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# Potential of marine algae (sea weeds) as source of medicinally important compounds

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## Abstract

Scientific research has always been concerned with aspects of human health. There are several systems of medicines besides the globally accepted allopathy, which are based on compounds originating from natural products. Recent research has been centred around validation of the traditional knowledge on medicinal products. The traditional systems in India, China and forklore medicines in other parts of the world have indicated the potential of natural products consist of various chemical compounds that could be used as drugs. The search for drugs against five major dreadful diseases namely, cancer, AIDS, heart disease, diabetes and pulmonary disorders that attack the present day human from natural products has been in progress for some time. Microbes, plants and animals are the sources of natural products. In the past five decades, the research on bioactive chemicals from marine algae has been incited and several compounds with biological activity were isolated from algae. Generally, these are secondary metabolites produced for chemical defence against the biotic pressure of predators, consumers and epibionts. These potential drugs are now attracting considerable attention from the pharmaceutical industries due to the necessity of identifying substances that could be utilized for novel therapeutic purposes. Several compounds such as alginate, carrageenans, sulphated and halogenated polysachcharise and other derivatives have been shown to provide drugs that could be antiviral, anticancer and antimicrobial. The present account is on the potential of marine macro-algae for medicinally important products.

**Keywords:** algae, seaweed, bioactive chemical, microbes

## Introduction

Algae belong to the primitive group of plants which evolved very early in the universe. Algae are both microscopic (microalgae) and macrophytic (macroalgae) occurring in freshwater as well as marine waters. In the marine ecosystem, the micro-algae are the major primary producers and the macro-algae are called as seaweeds, which flourish on surfaces of rocks, dead coral, stones, pebbles and any other suitable substrata are available for their attachment. Macro-algae are green algae (Chlorophyceae), brown algae (Phaeophyceae) and red algae (Rhodophyceae). Seaweeds are used as human food from 600 to 800 BC. In China, seaweeds were used from prehistoric time. In China and Japan, seaweeds are used as a stable diet item for a very long period. Fresh, dried and processed seaweeds are utilized for human consumption. Many types of seaweeds are used as food in Japan, China, Philippines and other countries of Indopacific regions. Seaweeds are one of the commercially important marine living and renewable resources of India. Commercial exploitation of marine algal species commenced in India since 1966 (Oza and Zaidi, 2001). One of the reports indicates that 1518 t of (dry weight) red algae and 2285 t of (dry weight) brown algae are utilized

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for manufacture of agar, alginate and liquid fertilizer (Kaliaperumal *et al.*, 2004). Seaweeds grow abundantly along the coastal waters of Tamilnadu, Gujarat, Andhra Pradesh, Orissa, West Bengal, Kerala, Maharastra, Lakshadeep and Andaman Nicobar Islands. There are also rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Vizhijzn, Pulicot and Chilka. Among the 20,000 species of seaweeds enumerated in the world, 271 genera and 1153 species are present in India with a total standing crop of 6, 77, 309–6, 82, 759 t fresh (Subba Rao and Mantri, 2006). According to Anantharaman *et al.* (2006), the total potential seaweed wealth is 8, 70,000 t fresh, present natural collection is 22,000 t fresh and through seaweed cultivation is 150 t dry. Natural habits of some of the prominent marine algae are presented in Fig. 1.

## Medicinal potential of seaweeds

Seaweeds 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 goitre and other glandular diseases. Romanians used the seaweeds for healing the wounds, burns and rashes. The British used *Porphyra* to prevent scurvy (vitamin C deficiency diseases) during long voyages. Seaweeds in general are used as verimifuge, for cough, stomach and chest ailments, bladder and kidney ailments (Schimmer and Schimmer, 1955, 1968; Hoppe, 1979; Stein and Borden, 1984; Smit, 2004; Anantharaman *et al.*, 2006). Alginates from seaweeds are known to be used in the preparation of the moulds for denture (Fig. 2 (a)). A survey of literature on the potential of the products obtained from marine algae for medicinal use indicates the wide range of remedial compounds against several ailments. There is a very good potential in the seaweeds for obtaining novel compounds to be used as drugs against simple ailments and chronic diseases such as cancer, cardiac disorders, respiratory problems, diabetes, and virus attacks such as human immunodeficiency virus (HIV). The promise and potential appear enormous and the search has been on for over several years. The products so far encountered are antivirus, antibiotic, antitumour, antioxidant and vermifuges or antiparasitic. Table 1 gives the details of the algal species, the type of compounds obtained and their medicinal importance. However, only few products have found application in pharmaceutical preparations. Research work done for over four decades are presented below.

## Antiviral activity

Seaweeds contain certain compounds that possess antiviral activity. Sulphated polysachharides such as galactan sulphate was tested in the laboratory to be effective against HIV and Herpes simplex virus (HSV). Xylomannan sulphate is anti-HIV and respiratory syncytial virus (RSV). Carrageenn, Fucoidion, Chondrion and dollabellans show anti-HSV activity. Fucoidion is also against RSV and human cytomegalovirus. These studies have been carried out using human cell lines and in some cases animal sources. A sulphated polysaccharide from *Schizymenia pacifica* was first shown to possess anti-HIV reverse transcriptase *in vitro* (Nakashima *et al.*, 1987a, b). Certain sulphated polysaccharides such as galactan sulphate from *Aghardhiella tenera* and xylomannan sulphate from *Nothogenia fastigiata* showed antiviral activities against HIV, HSV types 1 and 2 and RSV tested in the laboratory (Damonte *et al.*, 1994, 2004; Witvrouw *et al.*, 1994) and Kolender *et al.* (1995). These polysaccharides are shown to be active during the first stage of the RNA virus replication when the virus adsorbs onto the surface of the cell (De Clercq, 1996) and have very low cytotoxic activities towards mammalian cells. Carrageenans (Fig. 2(b)) from *Gigartina skottsbergii* have potent antiviral effects against different strains of HSV types 1 and 2 during the virus adsorption stage (Carlucci *et al.*, 1997, 1999a, b). Carrageenans from cystocarpic and tetrasporophytic stages of *Stenogramme interrupta* had similar activity (C´aceres *et al.*, 2000). High molecular weight galactan sulphate (Fig. 2(d)) from *Gracilaria corticata* (Mazumder *et al.*, 2002) and Fucoidan (Fig. 2(c)) had potent antiviral properties towards viruses such as RSV (Malhotra *et al.*, 2003). Malhotra *et al.* (2003) found that fractions containing an uncharacterised polysaccharide from *Caulerpa* sp., *Corallina* sp., *Hypnea charoides, Padina arborescens* and *Sargassum patens* have high antiviral activity against HSV types 1 and 2 and have low levels of cytotoxicity. Besides polysachchardes, antiviral activity by Chondriamide A (Fig. 2(e)) from *Chondria atropurpurea* against HSV type II (Palermo *et al.*, 1992) and Kahalalide F (Fig. 2(f)) from *Bryopsis* for its anti-HIV qualities are reported (Haefner, 2003). Recently, methanolic extracts of three species of *Sagassum* were shown to possess anti-herpes property (Zhu *et al.*, 2003) and hepatoprotective activity (Hiren *et al.*, 2016). The red seaweed *Solieria chordalis* was abundant in coastal area of France. The extract of *S. chordalis* from the coast exhibited potential antiviral activity (Ann-Sophie *et al.*, 2016). Structures of certain compounds obtained from marine algae are presented in Fig. 2

## Antimicrobial activity

The methodology used for investigating the antimicrobial potential of the marine algae in the laboratory is the simple diffusion plate technique. The extracts of the selected seaweed obtained from water or organic solvents are tested against Gram-positive and Gram-negative pathogenic

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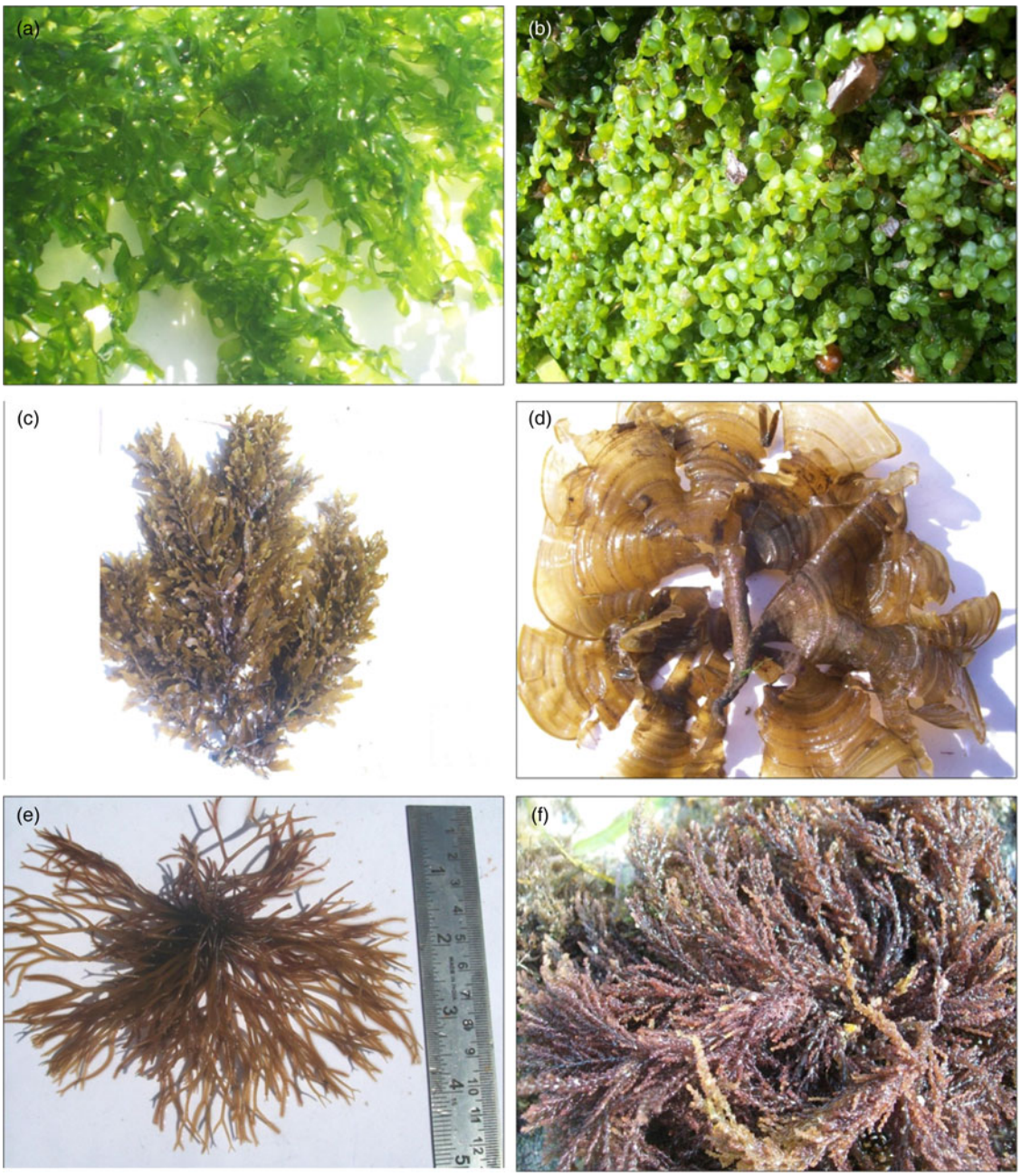


**Fig. 1.** Some common medicinally important seaweeds. *fam.* Chlorophyceae: (a) *Ulva retivulata*, (b) *Caulerpa racemosa; fam.* Phaeophyceae: (c) *Sargassum tennerium* (d) *Padina gymnospora; fam.* Rhodophyceae: (e) *Gracillaria edulis*, (f) *Acanthophora spicifera*.

bacteria. The antagonistic compounds such as fatty acids, bromophenols, tannins, phloroglucinol and terpenoids are useful as antibiotics for killing of bacteria, fungi and viruses (Hashimoto, 1979). Such compounds are from Phaeophyceae (Glombitza, 1979) and halogenated compounds and laurinterol from several members of the Florideophyceae (Fenical, 1975) In a screening of 151 species of British marine algae, 54 were found to be antibacterial (Homsey and Hide, 1974) and in *Laminaria saccharina* (L.) Lamouroux (Phaeophyceae) maximum activity was in extracts from older parts of the thallus. *Bryopsis* sp. contained depsipeptides Kahalalide A and F, which were noted for their *in vitro* activity against *Mycobacterium tuberculosis* (El Sayed *et al.*, 2000). Halogenated furanone or fimbrolide (Fig. 2(g)) that belong to a class of lactones extracted from *Delisea pulchra*

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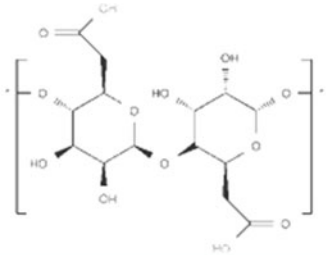
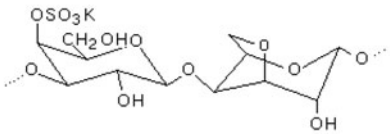
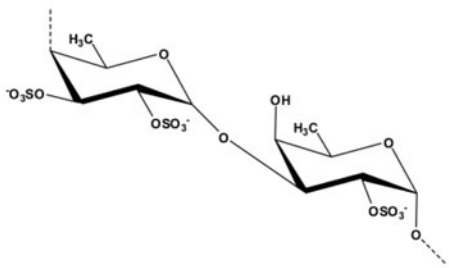
(a) Sodium alginate (after Fertah *et al.*, 2014 )



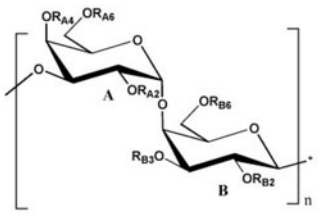
(b) **Carageenans** (after Jiao *et al.*, 2011)



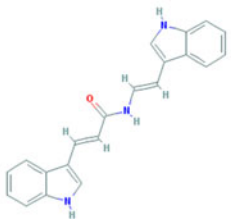

(c) **Fucoidan** (after Chevolot *et al.*, 1999)



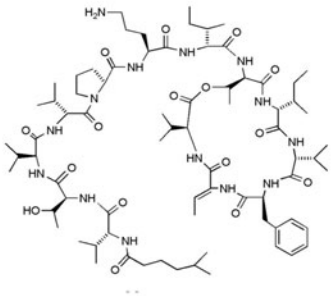

(d) **Galactan sulphate** (after Nishino *et al.*, 1994)



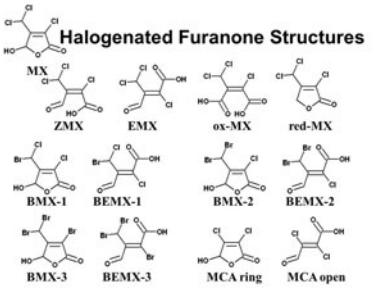

(e) **Chondriamide** (after Palermo *et al.*, 1992)



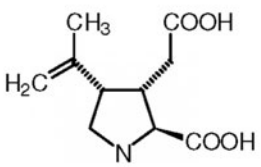
(f) **kahalalide** (after Hamann and Scheuer, 1993)



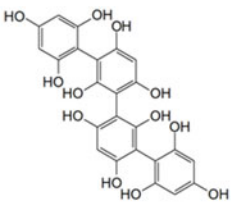
(g) **Halogenated Furanone or Fimbrolide** (after de Nys *et al.*, 1993)




(h) **Kainic acid** (after Impellizzeri *et al.*, 1975)




(i) **Phlorotannin** (after Wang *et al.*, 2008)



(j) **B-1, 3 glucan** (after Klarzynski *et al.*, 2000)

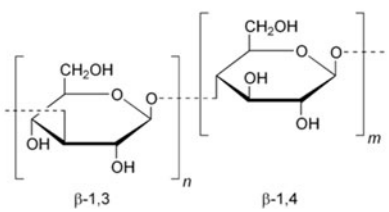



**Fig. 2.** Structure of compounds isolated and identified from marine algae. (a) Sodium alginate (after Fertah *et al.*, 2014). (b) Carageenans (after Jiao *et al.*, 2011). (c) Fucoidan (after Chevolot *et al.*, 1999). (d) Galactan sulphate (after Nishino *et al.*, 1994). (e) Chondriamide (after Palermo *et al.*, 1992). (f) Kahalalide (after Hamann and Scheuer, 1993). (g) Halogenated Furanone or Fimbrolide (after de Nys *et al.*, 1993). (h) Kainic acid (after Impellizzeri *et al.*, 1975). (i) Phlorotannin (after Wang *et al.*, 2008). (j) B-1, 3 glucan (after Klarzynski *et al.*, 2000).

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**Table 1.** Medicinally important compounds from marine algae

| Medicinal potential | Algal species | Isolated compounds | Biological activity | References |
|---|---|---|---|---|
| Antiviral | *Schizymenia pacifica* | Sulphated polysaccharides | Anti-HIV reverse transcriptase | Nakashima *et al.* (1987a, b) |
| | *Aghardhiella tenera* *Nothogenia fastigata* | Galactan sulphate Xylomannan sulphate | Antiviral activity against HIV, HSV 1 & HSV 2, RSV | Witvrouw *et al.* (1994), Damonte *et al.* (1994), Kolender *et al.* (1995) |
| | *Gigartina skottsbergii* | Carrageenans | Antiviral activity against HSV 1 & HSV 2 | Carlucci *et al.* (1997, 1999a, b) |
| | *Stenogramme interrupta* | Carrageenans | Antiviral activity against HSV 1 & HSV 2 | C´aceres *et al.* (2000) |
| | *Gracilaria corticata* | High molecular weight galactan sulphate, Fucoidan | Antiviral activity against RSV | Mazumder *et al.* (2002), Malhotra *et al.* (2003) |
| | *Chondria atropurpurea* | Chondriamide A | Antiviral activity against HSV type II | Palermo *et al.* (1992) |
| | *Bryopsis* sp., | Kahalalide F | Anti-HIV | Haefner (2003) |
| | *Sargassum chordalis* | Extract | Antiviral | Ann-Sophie *et al.* (2016) |
| Antimicrobial | *Laminaria saccharina* | Crude extracts | Antibacterial | Homsey and Hide (1974) |
| | *Bryopsis* sp., | Depsipeptides Kahalalide A and F | Against *Mycobacterium tuberculosis* | El Sayed *et al.* (2000) |
| | *Delisea pulchra* | Halogenated furanone or fimbrolide | Inhibition of *Pseudomonas aeroginasa* infection and formation of biofilm in the lungs of cystic fibrosis sufferers | Kjelleberg and Steinberg (2001) |
| | *Gracilaria cornea,* *Laurencia intricate,* *L. papillosa* | Crude extracts | Antibacterial | |
| | *Liagora farinose,* *Dasycladus vermicularis,* *Lobophora variegate* | | | Anantharaman *et al.* (2006) |
| | *Padina pavonica* | | | Ali *et al.* (2010) |
| | *Sargassum subrepindum* | | | Abu-El-Wafa *et al.* (2011) |
| | *Himanthalia elongata* | | | Rajauria *et al.* (2012) |
| Vermifuge activity | *Digenea* sp., | Kainic acid | Antihelmintics against ascaris | Nisiwaza (1979) |
| | *Corallina officinalis,* *Durvillaea* sp., *Sargassum* sp., | Kainic acid | Active against tape worm | Hashimoto (1979) |
| Anti-oxidant activity | *Porphyra yezoensis* | Polysaccharide | Superoxide radical scavenging activity | Xue *et al.* (1998) |
| | *Sargassum pallidum* | Polysaccharide | Superoxide radical scavenging activity | Ye *et al.* (2008) |
| | *Caulerpa lentifera,* *C. racemosa,* *Sargassum polycystum* | Phenol | Radical scavenging activity | Matanjum (2016) |
| | *Saccharina Latissima* | Extract | Seasonal variation in antioxidant activity | Ann-Dorit *et al.* (2016) |

*Continued*

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Table 1. (*Cont.*)

| Medicinal potential | Algal species | Isolated compounds | Biological activity | References |
|---|---|---|---|---|
| Antitumour and anticoagulant activity | *Kappaphycus strictum* | Aqueous and methanolic extract | Antiproliferative activity of HeLa cancer cell | Lau *et al.* (2009) |
| | *Kappaphycus strictum* | Kappa Carrageenan oligosaccharides | Inhibition of formation of sarcoma | Yuan *et al.* (2006) |
| | *Eucheuma cottonii* | Polyphenol rich extract | Suppress breast tumour | Nanovar *et al.* (2012) |
| | *Sargassum vulgare, Soleria chordelia, Laminaria digitalis, Padina pavonica, Hydroclathrus clathratus and Enteromorpha* sp., | Polysaccharides such as Alginates, Carrageenan, Beta-1,3 glucan and other polysaccharides | Antiproliferative | de Souse *et al.* (2007), Stephan *et al.* (2010), Vetrika and Yuin (2004), Awad *et al.* (2009), Jiao *et al.* (2009) |
| | *Caulerpa racemosa, Gracilaria caudata, Halymenia floresia and Padina gymnospora* | Sulphated polysaccharides | Anticoagulant and antithrombic activity | Rodrigues *et al.* (2011) |

(Kjelleberg and Steinberg, 2001). These are active against chronic *Pseudomonas aeruginosa* infection and formation of a 'biofilm' in the lungs of cystic fibrosis sufferers (Høiby, 2002). Antibacterial activity was studied in several seaweeds and positive results are obtained in *Gracilaria cornea, Laurencia intricata, Laurencia obtusa* and *Laurencia papillosa*. The extracts of *Liagora farinose, Dasycladus vermicularis* and *Lobophora variegate* have the highest inhibition zones and a wide spectrum of antibacterial activity (Anantharaman *et al.*, 2006). Ali *et al.* (2010) found a seasonal variation in the production of compounds of antibacterial activity in *Padina pavonica* (L.) Thivy from Tunisian coasts. The extracts from algae during the warmer months showed best activities against Gram-positive and Gram-negative strains of several bacteria. *Sargassum subrepindum* (Abu-El-Wafa *et al.*, 2011) from Egypt and *Himanthalia elongata* from West Coast of Ireland (Rajauria *et al.*, 2012) are the recent reports of antibiotic potential of brown algae. Extracts of several marine algae from various localities have been shown to possess antimicrobial characteristics (Shanmughapriya *et al.*, 2008; Alang *et al.*, 2009; Demirel *et al.*, 2009; Cox *et al.*, 2010; Manivannan *et al.*, 2011; Ferreres *et al.*, 2012; Kayalvizhi *et al.*, 2012; Arunkumar *et al.*, 2013; Elnabris *et al.*, 2013; Al-Saif *et al.*, 2014).

## Vermifuge activity

Marine algae were largely used in Asian marine regions for remedies and preventives since the people of the area were involved in maritime activities. Extracts of the red alga *Digenea* (Ceramiales) and other marine algae have been used as vermifuges or anthelmintics (killing intestinal worms, such as *Ascaris*) for over a thousand years as a most efficient vermifuge (Nisiwaza, 1979). The active component is kainic acid (Fig. 2(h)), which kills the tape worm. The red alga *Corallina officinalis* L., species of the brown algae *Durvillaea* and *Sargassum* and the green alga *Viva* spp. are also sources of vermifuges (Hashimoto, 1979).

## Antioxidant activity

Seaweeds are known to contain compounds such as glutathione peroxidase, catalase, superoxidedismutase and polyphenols with antioxidant or free radical scavenging properties. Specific techniques were used for the antioxidant or radical scavenging assays such as ABTS radical decolourization (beta-carotene bleaching) assay, DPPH radical scavenging assay and Ferric Reducing Antioxidant Assay (FRAP assay). Antioxidant properties of polysaccharides in scavenging superoxide radicals in *Porphyra yezoensis* was reported by Xue *et al.* (1998), *Sargassum pallidum* in Yellow sea, China (Ye *et al.*, 2008) and certain brown algae by Liu *et al.* (2007). Matanjum (2016) analysed the antioxidant activities and phenolic contents and found *Caulerpa lentifera, C. racemosa* and *Sargassum polycystum* possessed very good radical scavenging activity. *Brognioutella* sp., had best antioxidant activity among 24 red algal species tested from Brittany Coast, France (Zubia *et al.*, 2009). In *Porphyra* sp., activity of the endogenous enzymes was increased by sulphated galactans (Mohamed *et al.*, 2012). Seaweeds occurring in South Indian coasts were screened for antioxidant activities (Vadiapudi and Chandrasekhara Naidu, 2010; Karthika Devi *et al.*, 2011; Vijayabaskar and Shyamala, 2012; Indu and Srinivasan, 2013). *Gracilaria changii* has very good

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free radical scavenging property (Chan *et al.*, 2014). Natural antioxidants derived from marine algae have the potential for improving oxidative stability of lipids in food systems. The phlorotannin compounds (Fig. 2(i)) with better antioxidant activity were identified through HPLC–DAD–ECD–QTOFMSn (Ditte *et al.*, 2016). The seasonal variation in the antioxidant activity of sugar Kelp (*Saccharina latissima*) in different cultivation sites were recently reported (Ann-Dorit *et al.*, 2016).

## Antitumour activity/anticoagulant activity

Marine algae have been a good source of compounds that could be used for antitumour treatments. Kashiwagi *et al.* (1980) showed antitumour activity against lymphocytic leukaemia and Ehrlich ascites tumour in mice in extracts obtained from marine algae from Pacific islands. Chinese have used decoctions of *Sargassum* spp., *Laminaria* spp. as herbal medicines to treat cancer and a preliminary study reveals inhibition of leukaemia tumours (Yamamoto *et al.*, 1974). Cho *et al.* (1997) found that several red and brown algae had compounds that inhibited colon cancer cell growth. Iodine rich kelps, *Laminaria* (Funahashi *et al.*, 2001), *Champia feldmanni, Undaria pinnatifida* (Maruyama *et al.*, 2003), *Dictyopteris divaricata* and *Sargassum thumbergia* (Kim *et al.*, 2009) were all found to be good sources of antiproliferative and antitumour-producing compounds. Lau *et al.* (2009) have shown that both aqueous and methanolic extracts from *Kappaphycus strictum* had higher antiproloferative activity of HeLa cancer cells compared with *K. alverezii*. The role of k-carrageenan oligosaccharides from *K. strictum* in the inhibition of the formation of sarcoma was reported by Yuan *et al.* (2006). Polyphenol-rich extracts of *Eucheuma cottonii* suppressed breast tumour via hormone modulation and apoptosis induction (Nanovar *et al.*, 2012). Alginates from *Sargassum vulgare*, carrageenan from *Soleria chordelia*, B-1,3 glucan (Fig. 2(j)) from *Laminaria digitalis*, unknown polysaccharides from *Padina pavonica* and *Hydroclathrus clathratus* and *Enteromorpha intermedia* were shown to be antiproliferative (Vetrika and Yuin, 2004; de Souse *et al.*, 2007; Awad *et al.*, 2009; Jiao *et al.*, 2009; Stephan *et al.*, 2010). Fucoidan is found to be effective against bile duct cancer and breast cancer. Examples of algal extracts inhibiting various steps of cancerous tumour development or cell proliferation are outlined in detail by Mohamed *et al.* (2012). Several green, brown and red seaweeds are reported to contain sulphated polysaccharides (in the aqueous extract) which has anticoagulating and antithrombic activity. *Caulerpa racemosa, Gracilaria caudata, Halymenia floresia* and *Padina gymnospora* are reported in studies from Brazilian coast to be the source of anticoagulating substances (Rodrigues *et al.*, 2011).

## Pharmaceutical importance of seaweeds

Seaweeds have already found application as household medicine and pharmaceutical formulations in Southeast Asia and other parts of the world. Some of the instances are cited below.

(i) Obesity and diabetes: Extracts of *Pelvetia babingtonii* and *Ascophyllum nodosum* had potent alpha-glucosidase activity to support post parandial hyperglycaemia (Kim *et al.*, 2008). Extracts of pacific edible brown alga contain antidiabetic insulin-like and insulin-secreting activity (Kang *et al.*, 2008). The brown seaweeds contain high-dietery fibres and Fucoxanthin the main carotenoid showed antiobesity effects and reduced blood glucose (Abidov *et al.*, 2010). A recent Korean National Health survey revealed that seaweed consumption decreased diabetic risk in men (Lee *et al.*, 2010). The effects of seaweed extracts in preventing antiobesity and peroxidation in rats were studied via assessing the plasma lipids and plasma and organs malondialdehyde concentrations. These findings showed positive effects in inhibiting weight gain and have promising value in preventing obesity (Matanjum *et al.*, 2016).

(ii) Obstetrical uses: The dried stipes of *Laminaria* spp. have been used in obstetrical and gynaecological practices as a natural dilator of the cervix, thus making gynaecological treatment easier (Strauss *et al.*, 1979; Ye *et al.*, 1982). *Laminaria* was found to be particularly effective in intrauterine devices (IUD) for birth control (Manabe *et al.*, 1982).

(iii) Goitre treatment: Goitres are due to low iodine content in food. Marine algae are excellent sources of iodine and 'goitre sticks' made of *Phyllogigas*. Dried *Ulva* and *Porphyra* are used in the Peruvian Andes. The Chinese have used *Sargassum* as a remedy since 2700 BC. Vitamin A deficiency occurring in restricted areas of Burma can also be overcome by use of seaweed supplements in the diet (Michanek, 1979).

(iv) Hypertension: Seaweed hydrolyzates have antihypertensive properties and the examples are peptides from *Undaria pinnatifida* (Sato *et al.*, 1996) and phlorotanins from *Eklonia stolonifera* (Jung *et al.*, 2006). Carrageenans from red algae have dislepidaemic and lipids and bring down levels of cholesterol.

(v) Wound healing: Carbohydrate polymers like alginic acid are used in wound management. Alginates are highly viscous bio-absorbable guluronic and mannuronic acid polysaccharides. Hydrophilic sponges

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produced from calcium alginate have good absorption property of both blood and wound exudates as well as pain-stimulating compounds (Lloyd *et al.*, 1998; Matou *et al.*, 2002).

(vi) Pharmaceutical formulations: The pharmaceutical uses of algae involve the phycocolloids isolated from the selected members of brown and red algae. Carrageenan can be used in cough syrup emulsions (Chapman, 1979). Carrageenan and the other phycocolloids, such as fucoidan are used as binding agents for medical tablets. The bioactive ultra-high viscosity gels from alginates obtained from *Lessonia trabeculata* and *Lessonia nigrescens* are promising biomaterial approach for tissue engineering has been reported (Michel *et al.*, 2016). Sulphated polysaccharides from marine algae show very good anticoagulant activity. Alginates are a family of polysaccharides from brown seaweeds namely *Laminaria hyperborean* in Norway. The characterized alginate gels with chitooligosaccharides of varying composition as cross linkers for tissue engineering, cell immobilization and drug release has been established in Norway (Yiming *et al.*, 2016).

## Conclusion

The potential of the marine algae as source of compounds of medicinal importance is enormous. The general consensus of scientists is that the marine algae are less exploited and new formulations with novel compounds obtained from them could yield more useful and effective drugs. The search for remedies of human maladies appears to be a continuous process. It is our wish and hope that the marine algae will play a major role in the protection of human health.

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