ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
www.ijptonline.com
Review Article

REVIEW ONPHARMACOLOGY OF MARINE ALGAE

Mrs.S.Dhanalakshmi*,G. Sangeetha,Lakshmi.M,Elancheziyan. K, Thiyarajan. R
Department of Pharmacognosy, School of Pharmaceutical Sciences, Vels Institute of Science Technology and Advanced Studies(VISTAS), Velsuniversity, Old Pallavaram, Chennai- 600117.
Email:dhanadinesh2011@gmail.com

Received on 10-11-2016 *Accepted on: 29-11-2016*

Abstract:

The significance of marine creatures as a source of unique bioactive compounds is expanding. Marine organisms constitute nearly half of the wordwide biodiversity; thus, oceans and sea present a vast resource for new substances and it is considered the largest remaining reservoir of beneficial natural molecules that maight be used as functional constituents in the food sector. This review is an update to the information about recent functional seafood compounds (proteins, peptides, amino acids, fatty acids, sterols, polysaccharides, oligosaccharides, phenolic compounds, photosynthetic pigments, vitamins, and minerals) focusing on their potential use and health benefits.

Key Words: Red Algae, Brown Algae, Bioactive Compounds, Health benefit.

Introduction:

The marine world is a rich natural resource for many biologically active compounds. Marine organisms live in complex habitats and are exposed to extreme conditions, thus producing a wide variety of specific and potent active substances. Recently the marine organisms from the Ramanathapuram and Mandapam have attracted the attention of several investigators from the surrounding countries including Iran and India (1-6). From about 150 species of the marine algae collected in the South India, only a few have been subjected to biological and chemical investigation (7).

Polluted filamentous algae in the end of intertidal zone.Dense filamentous algae in the intertidal zone off plant.

Bioactive Component in Marine Algae:

Around 2400 years ago, Hippocrates set out guidelines for his students. One of his principles was "let food be your medicineand medicine be your food." The principle stressed the obvious relationship between food and good health (Chadwick 2003). The term "functional food" was first used in Japan in the 1980s for food products fortified with special constituents that had advantageous physiological effects. It was mainly the improved understanding of the relationship between nutrition and health that led to the development of the concept of functional food.

Table 1–PUFAs found in some marine organisms.

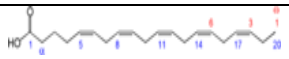
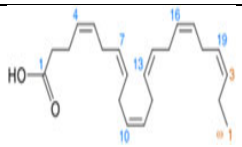
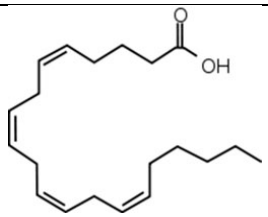
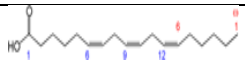
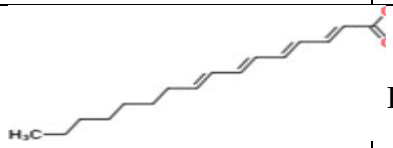
Name	**Main sources**	**Structure**	**Reference**
Eicosapentaenoic acid (EPA)	Herring, mackerel, sardine, salmon		Sijtsma and de Swaaf (2004)
Docosahexaenoic acid (DHA)	Herring, mackerel, sardine, salmon, *Spirulina*		Sijtsma and de Swaaf (2004) Lordan et and others (2011)
Arachidonic acid (AA)	*Mortierella*		Yap and Chen (2001)
γ -Linolenic acid (GLA)	*Mortierella, Spirulina*		Yap and Chen (2001)
Hexadecatetraenoic acid	*Ulva pertusa*		Lordan and others (2011)

Table 2 - Structure of some sterols found in seafood.

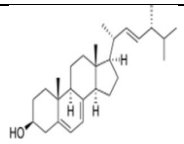
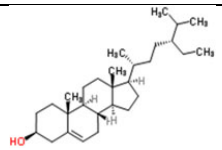
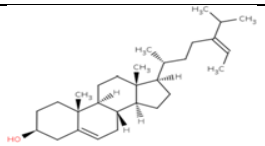
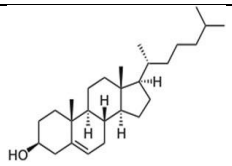
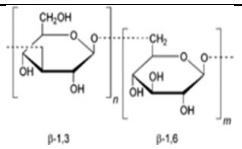
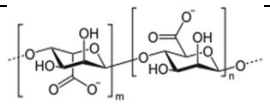
Name	**Main sources**	**Structure**	**Reference**
Ergosterol	*Chlamydomonasreinhardtii*		Brumfield and others (2010)
Clionasterol	*Spirulina*		Lordan and others (2011)
Fucosterol	Brown algae (*Pelvetiasiliquosa, Cystoseirafoenicul acea*)		Bouzidi and others (2014)
Cholesterol	Red algae (*Gracilariasalicor nia*and *Hypneaflagellifor mis*)		Nasir and others (2011)

Table 3-Some of the polysaccharides found in macro and microalgae

Name	**Main sources**	**Structure**	**Reference**
Laminarin	Brown algae (*Eiseniabicyclis*)		Menshova and others (2014)
Alginate	Brown algae (*Laminariadigitat,*		Fertah and others (2014)

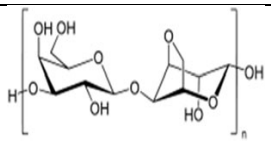
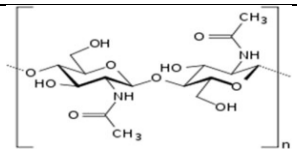
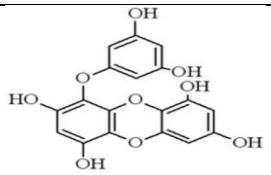
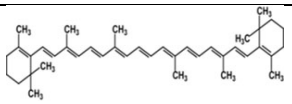
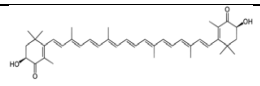
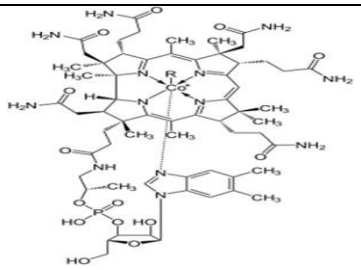
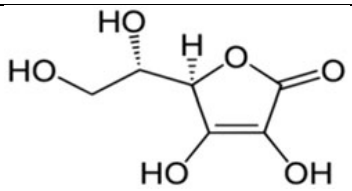
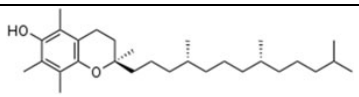
	Macrocystispyrifera)		
Agar	Red algae (*Gelidiellaacerosa*)		Prasad and others (2006)
Chitin	Crabs, shrimps, lobsters, prawns, krill		Rinaudo (2006).

Table 4 -Antioxidants and vitamins found in algae

Name	**Main sources**	**Structure**	**Reference**
Phlorotannin	Brown algae (Fucaceae, Sargassaceae, Cystoseiraceae, Laminariaceae		Shibata and others (2004)
β-Carotene	*Dunaliellasalina*		Guedes and others (2011)
Astaxanthin	*Haematococcusplu vialis*		Spiller and Dewell (2003)

Vitamin B12	*Porphyra*sp, *Enteromorpha*sp, *Spirulina*		Kim and Taylor (2011)
Vitamin C	*Undariapinnatifida*, *Porphyraumbilicalis*, *Ulva* spp		MacArtain and others (2007)
Vitamin E (α-tocopherol)	*Nannochloropsisoculata*		Durmaz (2007)

Pharmacological activity of Marine Algae:

Marine organisms are potentially prolific sources of highly bioactive secondary metabolites that might represent useful leads in the development of new pharmaceutical agents (Iwamoto et al., 1998, Iwamoto et al., 1999 and Iwamoto et al., 2001) Most of the seaweeds are red (6000species) and the rest known are brown (2000 species) or green (1200 species). Seaweeds are used in many maritime countries as a source of food, for industrial applications and as a fertilizer. Nori (*Porphyra spp.*), a Japanese red seaweed, is very popular in the Japanese diet, has ahigh protein content (25-35% of dry weight), vitamins (e.g. vitamin C) and mineral salts, especially iodine. Microalgae biomass has a chemical composition which varies depending onthe algae used. It can be rich in proteins or rich in lipids or have a balanced composition of lipids, sugars and proteins.

Table 5- Antiviral activities of algae polysaccharides derived from marine sources.

Organism	**Antiviral polysaccharide**	**Virus**	**Reference**
Red algae, *Gigartinaskottsbergii*	Carrageenan	Influenza virus, DENV, HSV-1, HSV-2, HPV, HRV, HIV	8
Red algae, *Callophyllis variegate, Agardhiella*	Galactan	HSV-1, HSV-2, HIV-	9

tenera, Schizymeniabinderi, Cryptonemia crenulata		1, HIV-2, DENV, HAV	
Brown algae, *Laminariahyperborea, Laminaria digitata, Laminaria japonica, Ascophyllum nodosum, Macrocystispyrifera*	Alginate	HIV, IAV, HBV	10
Brown algae, *Adenocytisutricularis, Undaria pinnatifida, Stoechospermummarginatum, Cystoseiraindica, Cladosiphonokamuranus, Fucus vesiculosus*	Fucan	HSV-1, HSV-2, HCMV, VSV, Sindbis virus, HIV-1	11
Brown algae, *Fucusvesiculosus, Saccharina longicruris, Ascophyllumnodosum*	Laminaran	HIV	12
Diatom, *Naviculadirecta*	Naviculan	HSV-1, HSV-2	13
Blue-green alga, *Arthrospira platensis*	Calcium spirulan	HSV-1, measles, mumps, influenza, polio, Coxsackie, HIV-1, HCMV	14
Blue-green alga, *Nostocflagelliforme*	Nostaflan	HSV-1, HSV-2, influenza A virus, human cytomegalovirus	15
Red alga,	Sea algae extract	HIV, AMV, RMLV	16

Schizymeniapacifica			

Table 6 -Antimicrobial activities of algae derived from marine sources.

Organism	Antimicrobial Agent	Against	Reference
Ulva rigida	sulfated glucuronorhamnoxyloglycans	Yeast - Candida spec, Bacteria (Gram-positive) E. faecali, Bacteria (Gram-negative)- S. aureus E. coli P. aeruginosa	17
Enteromorphalinzas	Sulfated polysaccharides	Yeast - Candida spec, Bacteria (Gram-positive) E. faecali, S. epidermidis S. aureus	18

Table 7 -Anti bacterial and Anti Obesity activities derived from Marine Source

Organism	Antibacterial and Anti obesity Agent	Against	Reference
Gracilariacorticata	aplysiatoxin	*E.coli P.vulgaris*	19
Spirulina platensis	g-linolenic acid	*Pseudomonas aeruginosa B.subtillis*	20

Table 8 -Anti Cardiovascular activities derived from Marine Source.

Organism	Anticardiovascular agent	Author	Reference
Krill (*Euphausiasuperba*)	Omega-3 PUFA (DHA and EPA)	Rasmussen and Morrissey (2007) Galarraga and others	21

		(2007)	
Bonito	Omega-3 PUFA (DHA and EPA)	Mozaffarian and Wu (2011) Rasmussen and Morrissey (2007	22

Table 9 - Anticanceractivities derived from Marine Source

Organism	**Anticancer agent**	**Author**	**Reference**
Cuttlefish (*Sepiellamaindroni, Euprymnaberryi*)	Omega-3 PUFA (DHA and EPA)	Liu and others (2008) Shanmugam and others (2008)	23
Squid (*Ommastrephes bartrami*	Polysaccharide	Chen and others (2010)	24

Table 10 -Other Pharmacological activities derived from Marine Source

Organism	**Agent**	**Activity**	**Reference**
Ulva pertusa, Scytosiphon lomentaria, Chaetomorpha crassa, Fish bones	Ca	Strengthening of teeth and bone Anti-osteoporosis	25 - Venugopal (2008) Nguyen and others (2011) Ito and Hori, (1989)
Ascophyllumnodosum Laminariadigitata Himanthaliaelongata	Mg	Neuroprotective Antidepressant Antiasmatic	26 - Eby and Eby (2006) Szewczyk and others (2008) Watson and others (2012)
Porphyratenera Sargassumfulvellum	Vitamin B12	Anti-aging Antianemia Promotion of neurite outgrowth	27 - Ravishankar and others (2005) Lordan and others (2011) Pangestuti and Kim

			(2011a, 2011b
Cyanobacteria (Spirulina, Nostoc, Anabaena) Red Algae (Porphyridium cruentum)	Phycobilinphycoerythrin and phycocyanin	Antioxidant Anticancer	28 - Shanab and others (2012) Hirata and others (2000)
Gelidiellaacerosa Padinapavonica Ulva reticulata, Laminariadigitata Porphyraumbilicalis Palmariapalmata	Vitamin C	Antioxidant Strengthening of the immune stimulant	29- Packer (1997) Witting and Stocker (2003
Codium fragile	Galactan	Antiviral Immunostimulating	30- Wijesekara and others2011) Lee and others (2010a)

Commercial products, patents and applications[31]

Due to their plethora of bioactive molecules, marine macroalgae have great potential forfurther development as products in the nutraceutical, functional food, and pharmaceuticalmarkets. Patent activity in this area has increased and several novel products based onmacroalgae have entered the market in recent years.

Company	**Compound**	**Activity / disorder**	**Development**
Various	Heparin and derivatives	Anti-coagulants	Since 1940's
Astellas	Auranofin (Ridaura)	Anti-rheumatic	1983
GSK	Zanamivir (Relenza)	Anti-influenza	1992
Johnson & Johnson	Topiramate (Topamax)	Anti-epileptic	1987
Bayer Acarbose	Acarbose(Glucobay) (Pseudo-oligosaccharide	Type II diabetes (a-glucosidase, aamylase inhibitor)	1990
Ortho-McNeil Janssen Pharmaceutical	Elmiron (Pentosanpolysulfate)	Cystitis (for CJD)	1996

Alfa Wassermann	Sulodexide (Vessel™)	Cardiovascular indications	Marketed since 1980
Hunter Fleming (now Newron)	HF0420 – low MWt oligosaccharide	neuroprotective	Phase I
Progen (Australia)	PI-88 (Phosphomannopentaose sulphate, Heparan sulfate mimetics) PG500 series Anti-angiogenic/anti-Preclinical (Heparan sulfate metastatic. mimetics)	Anti-angiogenic/anti-metastatic. Hepatocellular carcinoma Anti-angiogenic/anti-Preclinical	Phase III Preclinical
Endotis Pharma	EP42675 (org) EP224283 (org) EP37 EP8000 programme	Anticoagulant Neutralizable antithrombotic venous and arterial thromboses Anti-angiogenesis, anti- tumour growth /metastasis	Phase I Preclinical Preclinical Preclinical
BiotecPharmacpn (Norway)	SBG (Soluble beta glucan– beta-1,3/1,6 glucan)	Immune stimulation Anti-cancer nutraceutical	GRAS nutraceutical

Conclusion:

Marine Sourceare an interesting source for a myriad of different bioactive phytoconstitutents ranging from industrial applications to novel treatment. They possess manydifferent interesting and often exotic bioactive principles that are currently explored for theirfunctional properties in food and biomedicine. However, a far larger application would bethe use of carbohydrates from cultivated seaweeds for alternative fuel sources. Macroalgae are efficient solar energy converters, and can create large amounts ofbiomass in a short-term, however, marine biomass is often an overlooked source, andpotentially represents a significant source of carbohydrates as a renewable energy source.

Reference:

1. De Rosa S, Iodice C, Khalaghdoust M, Oryan S and Rustaiyan A. Spatanediterpenoids from the brown alga *Stoechospermummarginatum*(Dictyotaceae). *Phytochem.* (1999) 51: 1009-1012.
2. Heiba HI, Al-Easa HS and Rizk AFM. Fatty acid composition of twelve algae from the coastal zones of Qatar. *Plant Foods Hum. Nutr.* (1997) 51: 27-34.
3. Khanavi M, Nabavi M, Sadati N, Ardekani MS, Sohrabipour J, Nabavi SMB, Ghaeli P and Ostad SN. Cytotoxic activity of some marine brown algae against cancer cell lines. *Biol. Res.* (2010) 43: 31-37.
4. Rastian Z, Mehranian M, Vahabzadeh F and Sartavi K. Antioxidant activity of brown algae *Sargassum vulgare* and *Sargassumangustrifolum. J. Aquat. Food Prod. Tech.* (2007) 16: 17-26.
5. Rastian Z, Mehranian M, Vahabzadeh F and Sartavi K. Antioxidant activity of extract from a brown alga, *Sargassumboveanum*. *Afr. J. Biotech.* (2007) 6: 2740-2745.
6. Zandi K, Fouladvand M, Pakdel P and Sartavi K. Evaluation of *in-vitro* antiviral activity of a brown alga (*Cystoseiramyrica*) from the Persian Gulf against herpes simplex virus type 1. *Afr. J. Biotech.* (2007) 6: 2511-2514.
7. Sohrabipour J and Rabii R. A list of marine algae of seashores of Persian Gulf and Oman Sea in the Hormozgan Province. *Iran J. Bot.* (1999) 8: 131-162.
8. R. K. Jha and X. Zi-rong, "Biomedical compounds frommarine organisms," *Marine Drugs*, vol. 2, no. 3, pp. 123–146, 2004.
9. S. ZorofchianMoghadamtousi, H. Karimian, R. Khanabdali et al., "Anticancer and antitumor potential of fucoidan and fucoxanthin, two main metabolites isolated from brown algae," *The Scientific World Journal*, vol. 2014, Article ID 768323, 10 pages, 2014.
10. C. L. F. de Almeida, H. D. S. Falc˜ao, G. R. D. M. Lima et al., "Bioactivities from marine algae of the genus *Gracilaria*," *International Journal of Molecular Sciences*, vol. 12, no. 7, pp. 4550–4573, 2011.
11. S. La Barre, P. Potin, C. Leblanc, and L. Delage, "The halogenatedmetabolism of brown algae (phaeophyta), its biological importance and its environmental significance," *Marine Drugs*, vol. 8, no. 4, pp. 988–1010, 2010
12. R. Goss and T. Jakob, "Regulation and function of xanthophyll cycle-dependent photoprotection in algae," *Photosynthesis Research*, vol. 106, no. 1-2, pp. 103–122, 2010.

13. Vera, J. Castro, A. Gonzalez, and A. Moenne, "Seaweed polysaccharides and derived oligosaccharides stimulate defense responses and protection against pathogens in plants," *Marine Drugs*, vol. 9, no. 12, pp. 2514–2525, 2011.
14. D. Renn, "Biotechnology and the red seaweed polysaccharide industry: status, needs and prospects," *Trends in Biotechnology*, vol. 15, no. 1, pp. 9–14, 1997.
15. S.-H. Eom, Y.-M. Kim, and S.-K. Kim, "Antimicrobial effect of phlorotannins from marine brown algae," *Food and Chemical Toxicology*, vol. 50, no. 9, pp. 3251–3255, 2012.
16. J.-H. Guo, G. W. Skinner, W. W. Harcum, and P. E. Barnum, "Pharmaceutical applications of naturally occurring watersoluble polymers," *Pharmaceutical Science and Technology Today*, vol. 1, no. 6, pp. 254–261, 1998.
17. ÜnciT.NEY.,Antimicrobial Activities of the Extracts of Marine Algae from the Coast of Urla (Üzmir, Turkey), Turk J Biol 30 (2006) 171-175.
18. Sastry VMVS, Rao GRK. Antibacterial substances from marine algae: successive extraction using benzene, chloroform and methanol. Bot. Mar. 37: 357-360, 1994.
19. Kannan Et Al., Antibacterial And Antiobesity Activities Of Marine Algae GracilariaCorticata And Spirulina Platensis., International Journal Of Pharmacy And Pharmaceutical Sciences., Vol 6, Issue 6, 2014, Issn- 0975-1491
20. Mishra PS, Sree A. Antibacterial activity and GCMS Analysis of the extract of leaves of *Finlaysoniaobovata*(A Mangrove plant). *Asian J Plant Sci*, 2007;6(1):168-72.
21. Rasmussen RS, Morrissey MT. 2007. Marine biotechnology for productionof food ingredients. Adv Food Nutr Res 52:237–92.
22. Mozaffarian D, Lemaitre RN, Kuller LH, Burke GL, Tracy RP, Siscovick DS. 2003. Cardiac benefits of fish consumption may depend on the type of fish meal consumed. J Am Heart Assoc 107:1372–7.
23. Liu H, Fujiwara T, Nishikawa T, Mishima Y, Nagai H, Shida T, Tachibana K, Kobayashi H, Mangindaan REP, Namikoshi M. 2005. Lissoclibadins 1-3, three new polysulfur alkaloids, from the ascidian *Lissoclinum*cf. *badium*
24. Jimenez-Escrig A, Sanchez-Muniz FJ. 2000. Dietary fibre from edible seaweeds: chemical structure, physicochemical properties and effects on cholesterol metabolism. Nutr Res 20:585–98.
25. Venugopal V. 2008. Marine source of vitamins and minerals. In: Marine products for healthcare: functional and bioactive nutraceutical compounds from the ocean. Boca Raton, FL: CRC Press L. p 243–55.

26. Eby GA, Eby KL. 2006. Rapid recovery from major depression using magnesium treatment. Med Hypotheses 67:362–70.
27. Ravishankar GA, Sarada R, Sandesh Kamath B, Namitha KK. 2005. Food applications of algae. In: Pometto A, Shetty K, Paliyath G, Levin RE, editors. Food biotechnology. 2nd ed. Boca Raton, FL: CRC Press. p 493–6.
28. Shanab SMM, Mostafa SSM, Shalaby EA, Mahmoud GI. 2012. Aqueous extracts of microalgae exhibit antioxidant and anticancer activities. Asian Pac J Trop Biomed 2:608–15.
29. Packer L. 1997. The vitamin C radical and its reactions. In: Packer L, Fuchs J, editors. Vitamin C in health and disease. New York: CRC Press, p 75–95.
30. Wijesekara I, Pangestuti R, Kim SK. 2011. Biological activities and potential health benefits of sulfated polysaccharides derived from marine algae. CarbohydrPolym 84:14–21.
31. Stefan Kraan, Algal Polysaccharides, Novel Applications and Outlook, Chapter -22, 36-41, *Ocean Harvest Technology Ltd., N17 Business Park, Milltown, Co. Galway, Ireland.*
32. Jim´enez-Escrig A, Jim´enez-Jim´enez I, Pulido R Saura-Calixto F. 2001. Antioxidant activity of fresh and processed edible seaweeds. J Sci Food Agric 81:530-4.
33. Jin DQ, Lim CS, Sung JY, Choi HG, Ha I, Han JS. 2006. Ulva conglobata, a marine alga, has neuroprotective and anti-inflammatory effects in murine hippocampal and microglial cells. Neurosci Lett 402:154–8.
34. Jun SY, Park PJ, Jung WK, Kim SK. 2004. Purification and characterization of an antioxidative peptide from enzymatic hydrolysate of yellowfin sole (*Limandaaspera*) frame protein. Eur Food Res Technol 219:20–6.
35. Juturu V. 2008. Omega-3 fatty acids and the cardiometabolic syndrome. J Cardio MetabSyndr 3:244–53.
36. Kanazawa A. 2001. Sterols in marine invertebrates. Fisheries Sci67:997–1007.
37. Kanekiyo K, Hayashi K, Takenaka H, Lee JB, Hayashi T. 2007. Anti-Herpes simplex virus target of an acidic polysaccharide, nostoflan, from the edible blue-green alga Nostocflagelliforme. Biol Pharm Bull 30:1573-5.
38. Karleskint G, Turner R, Small J. 2012. Multicellular primary producers. In: Ryder M, editor. Introduction to marine biology. Belmont, MA: Cengage Learning. p 157–89.
39. Karmali RA, Reichel P, Cohen LA, Terano T, Hirai A, Tamura Y, Yoshida S. 1987. The effects of dietary omega-3 fatty acids on the DU-145 transplantable human prostatic tumor. Anticancer Res 7:1173–9.