and minimum by *Ulva lactuca* against *Pseudomonas aeruginosa*.

Karthigai Devi *et al*. [57] collected some commonly occurring green algae *Codium adherens, Ulva reticulata* and *Halimeda tuna* and evaluated its antibacterial activity by agar diffusion method. Seven different solvents namely acetone, methanol, chloroform, diethyl ether, ethyl acetate, ethanol and petroleum ether were used for extraction. The ethanol extract showed the better results when compared to for the other extracts. Some extracts found more effective than the commercial medicine. The maximum antibacterial activity was noted in ethanol extracts showed activity against *Staphylococcus* sp. and the minimum was recorded in methanol extracts against *Escherichia coli*, *Staphylococcus* sp., *Proteus* sp., *Streptococcus* sp. and *Enterococci* sp.

Patra *et al*. [58] studied the antibacterial activity of organic solvent extracts of three marine macroalgae *viz*., *Chaetomorpha linum* (Mell) Kuetzing, *Enteromorpha compressa* (L) Greville and *Polysiphonia subtilissima* Mont. against of three Gram negative bacteria (*Shigella flexneri, Vibrio cholerae* and *Escherichia coli)* and two Gram positive bacteria (*Bacillus subtilis* and *Bacillus brevis)*. The results revealed that the chloroform and ethyl acetate extracts were active against most of the pathogens whereas methanol and ethanol extracts were active only against *Shigella flexneri*.

Chiheb Ibtissam *et al*. [59] evaluated the antibacterial activity of methanolic extracts from 32 macroalgae for the production of antibacterial compounds against *Escherichia coli*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Klebsiella pneumoniae* and *Enterococcus faecalis*. Their results indicated that these species of seaweed have the antibacterial activities, which makes them interesting for screening for natural products.

Bouhlal Rhimou *et al*. [60] screened the antibacterial activity of extracts from 26 marine Rhodophyceae to assess their potential in the pharmaceutical industry. Their bioactivity was analyzed from crude methanolic extracts of dried samples against three Gram positive bacteria and two Gram negative bacteria using the disc diffusion technique. The 96% of extracts were active against at least one of the five tested microorganisms. *Staphylococcus aureus* was the most susceptible microorganism. Methanolic extracts of all seaweed extracts tested exhibited a broad spectrum of antibacterial activity with inhibition diameters ranging from 10 to 35 mm. An extract of *Hypnea musciformis* exhibited high antibacterial activity against all the bacteria.

Melika Nazemi *et al*. [61] conducted *in vitro* antibacterial screening tests against selected clinical isolates of bacteria. Methanolic and diethyletter extracts demonstrated activity against *Escherichia coli* and *Bacillus subtilis* microbes tested. Minimum inhibitory concentration and minimum bactericidal concentration were determined using bacterial broth dilution methods. The extracts showing good antimicrobial activity are undergoing further analysis to identify the active constituents.

Taskin *et al*. [62] assessed the antitumoral and antimicrobial activities of five algal extracts obtained from the marine algae *Scytosiphon lomentaria, Padina pavonica, Cystoseira mediterranea* (Phaeophyceae), *Hypnea musciformis* and *Spyridia filamentosa* (Rhodophyta) against the human breast adenocarcinoma cell line MCF–7 and the human prostate carcinoma epithelium like cell lines DU 145, LNCaP, PC3 using the cytotoxic assay, *in vitro*. The crude extract of *Spyridia filamentosa* showed strong cytotoxic activity against the DU-145 cell line and it showed less than 10% cell viability after treatment. Antimicrobial activities of the crude extracts of algae (with the exception of *Hypnea musciformis*) were also tested by disc diffusion assay against three Gram positive and five Gram negative bacterial strains and against the yeast pathogen *Candida albicans*. Among the extracts, *Scytosiphon lomentaria* extract (prepared with methanol) inhibited highly Gram-*negative* bacterium *Salmonella typhimurium* growth while *Candida albicans* growth was only inhibited by *Cystoseria mediterrranea* extract.

Subba Rangaiah [63] investigated the antimicrobial potentiality of the marine algae, two species of brown algae namely *Sargassum ilicifolium*, *Padina tetrastromatica* and one red algae *Gracilaria corticata* by agar well diffusion method. The zone of inhibition was measured for all the different crude algal extracts (chloroform, ethanol, methanol and water) against six strains of Gram positive, Gram-negative bacterial and fungal isolates. Crude extracts revealed a wide range of antimicrobial activity against tested pathogens. Seaweed extracts in different solvents exhibited different antimicrobial activities. In case of *Sargassum ilicifolium, Padina tetrastromatica,* of the various solvents used for seaweed extractions, maximum inhibition was noticed with ethanol extracts and minimum with chloroform crude extracts while in case of *Gracilaria corticata*, maximum inhibition was noticed with methanol and minimum with chloroform extracts.

Mohamed Elanwar Osman *et al*. [64] evaluated the antimicrobial activity of ethanol, methanol and acetone extracts of nine marine macroalgae against pathogenic microbes (*Bacillus subtilis, Staphylococcus aureus* and *Streptococcus pyogenes* as Gram-positive bacteria) and (*Escherichia coli, Salmonella typhi* and *Klebsiella pneumoniae* as Gram-negative bacteria) and one yeast strain *Candida albicans*. The best results were obtained by acetone extracts with inhibition activity (36.7%), followed by the methanol extracts (32.9%) and then ethanol extracts (30.2%) for all tested microorganisms. The tested species of Chlorophyta were the most active followed by Rhodophyta and Phaeophyta. The most active seaweeds were *Ulva fasciata* against all tested microorganisms.

Pandurangan Aruna [65] screened the antifungal activities of six seaweeds namely the green seaweed *Cladophora glomerata*, *Ulva lactuca* and *Ulva reticulata*, the red seaweed *Gracilaria corticata* and *Kappaphycus alvarezii* and the brown seaweed *Sargassum wightii* against fungal pathogens *Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus, Saccharomyces cerevisiae* and *Mucor indicus.* The zone of inhibition ranged between 56 – 58 mm in aqueous extract and 54 – 56 mm in methanolic extract. The maximum activity (56 mm) was recorded from 200mg of aqueous extract of *Ulva lactuca* against *Aspergillus flavus* and minimum (8 mm) by *Gracilaria corticata* against *Mucor indicus* at 50 mg level whereas, the methanolic extract showed the maximum activity (56 mm) was recorded from 200 mg of *Ulva lactuca* against *Aspergillus niger* and minimum (4 mm) by 50 mg of *Ulva reticulata* against *Aspergillus flavus.*

Eisha Soliman El-Fatimy and Alaa Abdel-Moneim [66] identified the antibacterial activity of the most dominant species (*Padina pavonia*) and compared with some antibiotics. Thirty four marine algal species were collected and identified. Two species (5.88%) of the collected algae (*Lyngbia* and *Rivularia*) were belonging to Cyanophyta, six species (17.65%) belong to Chlorophyta, thirteen species (38.24%) belonging to Phaeophyta and thirteen species (38.24%) belonging to Rhodophyta. The R/P ratio was 1.00 which indicated the rough weather of this area. *Padina pavonia* was the most dominant species at all samples, methanolic crude extract were tested against *Escherichia coli* and *Staphylococcus aureus* bacteria and matched with some famous antibiotics. All of the treatments were affected *Escherichia coli*, they could statistically ranked dissentingly as Ci > E15 > Sxt at the first rank and Te30 > *Padina* extract at the second rank while P10 came at the third rank with significant values. Meanwhile, *Staphylococcus aureus* was affected only by E15 antibiotic.

Lavanya and Veerappan [67] tested the *in vitro* antibacterial activity of six selected marine algae. Extracts of six seaweed samples namely *Codium decorticatum, Caulerpa scalpelliformis, Gracilaria crassa, Acanthophora spicifera, Sargassum wightii* and *Turbinaria conoides* were selected for antibacterial activity against selected human pathogens such as species *Vibrio parahaemolyticus*, *Salmonella* sp., *Shewanella* sp., *Escherichia coli*, *Klebsiella pneumoniae*, *Streptococcus pyogenes*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Pseudomonas aeruginosa* and *Proteus mirabilis*. All the seaweeds extracts have shown moderate antibacterial activity <10 mm of zone of inhibition, out of which only methanolic extract has shown significant activity. The results of their research showed that the higher antibacterial activity was found in *Acanthophora spicifera* and the minimum was found in *Codium decorticatum*.

Vijayabaskar and Shiyamala [68] tested the methanolic extracts of brown algae, *Sargassum wightii* and *Turbinaria ornata* against various Gram positive and Gram-negative human pathogenic microbes. The finding envisages that methanol extracts of *Turbinaria ornata* could be utilized as a good source of antimicrobial agent in pharmaceutical industry.

Hebsibah Elsie *et al*. [32] screened the secondary metabolites like, alkaloids, carbohydrates, saponins, glycosides protein and amino acids, phytosterol, phenolic compound, flavonoids, terpinoids, tannins. Antimicrobial activities of ethanolic and acetone extracts of *Gelidium acerosa* against human pathogens like *Staphylococcus aureus, Bacillus aureus, Micrococcus leutus, Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa* and fungi like *Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus, Candida albicans* and *Candida tropicalis*. Ethanolic extracts of *Gelidium acerosa* presented the highest antimicrobial activity and was effective against all pathogens tested than acetone extracts. *Gelidium acerosa* of ethanolic extracts shows presence of maximum number of secondary metabolites, than acetone extract.

Salem *et al*. [69] screened the methanolic and ethyl acetate extracts from eight different seaweeds for their antibacterial activities against both Gram-positive bacteria (*Staphylococcus aureus* and *Bacillus cereus*) and Gram-negative bacteria (*Escherichia coli*, *Enterococcus faecalis*, *Salmonella* sp. and *Pseudomonas aeruginosa*). The antibacterial activities were expressed as zone of inhibition and minimum inhibitory concentrations. Ethyl acetate extracts of *Caulerpa racemosa*, *Caulerpa fragile* and *Padina gymnospora*; methanolic extracts of *Padina gymnospora* and *Caulerpa fragile* showed higher antibacterial activities than other members of the tested algae. The most resistant bacteria was *Enterococcus faecalis* against both solvents extracts of *Sargassum dentifolium*, *Cystoesira myrica* and *Actinotrichia fragilis* while, *Salmonella* sp. and *Pseudomonas aeruginosa* were resistant to methanolic extracts of *Caulerpa racemosa*, *Sargassum dentifolium* and *Actinotrichia fragilis*. On the other hand, *Bacillus cereus*, *Staphylococcus aureus* and *Escherichia coli* were the most sensitive to all seaweed extracts. The susceptibility of Gram-positive bacteria to the algal extracts was more than those of Gram-negative bacteria. The activities of ethyl acetate extracts were higher than those of methanolic extracts and the most powerful inhibitory extract was ethyl acetate extract of *Caulerpa racemosa*.

Priyadharshini *et al*. [70] evaluated the *in vitro* antimicrobial and haemolytic activity of marine macroalgae *Ulva fasciata*. Methanol, butanol and aqueous extracts were tested against selected fish pathogens, *Aeromonas hydrophila*, *Pseudomonas fluorescens*, *Proteus* sp., *Vibrio alginolyticus* and *Enterobacter* sp. and fungal pathogens *Rhizopus* sp., *Aspergillus flavus*, *Aspergillus* sp., *Aspergillus niger* and *Candida* sp. The extract was subjected to TLC to determine the presences of peptides and amide groups and the haemolytic activity was assayed. Maximum of 16 mm inhibition zone was observed against *Vibrio alginolyticus* and the minimum 12 mm against *Enterobacter* sp., respectively. *Ulva fasciata* showed poor activity against the fungal pathogens. Their results showed the use of seaweeds as antimicrobial agents for pharmacology or as a health promoting food for aquaculture. The screening results confirmed that these seaweeds need further studies and used as possible source of antimicrobial compounds.

Uses of Seaweeds: Seaweeds contain different vitamins, minerals, trace elements, protein, iodine and bioactive substances. They are the only source for the production of phytochemicals such as agar (China grass), carrageenan and algin. Agar is extracted from red algae such as *Gelidiella, Gracilaria, Gelidium* and *Pterocladia.* Some other red algae *viz*., *Bucheuma, Chondrus, Hypnea* and *Gigartina* are used for the production of carrageenan. Algin was manufactured from brown algae like *Sargassum, Turbinaria, Cystoseira, Lalllinaria, Macrocystis* and *Ascophyllum.* The phytochemicals from these seaweeds were used as gelling, stabilizing and thickening agents in food, pharmaceutical, confectionary, dairy, textiles, paper, paint, varnish industries.etc. Other chemical products such as mannitol, iodine, laminarin, fucoldinare also obtained from marine algae.

Many protein rich seaweeds like *Ulva* sp., *Enteromorpha* sp., *Caulerpa* sp., *Codium* sp., *Monostroma* sp., *Sargassum* sp., *Hydroclathrus* sp., *Laminaria* sp., *Undaria* sp., *Macrocystis* sp., *Porphyra* sp., *Gracilaria* sp., *Eucheuma* sp., *Laurencia* sp. and *Acanthophora* sp. are used as human food in countries like Japan, China, Korea, Malaysia, Thailand, Indonesia, Philippines and other South East Asian countries in the form of soup, salad, curry, etc. In Japan, China and Korea, *Ulva* sp., *Enteromorpha* sp., *Monostroma* sp. and *Porphyra* sp. are added in soup and *Undaria* sp. and *Laminaria* sp. are eaten in dried form. In Philippines, *Caulerpa lentiifera* is consumed as salad while *Codium tomentosum*, *Eucheuma denticulatum* and *Kappaphycus alvarezii* in the form of curry. The seaweed food products such as jelly from *Gelidiella* sp. and *Gracilaria* sp; jam from *Ulva* sp. and *Enteromorpha* sp; pickle from *Gracilaria* sp., *Hypnea* sp., *Acanthophora* sp. and *Laurencia* sp. can be prepared and marketed.

The food value of seaweed depends on the minerals, trace elements, proteins and vitamins present in them. Marine algae have all essential amino acids needed in the human diet, which are not available in vegetable food materials. In India, seaweeds are not eaten except the jelly prepared from agar and porridge prepared from *Gracilaria edulis* in the coastal areas of Ramanathapuram District. Agar is added in the preparation of following foodstuffs – ice cream, tomato sauce, jelly, marmalade, blancmange and lime jelly.

Seaweeds are cheap source of minerals and trace elements. Hence, meal could be prepared by grinding the cleaned and washed seaweeds. It can also be mixed with fishmeal and used in different parts of the world as fertilizer for various land crops. In India, freshly collected and cast ashore seaweeds are used as manure for coconut plantation either directly or in the form of compost in coastal areas of Tamil Nadu and Kerala. Seaweed manure has been found superior to farm yard manure. The high amount of water-soluble potash, other minerals and trace elements present in seaweeds are readily absorbed by plants and they control deficiency diseases. The carbohydrate and other organic matter present in the marine algae alter the nature of soil and improve the moisture retaining capacity.

The liquid seaweed fertilizer obtained from seaweed extract is used as foliar spray for inducing faster growth and yield in leafy and fleshy vegetables, fruits, orchards and horticultural plants. There are several medicinal properties of seaweeds. Marine algae were considered to be of medicinal value in the Orient as early as 3000 B.C. The Chinese and Japanese used them in the treatment of goiter and other glandular diseases. Though the Romans believed seaweeds to be useless, they also used them to heal wounds, bums, scurvy and rashes. The British used *Porphyra* sp. to prevent scurvy during long voyages.

The red algae *Gelidiella acerosa*, *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilaria crassa* and brown algae *Sargassum* sp., *Turbinaria* sp. and *Cystoseira trinodis* are exploited at present from Mandapam coast and they are used as raw material by Indian seaweed industries for the production of agar, alginates and liquid seaweed fertilizer. The seaweed resources of Mandapam area should also be made use for the production of other phytochemicals such as carrageenan, seaweed food products like jam, jelly, pickle and feed for farm animals.

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