IJPSR (2019), Volume 10, Issue 8 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 14 December 2018; received in revised form, 05 February 2019; accepted, 27 February 2019; published 01 August 2019

A REVIEW OF PHARMACOLOGICAL ACTIVITY OF MARINE ALGAE IN INDIAN COAST

Ankita Sharma *, Raju Koneri and Deepak Kumar Jha

Department of Pharmacology, Karnataka College of Pharmacy, Bengaluru - 560064, Karnataka, India.

Keywords:

Seaweeds, Marine algae, Pharmacological activity and Indian coast

Correspondence to Author:
Ankita Sharma

Department of Pharmacology, Karnataka College of Pharmacy, Bengaluru - 560064, Karnataka, India.

E-mail: ankitaroing99@gmail.com

ABSTRACT: Indian coastline stretches about 5700 km covering 9 states on the mainland and about 7500 km including islands and union territories. Seaweeds, a renewable natural resource, found growing in large quantities along the Indian coast. Seaweeds are currently worldwide interest in finding new and safe promising organisms for health. It is one of the important essential producers of biomass in the marine environment. Seaweeds are not only of high ecological but also of great economic importance as they produce a wide variety of chemically active metabolites in their surroundings. The potential uses of algal biomass for the benefit of mankind have been intensively reviewed in the last few years. Marine algae have been used as a novel food with potential nutritional benefits in industry and medicine for various purposes. Furthermore, marine algae have shown to provide a rich source of natural bioactive compounds with antidiabetic, hepatoprotective, antiviral, antifungal, antibacterial, antioxidant, anti-inflammatory, anti-hypercholesterolemia and hypolipidemic and antineoplastic properties, *etc*. The present review is focusing on the bioactivities and potential pharmacological activity of marine algae which are found on the Indian coast.

INTRODUCTION: In modern medicine, no satisfactory effective therapy is yet available. Marine algae compounds have contributed to the global search for novel medicinal agents. In recent years, a significant number of novel metabolites with potent pharmacological properties have been discovered from the marine organism. Marine algae are one of the richest sources of structurally diverse natural products [1-3]. An increasing number of novel compounds have been isolated from marine algae, and many of them have been reported to possess interesting biological activities [4, 5].

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.10(8).3540-49

The article can be accessed online on www.ijpsr.com

DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.10(8).3540-49

Marine algae or seaweeds have formed an important part of the diet of many eastern countries, and their use as food is well documented. Seaweed contains a range of components which have potential health benefits, and some have been demonstrated as potential chelators of heavy metals, Marine macro-algae are a primitive type of plants lacking true roots, stems and leaves and have been classified based on pigmentation into Phaeophyta (Brown), Rhodophyta (Red) and Chlorophyta (Green) types [6].

The marine algae are a rich natural resource of many biologically active compounds such as polyunsaturated fatty acids (PUFAs), sterols, proteins, polysaccharides, antioxidants, and pigments. They contain more than 60 trace elements in a concentration much higher than in terrestrial plants. They also contain protein, iodine, bromine, vitamins, and substances of stimulatory

and antibiotic nature. Seaweeds are also traditionally consumed in different parts of the world. Many marine organisms live in complex habitats exposed to extreme conditions and, in adapting to new environmental surroundings, they produce a wide variety of secondary metabolites which cannot be found in other organisms. Numerous marine bioactive molecules have been identified, whose biological activities could interfere with the pathogenesis of many diseases [7].

Reported literature on the uses of seaweeds has been cited as early as 2500 years ago in China. Every year about 7.5-8 million tons of wet seaweeds is being produced along the coastal regions worldwide [8]. The history of Indian seaweed research is not more than 75 years. The state of the Indian seaweed resources was last reviewed in 1998, and subsequently, a lot of new information relating to resources, utilization and commercial cultivation has been added. India (08.04–37.06 N and 68.07–97.25 E), a tropical South Asian country has a stretch of about 7500 km coastline, excluding its island territories with 2 million km^2 Exclusive Economic Zone (EEZ) and nine maritime states like Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Orissa, Andaman and Nicobar, Lakshadweep Islands.

The seaweed flora of India is highly diversified and comprises mostly of tropical species, but boreal, temperate and subtropical elements have also been reported. In all, 271 genera and 1153 species of marine algae, including forms and varieties have been enumerated till date from the Indian waters [9].

TABLE 1: REPORTED SPECIES COMPOSITION ENCOUNTERED DURING DIFFERENT SURVEYS

State	Green	Brown	Red	Blue-green	Total	References
Gujarat	29	24	39	Nil	92	Chauhan and Mairh [10]
Maharashtra	11	11	14	Nil	36	Chauhan [11]
Karnataka*	16	10	16	1	43	Agadi [12]
Kerala	13	3	17	2	35	Chennubhotla *et al.* [13]
Tamil Nadu	113	83	225	5	426	Anon [14]
Orissa*	8	Nil	6	Nil	14	Sahoo *et al.* [15]
Nicobar Islands	18	15	18	Nil	51	Ravindran *et al.* [16]
South Andaman Islands	29	15	11	Nil	55	Muthuvelan *et al.* [17]
Lakshadweep Islands	33	10	39	Nil	82	Anon [18]

*Qualitative survey only

Seaweeds differ from countries to countries. Cultivation conserves natural resources and improves the germplasm. Seaweed cultivation in India is still in the experimental stage they are collected manually from their natural habits. This harvesting is one of the important sources of livelihood to the coastal fisher-folk community. Seaweed collections are mainly centered along the southeastern coast of India from Rameswaram to Kanyakumari. There are about 25 agar industries and 10 align industries situated at different places in the maritime states of Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, and Gujarat. Seaweeds are one of the foods yielding plants, which are found in lagoons and reed areas of coastal regions of India. The development of tissue culture techniques in seaweeds is essential for biotechnological application in strain improvement (Stevens & Purton, 1997). Seaweeds have a great value in providing low-cost nutrition and therapeutic protection almost everywhere in the world.

Marine algae are known to produce a wide variety of bioactive secondary metabolites, and several compounds have been derived from them for prospective development of novel drugs by the pharmaceutical industries. Now the red algae such as *Gelidiella acerasa, Gracilaria edulis, G. crassa* used for agar manufacture and brown algae *Sargassum* sp., *Turbinaria* sp. and *Cystoseira* sp. are used for alginates production (Anon 2004).

Marine algae are popular food ingredients in Asian countries. Studies have suggested that bioactive compounds isolated from marine organisms exhibit anti-cancer, anti-microbial, anti-fungal or anti-inflammatory and other pharmacological activities. Several algae have been found to have secondary metabolites most of which are a phenolic compound, which had medicinal potentials [19, 20]. Therefore, the aim of the present review was to facilitate discussion on the marine algae; the following review examines the existing scientific knowledge.

Bioactivities of Algae and Potential Use in Pharmacology:

***Padina boergesenii* (Brown Algae):** Sudha *et al.*, (2014) were reported antidiabetic activity [21], antioxidant activity [22], hepatoprotective activity [23], chemo-preventive effects [24] and herbivory effects [25] of *Padina boergesenii*, Brown algae abundantly growing in Gulf of Mannar, southeast coast of Tamil Nadu, India. Oral administration of the *Padina boergesenii* to the STZ induced diabetic rats showed abridged effects on fasting blood glucose, insulin and lipoprotein levels. And also observed in liver glycogen and total protein levels in diabetic rats. The extract also significantly increased the activities of the key glycolytic enzymes like hexokinase, aldose, and phosphoglucoisomerase and decreased the activities of gluconeogenic enzymes like fructose-6-phosphatase and fructose-1, 6- diphosphatase in liver and kidney of diabetic rats.

***Sargassum wightii* (Brown Algae), *Chaetomorpha linum* (Green Algae) and *Padina gymnospora* (Light Brown Algae):** Janarthanan S *et al.*, (2012) was screened the antibacterial efficacy of various solvent namely; hexane, ethyl acetate, acetone and methanolic extracts for all three marine algae were tested against gram positive and gram negative human pathogenic bacteria using disc diffusion method. All three marine species were collected during low tide by hand-picking from the coast of Tuticorin, Tamil Nadu, India. And screened for antibacterial studies and were found that the acetone extracts of all the three marine algae showed higher inhibitory activity for the selected bacterial species than the other solvent extracts. And also revealed that among the three marine algae *Padina gymnospora* and *Sargassum wightii* were found to more active than *Chaetomorpha Linum*. [26]

***Halimeda tuna (H. tuna), Turbinaria conoides (T. conoides)* and *Gracilaria foliifera (G. foliifera)*:** Anantharaman P *et al.*, (2011) was reported *in-vitro* antioxidant activities of three selected Indian seaweeds and were collected from South East Coast of India. The samples were used to determine the phenolic content, antioxidant activity and reducing power. Among the three seaweeds, Total phenolic content and total antioxidant activity were higher (1.231 ± 0.173 mg GAE/g, 1.675 ± 0.361 mg GAE/g in *T. conoides* and exhibited higher radical scavenging activity when compared to *G. foliifera* and *H. tuna.* Reducing the power of crude methanolic extract increased with concentrations of the extract and researcher concluded seaweeds could be considered for curing diseases of oxidative deteriorations [27].

***Laurencia brandenii* (Red Algae):** Selvin J *et al.*, (2009) was observed cytotoxic potentials of red algae and specimens were collected from the habits of Kollam area located in the southwest coast of India. The red algae were extracted and fractionated in column chromatography using different solvent systems. The fractions were evaluated for brine shrimp cytotoxicity and hatchability assay using *Artemia salina*. The fatty acid composition of active fraction revealed that the main acid was 9, 12-Octadecadienoic acid (Z, Z) - (49.75%) followed by n-Hexadecanoic acid (14.24%) which might have functional role that confirmed by result at a dose of 200 µg/ml the active fraction of algae elicited 100% hatching inhibition, whereas in toxicity assay shown an LD_{50} value of 93 µg/ml, which might have cytotoxic activity [28].

***Gracilaria edulis* and *Sargassum polycystum*:** Koneri *et al.*, (2018) study were undertaken to evaluate antidiabetic activity of marine species in STZ induced diabetic rats. The marine algae were collected from the Mandapam coast (latitude 90 17' Longitude 790 22, E), Gulf of manner, Tamil Nadu, India. The composition of active like; Carbohydrates, glycosides, phytosterol, proteins and the main bioactive phytochemical was phytosterol, which might have biological activities. And the results were marked an increase in total cholesterol, LDL cholesterol, and TG, while a significant decrease in HDL cholesterol level, was found in the diabetic control group. Hyperlipidemia is a known complication of diabetes mellitus and coexists with hyperglycemia and is characterized by increased level of cholesterol, TG and LDL cholesterol, and all the lipid abnormalities associated with diabetes was significantly normalized by treatment with the methanolic extract of algae of *Sargassum polycystum* and *Gracilaria edulis*. Algae also reported a significantly increase in beta cell density indicating property insulin secretohoge activity and this

property may be due to regenerating activity on the beta cells [29].

Sargassum ilicifolium* (Brown Algae) *Kappaphycus alvarezii: Yende SR *et al.,* (2018) was screened anticonvulsant activity of brown algae in mice and an alga is a tropical and subtropical marine macroalgae collected from the inter-tidal rocky shore of Bhatkarwada, Ratnagiri coastal area of India. The researcher investigated the anticonvulsant activity of marine algae in maximal electroshock-induced convulsion and pentylenetetrazole (PTZ) induced convulsion and algae revealed the presence of alkaloids, terpenoids, Flavonoids, steroids, and saponin. The results of this study showed that chloroform extract (600 mg/kg) and ethanol extract (400 & 600 mg/kg) of algae significantly decreased the duration of tonic hind limb extension in maximal electroshock, as well as it significantly increased the latency to onset of convulsions in pentylenetetrazole model [30].

Rebeca LJ *et al.,* (2012) has reported antibacterial activity of *Sargassum ilicifolium, Kappaphycus alvarezii* and collected from different coastal regions of Rameshwaram (Southeastern coast of Tamil Nadu, India) were used in the present study. For microbiological testing of the seaweed extracts, agar well diffusion method was used.

The zone of inhibition was measured for all the different crude algal extracts against three strains of microorganisms namely, *Escherichia coli, Salmonella sp.* and *Klebsiella sp.* that cause diseases and disorders in human beings, animals and plants. Algae extracted prepared from chloroform, ethanol and methanol revealed a wide range of antibacterial activity against the mentioned pathogens. Researcher also revealed that maximum inhibition was noted with ethanol extracts in *Sargassum ilicifolium* rest all the extracts shown varied results in case of *Kappaphycus alvarezii*, the effect may be the bactericidal agents found in algae include amino acids, terpenoids, phlorotannins, acrylic acid, phenolic compounds, steroids, halogenated ketones and alkanes, cyclic polysulphides and fatty acids [31].

***Gracilaria corticata*:** The *Gracilaria corticata* are generally considered to be important because of their pharmacological uses due to the presence of constituents like α-(1, 4)-3,6-anhydro-l-galactose and β-(1,3)-d-galactose [32, 33]. Deepa S *et al.,* (2017) was reported to bioactivities of *Gracilaria corticata* algae which is one of the important species rich in various constituents responsible for various pharmacological activities.

The methanolic extracts of *Gracilaria corticata* rich in phenols and has higher percentage scavenging activity towards nitric oxide, hydroxyl radicals, hydrogen peroxide. The crude methanolic extracts of *Gracilaria corticata* was found to possess potent antimicrobial activity which was tested using well diffusion technique, and it also shows significant anticancer activity that was tested using various cancer cell lines like MCF7, normal VERO cell lines, and Hep-G2 by MTT assay [34].

Movahedinia A *et al.,* (2014) reported anti-oxidant properties of methanolic extracts of brown and red algae especially *Gracilaria corticata* was carried out by using ferric reducing ability of plasma (FRAP) method and diphenyl picrylhydrazyl (DPPH). And reported results, 50 mg/ml concentration both algae had no anti-oxidant activity with ABTS (μmol/g extract) and also there were no significant differences ($p>0.05$) between the studied algae in phenolic compounds and antioxidant activities that was tested by the DPPH and FRAP tests [35].

Dist A *et al.,* (2013) has reported the antioxidant of some seaweed constituents. They have reported antioxidant, anti-cholesterolemic and anti-tumor activity of ethanolic extract of *Gracilaria corticata* by performing antioxidant and cytotoxic potency of the *in-vitro* antioxidant assay using DPPH radical and reducing power [36].

Rout S *et al.,* (2015) has screened aqueous extract of *Gracilaria corticata* in diabetic rats was valued for two dissimilar doses such as 200 & 400 mg/kg by considering the method of blood glucose level, glycosylated hemoglobin, and hepatic glycogen level. And results revealed aqueous extract of *Gracilaria corticata* drop blood glucose and glycosylated hemoglobin level in a dose dependent way and matched against the standard glipizide followed by the dose of 200 and 400 mg/kg showed 22.23 mg/g and 24.78 mg/g respectively in hepatic

glycogen content which was ominously diminished by alloxan treated diabetic rats [37].

Sampathkumar P *et al*., (2008) was investigated the hepatoprotective activity using aflatoxin B1 (AFB1) induced hepatotoxicity effect of marine algae *Gracilaria corticata* in contrast to AFB1 (1ppm) induced hepatic damage which were examined using important refereeing parameters like total protein content, weight of the liver albumin, body weight gain and tested along transaminase (SGOT and SGPT), lactate dehydrogenase (LDH) and alkaline phosphatase (ALP) as enzyme markers. And results revealed a decreased level of the above said parameters authenticated the Hepatic damage significantly ($p<0.05$) with the aqueous extract concentration of 250 mg kg-1 body weight [38].

***Gracilaria verrucosa* (Red), *Enteromorpha compressa* (Green), *Ulva fasciata* (Green), *Turbinaria conoides* (Brown):** Mohapatra L *et al.*, (2016) the study was designed to evaluate the antioxidant, hypoglycemic and antidiabetic activities of different solvents extract *viz*. Petroleum ether, ethyl acetate and methanol extracts of these seaweeds. And the extracts were evaluated for total phenolic content, Reducing power, nitric oxide, and H_2O_2 scavenging tests. The extracts with superior antioxidant activity among these seaweeds were further tested hypoglycemic and antidiabetic activity. The IC_{50} value of ethyl acetate of *Ulva fasciata* was found to be 123.39 and 127.65 µg/ml for H_2O_2 and NO free radical scavenging activity respectively. Total phenol content for ethyl acetate of *Ulva fasciata* was 207.23 ± 2.41 mg/g. Fasting plasma glucose level in normal mice was significantly ($p<0.05$) decreased even after 6 days of ethyl acetate of *Ulva fasciata* treatment at the dose 200 mg/kg. The area under the curve of oral glucose tolerance test was not affected significantly, though the considerable reduction in area under the curve was found in both ethyl acetate of *Ulva fasciata* 100 and 200 mg/kg treated groups. It was found that ethyl acetate of *Ulva fasciata* has potent *in-vitro* alpha-amylase inhibiting property when compared to the standard, acarbose. And results suggested that the anti-diabetic activity of *U. fasciata* may be due to its underlying antioxidant, hypoglycemic and alpha-amylase inhibiting property.

Presence of alkaloid was detected in Petroleum ether of *Ulva fasciata*. Gum and mucilage were detected in two green seaweed extracts (methanol extract of *Ulva fasciata* and methanol extract of *Enteromorpha*). Tannins, protein and amino acids were detected in methanol extracts of all seaweeds. Phenolic compounds were detected in ethyl acetate and methanol extracts of all seaweeds. Whereas, carbohydrate was absent in all the seaweed extracts [39].

***Acanthophora spicifera* (Red), *Padina tetrastomatica* (Brown) and *Caulerpa scalpelliformis* (Green):** Radhika D *et al.*, (2015) the experiment was carried out for antidiabetic activity against alloxan-induced diabetic rats were collected from Tuticorin coast (08° 46' 2.15"N lat; 78°11' 16.05" E long) and fully grown & submerged underwater from the tidepools. In diabetic control rat, liver glycogen content decreased significantly by 79.89 % as compared to non-diabetic control. Seaweed extracts of *A. spicifera*, *P. tetrastomatica*, and *Caulerpa scalpelliformis* at a dose 200 mg/kg led to 74.47%, 66.05%, 68.79% and 70.56% increase in liver glycogen content in compared to diabetic control group. And also revealed that mean level of enzymes Hexokinase, Glucokinase and substrate Glucose-6-phosphatase values decreased in diabetic control. The respective percentage decrease was 56.19%, 79.96% and 67.69% in diabetic control.

Treatment with extracts of *A. spicifera*, *P. tetrastomatica*, and *Caulerpa scalpelliformis* led to rising in the percentage of these parameters by 22.03% and 56.03%, 45.21% and 34.28%, 67.78% and 47.5% and 33.33%, 67.88% and 45.76% respectively ($p<0.001$) as compared to diabetic control. There were no statistically significant differences were seen in the mean WBC, and RBC counts, HB and Platelet values as compared to the non-diabetic animals [40].

***Acanthophora specifera*:** Kumar RR *et al.*, (2015) has reported *in-vitro* antioxidant efficacy and antimutagen on selected algae. And they were collected from Mandapam Coastal Area, Rameswaram Tamil Nadu, India. The algae revealed the presence of saponin, tannin, Flavonoids, steroids, terpenoids, alkaloids, amino acid, polyphenol, anthraquinones, and glycosides.

Different concentrations of *Acanthophora specifera* **(**20, 40, 60 and 80 µg/ml) were chosen for *in-vitro* antioxidant activity and standard L-Ascorbic acid was used. Results were demonstrated in vitro antioxidant property of *Acanthophora specifera* in respect to DPPH radical scavenging assay, Hydroxyl radical scavenging assay, Superoxide anion scavenging assay, nitric oxide scavenging assay, Fe^{2+} chelating assay, Reducing power assay and studied was suggested that the algae might have an antioxidant, anti-allergic, anti-inflammatory, anti-microbial, anti-cancer activity due to the presence of mentioned bioactive chemicals.

***Gelidiella acerosa*:** Syad AN *et al.,* (2012) was assessed of anticholinesterase (AChE), and butyryl-cholinesterase (BuChE) activities of algae[42] were collected from the South Indian coastal area, Tamil Nadu and inhibitory activities were analyzed by spectrophotometric method. Benzene and ethyl acetate extract showed positive results for the presence of terpenoids, cardiac glycosides, alkaloids, and tannins. The results showed that, at 487.80 µg/mL, benzene extract showed significant ($p<0.05$) inhibitory activity against both AChE and BuChE with the percentage of inhibition 54.18 ± 5.65% (IC_{50} = 434.61 ± 26.53 µg/mL) and 78.43 ± 0 % (IC_{50} = 163.01 ± 85.35 µg/mL), respectively. The mode of inhibition exhibited by benzene extract against the AChE and BuChE was found to be the competitive and uncompetitive type of inhibition. GC-MS illustrates that the benzene extract possesses a high amount of terpenoids, which could be the reason for potential cholinesterase inhibitory activity.

Several marine algae's like; *Caulerpa racemosa, Codium capitatum, Ulva fasciata, Halimeda cuneata, Amphiora ephedraea, Amphiora bowerbankii, Dictyota humifusa, Hypnea valentiae, Padina gymnospora, Ulva reticulate, Gracilaria edulis, Ecklonia stolonifera, Ishige okamurae*

Kim SK *et al.,* (2011) was mentioned in their review paper, the above several marine algae's of methanolic extracts which have potential Acetylcholinesterase inhibitory activities [43]. The inhibition of acetylcholinesterase (AChE) enzyme, which catalyzes the breakdown of ACh, may be one of the most realistic approaches to the symptomatic treatment of Alzheimer's disease, which is known for an irreversible, progressive neurodegenerative disease and resulting in memory loss, behavior disturbances and decline the standard of life.

***Syncephalastrum racemosum* and *Gracilaria corticata*:** Ushasri R *et al.,* (2015) has reported *invitro* antidiabetic activity of ethanolic and acetone extracts of endophytic fungi of marine algae by alpha-amylase inhibition assay method.[44] the study was aimed at screening the diabetic ant activity of endophytic fungi isolated from *Gracilaria corticata*. Seaweed was processed, placed on potato dextrose agar (PDA) medium and Sabourds Dextrose Agar (SDA) medium respectively. The mycelial growth of *S. racemosum* was inoculated into Potato Dextrose Broth (PDB) and allowed for fermentation. The mycelial mat was extracted with acetone and ethanol. The crude extracts of fungi showed the highest inhibitory activity of 23.7% and 19.4%.

Brown seaweed: *Cystoseirra sp., Dictyopteris sp., Dictyota, Hormophysa, Hydroclathrus, Padina, Sargassum,* and *Turbinaria* is maximally fulfilled from Asian countries *viz*. Korea, Japan, China. Brown alga is a rich source of bioactive components like phlorotannins, polyphenols, pigments, sulfated polysaccharides, vitamins (A, B, C, and E), dietary fibers, omega-3 fatty acids, and essential amino acids. The anti-diabetic potential of brown algae is maximally due to polyphenols, polysaccharides, and pigments. Phlorotannins show α-glucosidase, α-amylase, and PTP inhibitory functions. The phlorotannins were found to enhance peripheral glucose utilization by activating glucose transporter sub-type 4 (GLUT-4) and activation of the protein kinase (AMPK) pathway. Fucoxanthin is a marine carotenoid present in brown marine seaweeds.

It induces the synthesis of docosahexaenoic acid (DHA) in the liver. Fucoxanthin reduces white adipose tissue fat accumulation and promotes weight loss. With 0.02% dose fucoxanthin there is a significant lowering of body weight. Fucoxanthin also helps to lower plasma and hepatic triglyceride concentrations. Adipocyte fatty acid synthesis, hepatic fatty acid, and triglyceride synthesis are also lowered by fucoxanthin.

Animal experimentations have shown that it slows down fasting blood glucose level and modulates plasma-insulin level in obese mice. Fucoxanthin controls insulin resistance, inhibits adipokines, TNF-α, monocyte chemoattractant protein-1(MCP-1), IL-6.

TABLE 2: COMPILED DATA ON MARINE ALGAE WITH PHARMACOLOGICAL ACTIVITY

S. no.	Algae	Source	Constituents	Specific activity	Reference
1	Brown	*Ecklonia stolonifera*	Poly-phenols	*Ecklonia stolonifera* were investigated using non-insulin dependent diabetic mice. And showed strong inhibition of alpha-glucosidase *in-vitro*. And the ingestion of extract suppressed the increase in plasma glucose and lipid peroxidation levels in unfasten KK-A(y) mice dose-dependently.	Iwai K. (2008) [45]
		Ecklonia cava		The inhibitory effect of polyphenols extracts of the marine algae on hyperlipidemia was investigated in ICR mice fed a high-fat diet for five weeks. And results showed significant reduction of the level of total cholesterol, TGs, and LDL in the serum of high-fat diet mice. In Oil Red O staining using 3T3-L1 preadipocytes, it was shown that markedly inhibited lipid accumulation of 3T3-L1 cells. Furthermore, significant inhibition of adipogenesis of adipocytes HMG-CoA reductase activity *in-vitro*. Dieckol isolated from *Ecklonia cava* inhibits alpha-glucosidase and alpha-amylase *in-vitro* and alleviates postprandial hyperglycemia in STZ induced diabetic mice	Yeo AR and Lee J *et al*., (2012) [46]
				E. cava was able to suppress the levels of pro-inflammatory cytokines such as; TNF-α, IL-6, Il-1β, LPS, NF-ƙβ, and MAPKs activation.	Kim SK *et al*., (2011) [42]
2	Green	*Cladophora rupestris*	Fucoidan Phenol, 2,4-bis (1,1-dimethylethyl) and z, z-6,28-heptatriactontadien -2-one	*Cladophora rupestris*, were chosen to evaluate alpha-amylase, alpha glucosidase inhibitory, and antioxidant activity *in-vitro* and IC_{50} – 666.3 µg/ml showed notable free radical scavenging activity	Unnikrishnan PS (2015) [47]
3	Red	*Euchema kappaphycus Gracilaria edulis*	Poly-phenols	The antioxidant activities of total methanol extract and 5 different solvent fractions; petroleum ether (PE), ethyl acetate (EA), dichloromethane, Butanol were evaluated. EA fraction of *A. spicifera* exhibited higher total antioxidant activity (32.01 mg ascorbic acid equivalent/g extract) among all the fractions. Higher phenolic content (16.26 mg gallic acid equivalent/g) was noticed in PE fraction of *G. edulis*. Reducing the power of crude methanol extract increased with increasing concentration of the extract. Reducing power and hydroxyl radical scavenging activity of *E. kappaphycus* was higher compared to standard antioxidant (alpha-tocopherol). *In-vitro* antioxidant activities of methanol extracts of all three marine algae exhibited dose-dependent effect	Ganesan P *et al*. (2008) [48]
		Acanthophora spicifera			
4	Green	*Enteromorpha compressa* (L.)	As pigments, phenolic compounds, and essential oils	*E. compressa* extracts alleviated the IgE levels raised against ovalbumin and other allergens in mice. Furthermore, significantly down-regulated the serum IgE levels in different murine models irrespective of their genetic background. The study suggested that *E. compressa* extract has compound(s), which inhibit IgE immune response and may have potential in the suppression of allergens	Rao DN *et al*., (2004)[49]
				Enteromorpha compressa extracts also have the antioxidant activity may be the presence of promising active compounds which were separated from *E. compressa* against ABTS radical and this is	Shanab SM M *et al*., (2011) [50]

				maybe the presence of different electronegativity groups in the structure may lead to less stability of different atoms (*e.g.*, methylene group) because these groups can attach electron from methylene group and convert it to radical form. So, the activity of the active compound may be due to the reaction between methylene group radicals or hydrogen proton with ABTS radical	
5	Green	*Chaetoorpha antennina*	Mostly all abundant phytochemicals	Seaweeds are a promising source of natural products. *Chaetomorpha antennina* showed the presence of flavonoids, triterpenoids, alkaloids, coumarins, quinones, and saponins. Flavonoids are important for their antioxidant and free radical scavenging activities. Quercetin, the most abundant dietary flavonol, is a potent antioxidant because it has all the right structural features for free radical scavenging activity	Subathraa K and Poonguzhali TV (2013) [51]
6	Red	*Gracilaria corticata*	Alkaloids, Flavonoids, Glycosides, Phenols, & Saponin, etc	*Gracilaria corticata* was tested for probable antitumoral activity on Jurkat and molt-4 human lymphoblastic leukemia cell lines. And the cells were treated by different concentration of extract and the number of viable cells and cytotoxicity of the extract was evaluated by MTT assay. A result was shown that 9.336 and 9.726 µg/µl of algal extract was the most effective concentrations. This can be used for the development of potential anticancer drug	Zandi K *et al*., (2010) [52]
7	Green Red Red Brown	*Caulerpa racemosa* *Gracillaria gracillis* *Chondrococcus hornemanni* *Padina gymnospora*	Terpenoids, Polysaccharides, Phenols, & Fatty acids	Screening of seaweeds collected from the southeast coastal area of India and algae extracted with ethyl acetate for alpha-amylase inhibitory activity, antioxidant activity, and biocompatibility	Senthil SL *et al*., (2013) [53]
8	Brown	*Cystoseira moniliformis*	Saponins, anthraquinones, Flavonoids, terpenoids, steroids	The studied was investigated for Type I antidiabetic activity and screened the effect of brown algae of *Cystoseira moniliformis* extract on the blood glucose level of alloxan-induced hyperglycaemic albino mice and results showed a promising effect against alloxan-induced diabetic mice	Hongayo MC (2011) [54]
9	Green	*Caulerpa lentillifera*	Polysaccharide & sterols	The experiment was screened for antidiabetic effects of *Caulerpa lentillifera* on RIN-5F cells and evaluated for stimulation of insulin secretion in pancreatic beta cells and enhancement of glucose uptake in adipocytes. Showed significant changes in among different group compared to the diabetic control *in-vitro* model	Sharma BR *et al*., (2014) [55]
10	Red	*Callophyllis japonica* & *Gracilaria tenuistipitata*	Poly-phenols	Ethanol extracts of the marine species of red algae reported antioxidant effects and suppressed H_2O_2 induced cellular apoptosis and activated cellular antioxidant enzymes and also revealed that the cell line H1299 showed that treatment with an aqueous extract of *G. tenuistipitata* enhanced the recovery of these cells from H_2O_2-induced DNA damage, counteracts cellular proliferation, and induced G2/M arrest	Kang KA *et al.*, (2005) [56] & Yang JI *et al*., (2012) [57]
			Proteins, Lipids, Terpenoids, Dietary fiber, macro element contents, amino acids	Studied also revealed that An aqueous extract of *G. tenuistipitata* suppressed virus-induced inflammation, a polysaccharide from *Porphyridium* sp. inhibited the replication of retroviruses, and an ethanol extract of *Polyopes affinis* suppressed asthmatic reactions	Chen KJ *et al*., (2013) [58] & Talyshinsky MM *et al*., (2002) [59]

CONCLUSION: Marine algae biodiversity needs systematic study. In this review, we were able to show that these all marine algae of Indian coast and the most probable reason for their potential activity might be related to the presence of different bioactive compounds in marine algae, and are easily extracted with solvents can be used for development of drugs in the pharmaceutical industries. The significance of these marine algae's need to further characterize, and they will be evaluated for their bioavailability. However, corrective measures like scientific research, education, conservation, and awareness are essential to increase the use of marine algae.

ACKNOWLEDGEMENT: The author is grateful to the Department of Pharmacology, Karnataka College of Pharmacy, Bangalore, India for their support and useful discussions with Dr. Raju Koneri and Mr. Deepak Kumar Jha.

CONFLICT OF INTEREST: We declare that we have no conflict of interest.

REFERENCES:

1. Wijesekara I, Pangestuti, R and Kim SK: Biological activities and potential health benefits of sulfated polysaccharides derived from marine algae. Carbohydr Polym 2011; 84: 14-21.
2. Guven KC, Percot A and Sezik E: Alkaloids in marine algae. Mar Drugs 2010; 8: 269-84.
3. El-Gamal AA: Biological importance of marine algae. Saudi Pharm J 2010; 18: 1-25.
4. UK Prospective Diabetes Study Group. Intensive blood glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). Lancet 1998; 352: 837-53.
5. Bailey CJ and Day C: Traditional plant medicine as treatments for diabetes. Diabetes Care 1989; 12: 553-64.
6. Nwosu F, Morris J, Victoria AL, Stewart D and Heather A: Anti-proliferative and potential anti-diabetic effects of phenolic-rich extracts from edible marine algae. Food Chemistry 2011; 126: 1006-12.
7. Wang H, Fu Z and Han C: The potential applications of marine bioactive against diabetes and obesity. American Journal of Marine Science 2014; 2(1): 1-8.
8. McHugh DJ: A guide to the seaweed industry. FAO Fisheries Technical Paper 2003; 441: 105.
9. Anon., Seaweeds: Wonder Plants of the Sea. Aquaculture Foundation of India, Chennai 2005; 30.
10. Chauhan VD and Mairh OP: Report on survey of marine algal resources of Saurashtra Coast, India. Salt Res Ind 1978; 14: 21-41.
11. Chauhan VD: Report of the survey of marine algae resources of Maharashtra coast. Salt Res Ind 1978; 14: 1-10.
12. Agadi VV: Distribution of marine algae in the littoral zone of the Karnataka coast. In: Krishnamurthy V. And Untawale A.G. (eds), Marine Plants. Seaweed Res Utiln. 1985: 35-42.
13. Chennubhotla VSK, Ramachandrudu BS, Kaladharan P and Dharmaraj SK: Seaweed resources of Kerala coast. Aquat Biol 1988; 7: 69-74.
14. Anon: A report on the survey of marine algal resources of Tamil Nadu, 1971-1976, Central Salt and Marine Chemicals Research Institute, Bhavnagar 1978; 137.
15. Sahoo D, Sahu N and Sahoo D: A critical survey of seaweed biodiversity of Chilika Lake, India. Algae 2003; 18: 1-12.
16. Ravindran VS, Thangaradjou T and Kannan L: Qualitative and quantitative distribution of seaweeds in the Great Nicobar Island. Seaweeds – 2004 – National Symposium and Exposition, Cochin, Abst 2004: 27.
17. Muthuvelan B, Chennubhotla VSK, Nair KVK, Sampath V and Ravindran M: Standing crop biomass and comparative distribution of agarophytes, alginophytes and other algae in South Andaman. Indian Hydrobiol 2001; 4: 130-38.
18. Anon: A report on the survey of marine algal resources of Lakshadweep. Central Salt and Marine Chemicals Research Institute, Bhavnagar 1979; 48.
19. Abou-Elela, Gehan M. Elnaby AH, Hassan AH. Ibrahim and Okbah MA: Marine natural products and their potential applications as anti-infective agents. World Appl Sci J 2009; 7(7): 872-880.
20. Mohammed A, Adelaiye AB, Abubakar MS and Abdurahman EM: Effects of aqueous extract of *Ganoderma lucidum* on blood glucose levels of normoglycemic and alloxan-induced diabetic Wistar rats. J of Medicinal Plants Res 2007; 1(2): 34-37.
21. Senthilkumar P, Sudha S and Prakash S: Antidiabetic activity of aqueous extract of *Padina boergesenii* in streptozotocin-induced diabetic rats. Int J Pharm Pharm Sci 2014; 6(5): 418-22.
22. Rajamani K, Manivasagam T and Ananatharaman P: Chemopreventive effect of *Padina boergesenii* on ferric nitrilotriacetate (Fe-NTA) induced oxidative damage in Wistar rats. J Appl Phycol 2010; 257(2): 257-63.
23. Vasanthi HR, Jaswanth A. Saraswathy and Rajamanickam GV: Control of urinary risk factors of stones by *Padina boergesenii* (Allender and Kraft), brown algae in experi-mental hyperoxaluria. J Nat Rem 2003; 3(2): 189-94.
24. Guillermo D, Villamil L and Almanza V: Herbivory effects on the morphology of the brown alga *Padina boergesenii* (Phaeophyta). Phycol 2007; 46(2): 131-36.
25. Pandit R, Phadke A and Jagtap A: Antidiabetic effect of *Ficus religiosa* extract in streptozotocin-induced diabetic rats. J. Ethnopharmacol 2010; 128: 462-66.
26. Janarthanan S, Rosaline XD, Sakthivelkumar S and Rajendran K: Screening of selected marine algae from the coastal Tamil Nadu, South India for antibacterial activity. Asian Pacific Journal of Tropical Biomedicine 2012; S140-S146.
27. Anantharaman P, Devi GK, Manivannan K and Rajathi AA: *In-vitro* antioxidant activities of selected seaweeds from Southeast coast of India. Asian Pacific Journal of Tropical Medicine 2011; 205-11.
28. Manilal A, Sujith S, Seghal Kiran G, Selvin J and Shakir C: Cytotoxic potentials of red alga, *Laurencia brandenii* collected from the Indian Coast. Global Journal of Pharmacology 2009; 3(2): 90-94.
29. Koneri R, Jha DK and Mubasheera MG: An investigation on the type I antidiabetic activity of methanolic extract of Marine algae, *Gracilaria edulis* and *Sargassum polycystum*. Int J Pharm Sci Res 2018; 9(7): 2952-59.

30. Yende SR, Harle UN, Arora SK and Pande VB: Phytochemical screening and anticonvulsant activity of *Sargassum ilicifolium* (brown algae) in mice. J Phytopharmacol 2018; 7(1): 25-28.
31. Rebecca LJ, Dhanalakshmi V and Shekhar C: Antibacterial activity of *Sargassum ilicifolium* and *K. alvarezii*. J Chem Pharm Res 2012; 4(1): 700-05.
32. Falcão VR: PhD Thesis. Institute of Chemical, University of São Paulo; São Paulo, Brazil. Aspectos moleculares de nitrato redutase da macroalga marinha *Gracilaria tenuistipitata* (Rhodophyta): Seqüenciamento do gene e estudo da expressão do RNA mensageiro 2006: 1-187.
33. Kain JM and Destombe C: A review of the life history, reproduction and phenology of Gracilaria. J Appl Phycol 1995; 7: 269-81.
34. Narasimhan MK, Pavithra SK, Krishnana V and Chandrasekaran M: *In-vitro* analysis of antioxidant, antimicrobial and antiproliferative activity of *Enteromorpha antenna*, Enteromorpha linza and *Gracilaria corticata* extracts. Jundishapur J Nat Pharm Prod 2013; 8(4): 151-9.
35. Movahedinia A and Heydari M: Antioxidant activity and total phenolic content in two alga species from the Persian Gulf in Bushehr Province. Iran Int J Res & Sci 2014; 3(5): 954-8.
36. Dist A: Antioxidant and brine shrimp cytotoxic activities of ethanolic extract of red alga *Gracilaria corticata*. Indian J Nat Prod Resour 2013; 4(2): 233-7.
37. Rout S and Kumar A: A review on the potentiality of marine seaweeds. World Journal of Pharmacy and Pharmaceutical Sciences 2015; 4(10): 458-76.
38. Sampathkumar P: Potential hepatoprotective effect of aqueous extract of *Gracilaria corticata* in AFB1 induced hepatotoxicity in Wister rats. J Biol Sci 2008; 8(8): 1352-5
39. Mohapatra L, Bhattamisra SK, Panigrahy RC and Parida SK: Evaluation of the antioxidant, hypoglycaemic and antidiabetic activities of some seaweed collected From the East Coast of India. Biomed Pharm J 2016; 9(1): 365-75.
40. Radhika D and Priya R: Assessment of antidiabetic activity of some selected seaweeds. EJBPS 2015; 2(6): 151-54.
41. Kumar RR and Jeyaprakash K: Screening of phytochemical and *in-vitro* antioxidant efficacy on selected red seaweed (*Acanthophora specifera*) collected from Gulf of Mannar, Tamil Nadu, India. World Journal of Pharmaceutical Research 2015; 4(6): 1505-18.
42. Syad AN, Shunmugiah KP and Kasi PD: Assessment of anticholinesterase activity of *Gelidiella acerosa*: implications for its therapeutic potential against Alzheimer's disease. Evidence-Based Complementary and Alternative Medicine 2012; 497242.
43. Kim SK and Pangestuti R: Neuroprotective effects of marine algae. Mar Drugs 2011; 9: 803-18.
44. Ushasri R and Anusha R: *In-vitro* anti-diabetic activity of ethanolic and acetone extracts of endophytic fungi *Syncephalastrum racemosum* isolated from the seaweed Gracilaria corticata by alpha-amylase inhibition assay method. Int J Curr Microbiol App Sci 2015; 4(1): 254-59.
45. Iwai K: Antidiabetic and antioxidant effects of polyphenols in brown alga *Ecklonia stolonifera* in genetically diabetic KK-A(y) mice. Plant Foods Hum Nutr 2008; 63(4): 163-9.
46. Yeo AR, Lee J, Tae IH and Park SR: Anti-hyperlipidemic effect of polyphenol extract (Seapolynol^{TM}) and Dieckol isolated from *Ecklonia cava* in *in-vivo* and *in-vitro* Models. Prev Nutr Food Sci 2012; 17: 1-7.
47. Unnikrishnan PS, Suthindhiran K and Jayasri MA: Alpha-amylase inhibition and antioxidant activity of marine green algae and its possible role in diabetes management. Pharmacogn Mag 2015; 11(4): S511-S515.
48. Ganesan P, Kumar CS and Bhaskar N: Antioxidant properties of methanol extract and its solvent fractions obtained from selected Indian red seaweeds. Bioresour Technol 2008; 99(8): 2717-23.
49. Rao DN, Radhakrishnan TM and Raman BV: *Enteromorpha compressa* (L.) Greville AN edible green alga as a source of antiallergic principle(S) Indian Journal of Clinical Biochemistry 2004; 19(1): 105-09.
50. Shanab SMM, Shalaby EA and Fayoumy EAE: *Enteromorpha compressa* exhibits potent antioxidant activity. Journal of Biomedicine and Biotechnology 2011.
51. Subathraa K and Poonguzhali TV: Effect of different extracts of *Chaetomorpha antennina* and their phytochemical screening. Int J Curr Sci 2013, 6: E35-39.
52. Zandi K, Tajbakhsh S, Nabipour I and Rastian Z: *In-vitro* antitumor activity of *Gracilaria corticata* (a red alga) against Jurkat and molt-4 human cancer cell lines. African Journal of Biotechnology 2010; 9(40): 6787-90.
53. Senthil SL, Kumar TV, Geetharamani D and Maruthupandi T: Screening of seaweeds collected from southeast coastal area of India for α-amylase inhibitory activity, antioxidant activity and biocompatibility. International Journal of Pharmacy and Pharmaceutical Sciences 2013; 5(1): 204-44.
54. Hongayo MC: The effect of brown alga *Cystoseira moniliformis* (kützing) Hauck extract on the blood glucose level of alloxan-induced hyperglycaemic albino mice. Journal of Pharmacy and Clinical Sciences 2011; 3: 1-12.
55. Sharma BR and Rhyu DY: Anti-diabetic effects of *Caulerpa lentillifera*: stimulation of insulin secretion in pancreatic β-cells and enhancement of glucose uptake in adipocytes. Asian Pac J Trop Biomed 2014; 4(7): 575-80.
56. Kang KA, Bu HD, Park DS, Go GM, Jee Y, Shin T and Hyun JW: Antioxidant activity of ethanol extract of *Callophyllis japonica*. Phytother Res 2005; 19(6): 506-10.
57. Yang JI, Yeh CC, Lee JC, Yi SC, Huang HW, Tseng CN and Chang HW: Aqueous extracts of the edible *Gracilaria tenuistipitata* are protective against H_2O_2-induced DNA damage, growth inhibition, and cell cycle arrest. Molecules 2012; 17(6): 7241-54.
58. Chen KJ, Tseng CK, Chang FR, Yang JI, Yeh CC, Chen WC, Wu SF, Chang HW and Lee JC: Aqueous extract of the edible *Gracilaria tenuistipitata* inhibits hepatitis C viral replication *via* cyclooxygenase-2 suppression and reduces virus-induced inflammation. PLoS One 2013; 8(2): e57704.
59. Talyshinsky MM, Souprun YY and Huleihel MM: Anti-viral activity of red microalgal polysaccharides against retroviruses. Cancer Cell Int 2002; 2(1): 8.

How to cite this article:
Sharma A, Koneri R and Jha DK: A review of pharmacological activity of marine algae in Indian coast. Int J Pharm Sci & Res 2019; 10(8): 3540-49. doi: 10.13040/IJPSR.0975-8232.10(8).3540-49.