Therapeutic potential of seaweeds

Rajeev Goel1*, Tushar Saini2, Binny Mahendru3

1Department of Biophysics, 2Department of Forensic Medicine, Dr. Rajendra Prasad Government Medical College, Kangra at Tanda, Himachal Pradesh, India
3Department of Pharmacology, Dr Radhakrishnan Government Medical College, Hamirpur, Himachal Pradesh, India

Received: 11 March 2021
Accepted: 06 April 2021

*Correspondence:
Dr. Rajeev Goel,
Email: rgoel302@yahoo.com

ABSTRACT

Seaweeds in general are known to contribute to the maintenance of health through their nutritional and medicinal properties and are served in soups and salads, cooked with grains, legumes or miso-soup broth, vegetable pies, stews and even consumed dried. The medicinal properties of seaweeds or vegetables have long been known in many cultures of people particularly those living in the coastal regions who are consuming these from centuries. Traditional Chinese dietotherapy (TCD) makes good use of natural marine nutrients and food to preserve health. Koreans wrap their bodies in seaweeds to get rid of deadly body toxins and Japanese who eat large quantities of seaweeds have very low incidence of cancers. The compounds with diverse biological activities such as antioxidant, antiviral, antifungal, antineoplastic, antimicrobial etc. have been isolated from the flora in the sea. A score of these bio-medicinal compounds are in different stages of clinical trials & analysis and are the focus of this article.

Keywords: Seaweeds or vegetables, Marine natural products, Marine pharmacology, Marine therapeutics

INTRODUCTION

The seaweeds or vegetables grow both on the rocks washed by the sea, on the sea floor in the inter-tidal zone and shallow sea water or at the narrow interface where the sea and land meets. Seaweeds belong to a group of plants known as algae which are classified as Rhodophyta (red algae), Phaeophyta (brown algae), or Chlorophyta (green algae) depending upon their nutrients and chemicals composition.

The seaweeds are rich in vitamins and minerals, dietary iodine, food pigments as anti-oxidants, phycocolloids-the long chain carbohydrates, proteins and even fats good for health. The edible sea weeds or sea vegetables such as nori and dulse (both red algae), sea palm and hijiki (brown algae), the large kelps (brown algae, mostly Laminaria species) and edible green algae sea lettuce (Ulva lactuca and Monostroma species), to name a few, are nowadays used as a regular part of the diet worldwide particularly in East Asian countries such as Japan, Korea and China. Some seaweeds are microscopic such as phytoplankton and diatoms, others are enormous like giant kelp but most are medium sized and come in the colors of green, red, brown and black.1,2

Seaweeds are considered as a source of bioactive compounds which are produced as a great variety of secondary metabolites characterized by a variety of broad spectrum of biological activities. Consequently, these have been used traditionally for the treatment of cough, asthma, hemorrhoid, boils, goiters, stomach ailments, ulcers, headaches, urinary diseases and in various cancers.

PHARMACOLOGICAL EFFECTS FOR BIO-ACTIVE COMPOUNDS FOUND IN SEAWEEDS

Seaweeds contain many polysaccharides such as alginic acid, laminarin, fucosxantin, fucoidan etc. which have tremendous biomedical potentials.3 The Fucoidan is a...
sulfated fucose (polysaccharide) and is found in various species of brown sea weeds such as kombu (Laminaria japonica), limumou, bladder wrack (Fucus vesiculosus), wakame, mozuku and hijiki. Fucoidan has been shown to induce apoptosis in lymphoma cell lines and also inhibit hyperplasia in rabbits.9 Several brown algae including bladderwrack (Fucus vesiculosus) appear to suppress the growth of various cancer cells in vitro studies.5-7 The intake of Fucus vesiculosus has shown to help women with abnormal menstrual cycling patterns and/or menstrual related disorders.8-10

Nori, a species of red algae genus Porphyra which includes most notably Porphyra yezoensis and Porphyra tenera is a rich source of vitamins A, B and C, iodine, protein, carotene and easily digestible dietary fibers. The vitamin C content in nori is even more than the raw oranges. A 14 kDa protein-PYP (Pyropia yezoensis protein) isolated from Porphyra yezoensis has recently been demonstrated to have a chemo-preventive effect against the acetaminophen induced liver injury in rats.11

Nori contains a sulfated polysaccharide called porphyran which is a complex galactane and is known to inhibit the growth of certain tumors as it prevents a purposely induced carcinogenesis. Nori, is also used to treat lower respiratory tract diseases. Another red marine alga, Dumontia is dried, powdered, encapsulated and used as a genital herpes suppressant.

An edible red alga, Palmaria palmata which grows widely along the shorelines of North Atlantic is high in vitamins especially B, lot of fibers and proteins. Extracts from Palmaria palmata are known antioxidants and have anti-proliferative effects on HeLa cell proliferation in vitro.12

The accumulation of kainoids, the unusual excitatory amino acids from diatoms, in high concentration in shell fish are well known to cause Amnesic shellfish poisoning (ASP) when consumed by humans.13

The marine brown algae bull kelp (Nereocystis luetkeana) consumed in powdered form is effective in insomnia, hyperactivity, depression and schizophrenia. The brown algae Bladder Wrack (Fucus vesiculosus) is said to normalise enlarged prostate in early stages. Its consumption also tends to lower blood pressure by inhibiting angiotensin converting enzyme (ACE), removes arterial plaque, possess antibacterial and anti-oxidative properties due to the high polyphenolic content. The regular consumption of brown algae hijiki (Cystercia geminata) and sargassum (Sargassum muticum) has been shown to improve overall lung functions.14

A study has shown that a microbicide, carraguard or PC-515(a gel formulation) for vaginal use, made from a seaweed extract called carrageenan is known to provide protection from human paplioma virus (HPV) in addition to its protection against HIV infection.15 The phase III clinical trials of testing carrageenan’s efficiency against HIV infection are already underway. The carrageenans namely λ-carrageenan (2), possess potent antiviral activities against several strains of herpes simplex virus (HSV) types 1 and 2 genital infection.16,17 Carrageenan because of its microbiocidal properties is also used in the form of wound dressings for successful wound healing. Carrageenan, is a water-soluble mixture of sulfated polysaccharides extracted from a red algae Chondrus crispus (common name Irish moss or Carregeen moss) and other species such as Gigartina, Eucheuma, Furcellaria and Phylophora. The studies are in progress on the use of Kappa-carrageenan as a potential biomaterial for skeletal regeneration.

A phycocollloid gel out of Chondrus crispus is effective in long term treatment of damage to lungs particularly after pneumonia, smoking and chronic bronchitis. According to ancient Irish folklore, it was carried on trips for protection and safety and was used widely in the treatment of tuberculosis and pneumonia.18

A polysaccharide having antiviral effect has been extracted from green alga Ulva lactuca and is known to provide nutrition to aging and environmentally damaged skin.19

A compound fucoxanthin (a subset of carotenoids) from the edible brown seaweed Undaria pinnatifida, has been shown to burn fatty tissue. It induces the expression of fat burning protein UCP1 (a member of uncoupling protein family in mitochondria) that accumulates in fat tissue around the internal organs.20

The capsules of Undaria pinnatifida, promote healing and inhibit the infection when given to patients suffering from viral infections such as herpes zoster (chicken pox) and Epstein - Barr virus (EBV). A major sulfated poly-anion characterized as galactofucan sulfate extract (GFS) from Tasmanian Undaria pinnatifida is shown to have immune stimulating qualities in vitro and is associated with healing and inhibition of reactivation of herpes.21-24

Most of the sea weads or plants widely have sulphur containing but phosphorus free lipid namely sulfoquinovosyl diacylglycerol (SQDG) which is generally found in many photosynthetic organisms. One of the fatty acids component namely eicosapentaenoic acid of SQDG is a potent telomerase inhibitor and consequently a potent candidate for the therapeutic importance in cancer therapy.25

The hydrolysates of Undaria pinnatifida derived after treatment with proteases have shown anti-hypertensive effect via inhibiting angiotensin -1 converting enzyme (ACE) activity.26-29

A red alga, an agarophyte Gracilaria tenistipitata, found in Caribbean islands is known to be a potent virility tonic helpful in erectile dysfunction (ED) in males and is
consumed as a "Seaweed drink" or "Sea moss tea" in the Caribbean. Gracilaria is a gem of red algae (Rhodophyta). Its species are also notable for its economic importance as an agarophyte and are commonly used for the treatment of gastrointestinal disorders. Notable genera of commercially valuable agarophytes are Gracilaria, and Gelidium.

The list of medicinal compounds from seaweeds is endless and many more sea weed species are on the bench top of biomedical researchers to look out for novel compounds having therapeutic value. A few of bioactive compounds with their structures (Figure A, B) and corresponding therapeutic activities are discussed in successive section.

Some carrageenans such as μ-carrageenan (1), λ-carrageenan (2), κ-carrageenan (3) and -carrageenan (4) have potent antiviral activities against several strains of HSV types 1 and 2.

Chondriamide A (5) from Chondria atropurpurea shows antiviral activity against HSV type II and cytotoxicity against human nasopharyngeal and colorectal cancer cells. Chondriamide C (6), also from Chondria atropurpurea, displays cytotoxic and in vitro anthelmintic properties.

Cyclic depsipeptides kahalalide A (7) and F (8) are produced by a species of Bryopsis. Both show in vitro activity against Mycobacterium tuberculosis. Kahalalide F has anti-HIV qualities which are being further studied in clinical trials and its effectiveness as treatment of lung cancers and tumours are also being studied.

(5Z)-4-bromo-5-(bromomethylene)-3-butyl-2(5H)-furanone (9) is a halogenated compound from Delisea pulchra which displays strong antifouling properties.

α-Kainic (10) and domoic acids (11) are pyrrolidine dicarboxylates with excitatory and excitotoxic activities. Kainoids occur in some pennate diatoms where they cause amnesic shellfish poisoning, but they are also produced by some members of the Ceramiales. They are used as tools in research into neurophysiological disorders such as Alzheimer’s and Parkinson’s disease, and epilepsy. Domoic acid-containing extracts of Digenea simplex and Chondria armata have been used by the Japanese as anthelmintic agent, and it also has insecticidal properties.

Aplysiatoxin (12) and debromoaplysiatoxin (13) are potent tumour promoters used in medical research, and are responsible for non-fatal poisonings associated with eating Gracilaria coronopifolia.

Manauealide A (14), manauealide B (15) and manauealide C (16) compounds corresponding to debromoaplysiatoxin extracted from a red alga Gracilaria coronopifolia were shown to induce diarrhea in mice and were considered to be the causative toxins of food poisoning in Hawaii.

Polycavernosides (17) isolated from the red alga Polycavernosa tsudae are complex glycosidic toxins belonging to a class of macrocyclic lactones and are the causative agents for the fatal human poisonings following consumption of Polycavernosa tsudae.

Prostaglandin E2 (18) is a product of PUFA metabolism in some species of Gracilaria and is the causative agent responsible for the fatal ‘ogonori’ poisoning resulting from their consumption.

---

Figure 1: (A and B) The chemical structures of μ-carrageenan (1); λ-carrageenan (2); κ-carrageenan (3); ψ-carrageenan (4); chondriamide A (5); chondriamide C (6); kahalalide A (7); kahalalide F (8); (5Z)-4-bromo-5-(bromomethylene)-3-butyl-2(5H)-furanone (9); α-kainic (10); domoic acid (11); aplusiatoxin (12); debromoaplysiatoxin (13); manauealide A (14); manauealide B (15); manauealide C (16); polycavernoside A (17) and prostaglandin E2 (18).
Summary of biological activities of bio compounds from seaweeds\textsuperscript{34-35}

- Antioxidant activity (Fucoxanthin, phycoerythrobilin, chlorophyll-a and derivatives)
- Antiviral activity (Sulfated glucuronogalactan, sulphated galactans, sulphated fucans, carrageenan)
- Cardiovascular protection (Carotenoids, sterols, cardiac glycosides, eicosapentaenoic acid, docosahexaenoic acid)
- Cytotoxicity, antimitogenic, anticancer and antitumour properties (Fucoidans, glucans, phloroglucinol, stypolidione, sesquiterpene elatol, carotene, lutien)
- Antithrombic and anticoagulant activities (Galactans/Carrageenan, fucoidans, heparins, phlorotannins, phloroglucinol)
- Toxins-vermifuges, insecticides, ichthyotoxins, neurotoxins
- Anti-inflammatory activity and effects on the immune response (Marine terpenes, bioactive peptides, sulfated polysaccharides, fucoidan, asphoPhyllan, algal polyphenols, phlorotannins, terpenes and steroids, alkaloids, commercially produced microalgal PUFAs)
- Agglutination, coagulation and the stimulation of cell migration
- Mitogenic activity.

CONCLUSION

Seaweeds which are consumed worldwide are now under consideration for medicinal value and future therapies besides their use in commercial goods. Many of the biomolecules extracted from the seaweeds are potent drug candidates and are in pre-clinical or early clinical development stages. The sulfated polysaccharides as antiviral substances, halogenated furanones from Delisea pulchra as antifouling compounds, and kahalalide F from a species of bryopsis as a possible treatment for lung cancer, tumors and AIDS are gaining attention from pharmaceutical companies. The indiscriminate collection or harvesting of the marine flora however, may unbalance the marine ecosystems. The sustainable management of seaweeds to conserve them for posterity is of utmost importance considering their ecological and medicinal value. It is high time to identify the genes that produce the desired bioactive compounds in the sea weeds and to transfer those genes to the microorganisms such as Escherichia coli that are easy to culture in the lab for medical pursuits.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Ellouali M, Boisson-Vidal C, Durand P. Antitumor activity of low mol. W. fucans extracted from brown seaweed Ascophyllum nodosum. Anticancer Res. 1993;13(6A):2011-20.
2. Le Tutour B, Benslimane F, Gouleau MP. Antioxidant and Pro-oxidant activities of the brown algae, Laminaria digitata, Himanthalia elongata, Fucus vesiculosus, Fucus serratus and Ascophyllum nodosum. J Applied Phycol. 1998;10(2):121-9.
3. Lamela M, Anca J, Villar R. Hypoglycemic activity of several seaweed extrals. J Ethnopharmacol. 1989;27(1-2):35-43.
4. Clark CD, Bassett B, Burge MR. Effect of kelp supplementation on thyroid function in erythroid subjects. Endocr Pract. 2003;9(5):363-9.
5. Durig J, Bruhn T, Zurborn KH. Anticogulant fucoidan fractions from Fucus vesiculosus induce plate activation in vitro. Thromb Res. 1997;85(6):479-91.
6. Teas J, Braverman LE, Kurzer MS. Seaweeds and Soy: Companion foods in Asian cuisine and their effects on thyroid function in American women. J Med Food. 2007;10(1):90-100.
7. Seaweeds, kelp, bladderwrackl (Fucus vesiculosus). Available at: http://www.nlm.nih.gov/medlineplus/druginfo/natural/patient_bladderwrack.html. Accessed on 10 Jan, 2020.
8. Aisa Y, Miyakawa Y, Nakazato T, Shibata H, Saitok K, Ikeda Y et al. Fucoidan induced apoptosis of human HS-sultan cells accompanied by caspase 3 activation and down regulation of ERK pathways. J Hematol. 2005;78(1):7-14.
9. Deux JF, Meddahi-Pelle A, Le Blanche AF, Colliec LJFS, Jouault, Low M. Fucoidan prevents neo intimal hyperplasia in Rabbit iliac artery in Stent restenosis model. Atherosclerosis, Thrombosis vascular biol. 2002;22:1604-9.
10. Thomas D. Seaweeds, The Natural History Museum, London. 2002.
11. Hwang HJ, Jin Kwon M, Kim IH, Nam TJ. Chemoprotective effects of a protein from the red algae Porphyra yezenonis on acetyaminophen induced liver injury in rats. Phytotherapy Res. 2008;22(9):1149-53.
12. Yuan YV, Carrington MF, Walsh NA. Extracts from Dulse (Palmaria palma). are effective antioxidants and inhibitors of cell proliferation in vitro. Food Chem toxicol. 2005;43:1073-81.
13. Bensemir A, Blume M, Schroder S, Lindequist Li. Screening of cultivated seaweeds for antibacterial activity against fish pathogenic bacteria. Aquaculture. 2006;252:79-84.
14. Chew YL, Lim YY, Omar M, Khoo KS. Antioxidant activity of Three selected brown seaweeds of India. Food Chem. 2008;107:707-13.
15. Maeda H, Hosokawa M, Sashima T, Funayama K, Miyashita K, Flucoxanthin from edible seaweeds, Undaria pinnatidata, shows anti-obesity effect Through UCP1 expression in white adipose tissues. Biochem Biophys Res Commun. 2005;332(2):392-7.
16. Eitsuka T, Nakagawak, Igarashi M, Miyazawat T. Telomeraser inhibition by sulfo-quinovosyl...
diacylglycerol from edible purpule Laver (*Porphyra yezoensis*). Cancer lett. 2004; 2021;2(1):15-20.
17. Burges D. Watson Public health and Carrageenan regulation: A review and analysis. J App Phycol. 2007;20:55-63.
18. Cox S, Abu-Ghannam N, Gupta S. An assessment of the antioxidant and antimicrobial activity of sex species of edible Irish seaweeds. Int. Food Res J. 2001;17:205-20.
19. Ivanova V, Rouseva R, Kolarava M, Serkedjieva J, Rachev R, Menolova N. Isolation of a polysaccharide with antiviral effect from *Ulva Lactuca*. Preparative Biochem Biotechnol. 1994;24:83-97.
20. Cooper R, lesDragar C, Elliott K, Fitton JH, Godwin J, Thompson K. A preparation of Tasmanian *Undaria pinnatifida* is associated with healing and inhibition of reactivation of Herpes. BMC complementary Alternative Med. 2002;2:11.
21. Shen BE, Yoshida Y, Kuroda E, Yameshita U. Immuno modulatory activity of seaweed extract of human lymphocytes in vitro. Int J Immunopharmacol. 1999;21(1):59-70.
22. Drum R. In: Sea vegetables for foods and medicine. Available at: http://www.naturespiritherbs.com/seavegetables article.Pdf. Accessed on 10 Jan. 2020.
23. Drum R. Medicinal uses of seaweeds, Island Herbs http://www.ryandrum.com/seaweeds.html. Accessed on 10 Jan. 2020.
24. Skibola CF. The effect of *Fucus vesiculosus* an edible brown seaweed, upon menstrual cycle length and hormonal status in pre-menstrual women: A Case report. BMC Complement Altern Med. 2004;4:10.
25. SatoMoba T, Yamaguchi T, Nakano T, Kahar T, Funayama K, Kabayashi A. Antihypertensive effects of hydro lysates of Wakame and their angiotensin converting anytime inhibitory activity. Ann Nutr Metab. 2002;46:259-67.
26. Abdussalam S. Drugs from Seaweeds. Med Hypothesis. 1991;32:33-5.
27. Bocanegra A, Bastida S, Benedi J, Rodenas S, Sanchez Muniz FJ. Characteristics and nutritional and Cardiovascular health properties of seaweeds. J Med Food. 2009;12:236-58.
28. Jimenez-Escrig A, Goni Combrordon I. Nutritional evaluation and physiological effects of seaweeds. Arch Latinoam Nutr. 1999;49(2):114-20.
29. Armisen R. Worldwide use and importance of *Gracilaria*. J Appl Phycol. 1995;7:231-43.
30. Albertus S. Medicinal and pharmaceutical uses of seaweed natural products: A Review. J Appl Phycol. 2004;16:245-62.
31. Khalid S, Abbas M, Saeed F, Bader-Ul-Ain H, Rasul Suleria HA. Therapeutic Potential of Seaweed Bioactive Compounds, Seaweed Biomaterials, 2018, Sabyasachi Maiti, IntechOpen. Available from: https://www.intechopen.com/books/seaweed-biomaterials/therapeutic-potential-of-seaweed-bioactive-compounds. Accessed on 10 Jan. 2020.
32. Salehi B, Sharifi-Rad J, Ana ML, Diana CGA, Pinto M, Trincone A et al. Current trends on seaweeds: Looking at chemical composition, phytopharmacology, and cosmetic applications. Molecules. 2019;24(22):4182.
33. Irkin LC, Yayintas Ö. Pharmacological Properties and Therapeutic Benefits of Seaweeds (A Review). Int J Trend Sci Res Dev. 2018;2:1126-31.
34. Pal A, Kamthania MC, Kumar A. Bioactive Compounds and Properties of Seaweeds: A Review. Open Access Libr J. 2014;1:e752.
35. Madhusudan C, Manoj S, Rhaul K, Rishi C. Seaweeds: A Diet with nutritional, medicinal and industrial value. Res J Med Plant. 2011;5:153-7.

Cite this article as: Goel R, Saini T, Mahendru B. Therapeutic potential of seaweeds. Int J Basic Clin Pharmacol 2021;10:591-5.