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Potential of Seaweed Resources from Andaman Sea, A Major Component in the Blue Revolution

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ABSTRACT

The consumption of seaweeds as a nutritive supplement in the form of marine vegetable is well accepted in Asian countries since time immemorial. In South East Asian countries and in Japan particularly, this is being consumed with an average of 1.6 kg (dry weight) per year per capita in different forms of food. There use not only serve as a rich source of vitamins, nutrients and fatty acids but also as a major source of polysaccharides for both the food and pharmaceuticals. In addition, these macrothalic algal components from the sea is a good source of natural antioxidant and is considered safe to be used as an ingredient in medicines, dietary supplements, nutraceuticals and cosmetics. Seaweeds contain high ash content (8-40%), high Dietary fibers (33-50% DW) and moderate lipid content (1-6% DW) and rich in omega-3-fatty acid and polyunsaturated fatty acids namely eicosapentaenoic acid. Polysaccharides like galactans, fucoidan, laminarin, alginates are the major derivative from seaweeds, which is used in food, beverages, pharmaceuticals stabilizers, emulsifiers, thickeners and as feed. Seaweed potential of Andaman Sea is highly recognized with a total availability of number of species. In the present paper, the importance of seaweed is being revisited with a view to elucidate its economic significance with the backdrop of blue revolution prospective from the Andaman Sea India.

Keywords: Seaweed; Diversity; Food; Therapeutic; Andaman Sea; Blue Revolution

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INTRODUCTION

Seaweeds or macrothalic marine algae are categorized by their pigmentation, morphology, anatomy and nutritional composition as red (Rhodophyta), brown (Phaeophyta) and green (Chlorophyta) seaweeds [1]. There are about 844 species of sea weeds reported from the coast of India [2], of which 206 species are reported from the Andaman and Nicobar Islands. The studies carried out in India are mainly focused on the ecology, physiology, phycocolloidal chemistry and pharmacological application of seaweeds. Also the seaweed resources are well utilized worldwide i.e. about 250 species are being utilized commercially whereas 150 species are being consumed as food by human being [3]. As evidence by several reports, human consumption of algae has shown a sharp rise i.e. green algae (5%), brown algae (66.5%) & red algae (33%) in South East Asian countries like Japan, China & Korea. In other Asian countries also seaweeds are often consumed as marine vegetables [4] and Japanese people are the main consumers with an average of 1.6 kg (dry weight) per year per capita [5]. Studies revealed that by consuming 100 g of seaweed daily requirement of vitamin A, B2 and B12 and two thirds of the vitamin C requirement can be fulfilled [6]. Additionally seaweeds also are a major source of dietary fiber, which is considered as an important component for preventing constipation, colon cancer and obesity [7]. They also possess natural hydro-soluble and liposoluble vitamins such as thiamin, riboflavin, beta-carotene, tocopherols as well as long-chain polyunsaturated essential fatty acids from the omega-3 family i.e. eicosapentaenoic acid, which is responsible for reducing the risk of heart disease, thrombosis and atherosclerosis [8,9].

Reports suggest that the nutrient composition of seaweeds vary from species to species on the basis of their geographic distribution, season and water temperature of the area, where they occur. But the demand for seaweed as an alternate ingredient of protein rich feed supplement in aquatic feeds is well examined in many regions of the world [10] not only due to their high protein content but also due to their high biomass with faster growth rate [11].In addition polymers from seaweeds are used as a major source of phycocolloids for thickening and gelling agents in food and pharmaceutical industries [12-14] signifying its economic potential in both the food and pharmaceutical industry [15] there by contributing to the economy of the nation. India has a coastline of more than 7,516 kms and these luxuriant marine environment houses about 844 species of seaweeds [2,16]. These are mainly distributed in the Andaman & Nicobar Islands, Tamil Nadu, Andhra Pradesh, Gopalpur coast and brackish water lake Chilika of Odisha, West Bengal, Gulf of Kutch, Kanyakumari, Kerala, Lakshadweep, Mandapam, Muttam and Arokiapuram Karnataka, South West Coast of India [17-22]. Though the commercial cultivation of seaweed is not that prominent, but at present about 20,000 tons of macro-algae are being harvested annually from Indian coast line [23]. Although Andaman Sea houses a diversified group of species (Figure 1), it needs special attention as these A & N group of Islands is inhabited by aborigines, where strong traditional health system of using indigenous medicinal plants for their food and medicine is in practice and even seaweeds too serve as a prominent source of herbal medicines for them.

Figure 1: Prominent Seaweeds along South Andaman Coast

SEAWEEDS FOR HUMAN CONSUMPTION

For most of the populations, seafood means protein in the form of fish, prawns, oysters and other shellfish. But there are many other food resources available from the sea and one such example is edible seaweeds. This major resource

of the sea is largely ignored in typical western diets. But by comparison these edible seaweeds are an integral part of the diet for people who live by the sea and such areas are like Asia, Pacific Islands including Hawaii, South America and Africa. With the increasing focus upon consumer health and nutrition in recent years seaweeds are now being reconsidered by many Western populations for their nutritional qualities. Edible seaweeds also serve as a good source of vitamins, nutrients and fatty acids and contain more than 54 different trace elements essential for human body's physiological functions [24,25].

Seaweeds are generally consumed in the form of soup, salad, boiled, fried and processed food etc. and available in many sea food shops or super markets all over the world and usually sold in dried form and can stored for longer period. Some seaweeds such as nori (*Prophyra porphyra*) is most often used as wrappers for making sushi rolls and comes packaged in sheets (Plate-2). Nutritionally this is rich in protein, full of omega-3 fatty acids and high in fiber. Nori contains vitamins C, A, B-12 and taurine, a chemical required for building block of protein. Dulse (*Palmaria palmata*) is available in the form of flakes and use in seasoning on salads, vegetables and soups. This contains protein, iron and sodium and is a good source of vitamin B such as riboflavin, niacin, B-6 and B-12. Arame (*Eisenia bicyclis*) is brown stringy sweet tasting seaweed is often found in health food stores and usually purchased as dried strands that can be soaked in cold water for 5 minutes and made ready to use. It offers essential nutrients such as calcium, iron, zinc, manganese, folate, vitamins A and K and iodine. [26]. Wakame (*Undaria pinnatifida*) is sweet flavored, leathery and deep green seaweed; often used in Japanese cuisines such as miso soup and adds flavor to salads and sandwiches. Wakame is rich in minerals, calcium, magnesium, phosphorous and potassium and contains beta carotene and folate. Kombu (*Laminaria saccharina*) also known as kelp is a mineral rich flavor enhancer used in Japanese dishes for centuries. Kombu can be found fresh, dried, pickled and frozen in many Asian markets. While it is rich in iodine, calcium and antioxidants. Some other edible seaweeds like *Ulva fasciata, Enteromorpha compressa, Caulerpa sertularioides, Porphyra vietnamensis and Gracillaria corticata* are also well consumed and possess high economic value.

Minerals

Seaweeds are rich in iodine, iron, potassium, magnesium, calcium, selenium, and phosphorus that are widely used in health beneficiary supplements [27]. Iodine in particular plays an important role in the functioning of the thyroid and prevent goiter, the content in the biomass is sometimes as high as 40% because of its capability to accumulate metal ions from salt water and concentrate those substances as carbonate salts [28] (Figure 2).

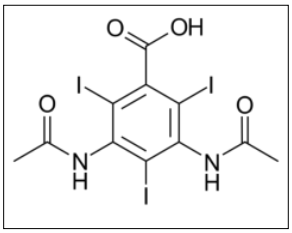

Figure 2: Structure of Iodine

Vitamins

Vitamins are essential nutrients found in foods. They perform specific and vital functions in a variety of body system and are crucial for maintaining optimal health [29]. Seaweed species provide rich source of vitamin A, B1, B2, B3, B9, C and E. where vitamin C and E are potent antioxidants [28].

Vitamin A:

Vitamin A is essential for preventing night blindness and maintaining a strong immune system. It also allows the body to use iron properly to produce healthy red blood cells. According to Linus Pauling Institute, [30] one cup serving of raw nori seaweed provides 4,161 international units of vitamin A or 83 percent of the daily value for vitamin A. Seaweed provides vitamin A is in the form of beta-carotene, which is an antioxidant.

B Vitamins

B vitamins increase the folate intake. According to Linus Pauling Institute [30] raw nori provides 117 micrograms of folate or 29 percent of the daily value in a one cup of serving. Folate is a B vitamin that works closely with vitamin B12 and vitamin B6 to metabolize an amino acid called homocysteine. Folate deficiency and high levels of homocysteine in the blood are risk factors for heart disease. Folate also helps protect against neural tube birth defects.

Vitamin B1:
Thiamin is another name for vitamin B1. It helps to convert blood sugar into energy for your body. It also helps the mucous membranes of the muscular, cardiovascular, and nervous systems in good shape.

Vitamin B2:
Riboflavin is another name for vitamin B2. It works with the other B vitamin complexes to process the carbohydrates, proteins, and fats into calories for energy in body. The body also needs this for healthy skin, good vision, growth, and red blood cell creation.

Vitamin B3:
Niacin is another name for vitamin B3. It also works with other B vitamin complexes to process the carbohydrates, proteins, and fats into calories for energy in the body. The difference is that it helps the digestive systems functions along with promoting a healthy appetite and healthy nerves.

Vitamin B9:
Folic Acid is another name for vitamin B9. It is very important during pregnancy since it is used for making and maintaining new cells. B9 prevents anemia by keeping up the production of red blood cells and prevent low birth weight and prematurity in births.

Vitamin C:
Vitamin C is an antioxidant vitamin and a necessary nutrient for a strong immune system. According to Linus Pauling Institute [30] each cup of raw nori seaweed supplies 31 milligrams of vitamin C or 52 percent of the daily value for vitamin C. It also allows the body to synthesize cartilage to maintain healthy joints. Vitamin C also helps the body to absorb iron from seaweeds

Vitamin E:
An antioxidant that helps the body gets rid of free radicals to keep tissues healthy. It is also used in the creation of red blood cells. The use of vitamin A, C and K are assisted by Vitamin E. They scavenge the free radicals in the body by preventing the oxidation of lipid molecules. Free radicals are very reactive and can steal electrons from membranes which could ultimately damage DNA.

Proximate Composition
The nutrient compositions of seaweeds are different depending on species, habitats, maturity and environmental conditions [31]. In general, green and red seaweeds contain higher protein contents i.e. 10–30% of dry weight than brown seaweeds i.e. 5–15% DW [5]. Rhodophyceae contain another protein phycoerythrin is used in biotechnology applications as dye in immune fluorescence reaction. The use of algae with high protein content in the production of feed for aquaculture farm could be another application of this marine plant resource. The lipid content of marine seaweeds accounts for 1–6% DW can be instrumental as a major source of energy. The element contents in seaweed are interpreted through their ash contents which range between 8–40% DW [12] and seaweed have more ash contents than terrestrial plants and animal products. Some of the trace elements in seaweeds are rare or absent in terrestrial plants [31,13] Thus, seaweeds are important sources of vital elements for the metabolic reactions in the human and animal health, such as enzymatic regulation of lipid, carbohydrate and protein metabolism [32,33].Seaweeds are also good sources of dietary fiber (33-50% DW), which can be classified as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) [7,34]. The characteristics of dietary fiber are related to their physicochemical properties such as swelling capacity, water holding capacity, and oil holding capacity, which are important for improvement of functional properties in food [35]

Antioxidant Activity
Seaweeds from natural resources produces various types of antioxidants e.g., polysaccharides, dietary fibers, minerals, proteins, amino acids, vitamins, polyphenols and carotenoids to counteract environmental stresses [36-42]. Therefore, seaweeds are the potential source of novel antioxidants. In addition, natural antioxidants are more acceptable than synthetic antioxidants as these antioxidants do not contain chemical contaminants and display a variety of beneficial functions. Thus, natural antioxidants are considered safe for use as ingredients in medicine, dietary supplements, nutraceuticals and cosmetics with the objective of improving consumer health, reducing the effects of harmful diseases and other broader aspects of immune system function [43] The antioxidant activity of several seaweeds has been reported from various countries, such as Malaysia [44], Indonesia [45], India [46], Korea

[47] and Japan [48]. Recently, the seaweed from the southern coast of Thailand [49] and the Andaman Sea [50,51] were also studied for their antioxidant activities.

Fatty Acids

The fatty acids in seaweeds are composed of polyunsaturated fatty acids (PUFAs) and is rich in omega-3-fatty acids [1,3] which play an important role in cellular and tissue metabolism, regulation of membrane fluidity, oxygen and electron transport and thermal adaptation [52]. In addition people show more attention towards healthy food in their busy life style [53] seaweeds are good nutritional source of C18 and C20 PUFAs such as eicosapentanoic acid (EPA) and docosahexaenoic acid (DHA), which cannot be synthesized by human bodies and must be gained from diet only [3]. The EPA is normally esterified to form a complex lipid molecule inside the cell and play an important role in higher plants and animals as a precursor for a group of eicosanoids, the hormone like substance such as prostaglandins, thromboxanes and leukotriens that are crucial in regulating development and physiology [54]. EPA has been found in wide variety of marine algae class But only some of them have the potential to demonstrate industrial production, mainly due to the fact that majority of marine algae have low specific growth rates and low cell densities when grow in autotrophic condition [55]. Fatty acid with two or more methylene interrupted double bonds is good for normal cell function and now has been entered in different areas like biomedical and nutraceutical. (Figure 2)

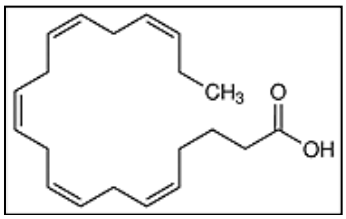

Figure 2: Structure of eicosapentaenoic acid

Polysaccharides

Polysaccharides from natural sources are found to be effective, non-toxic substances with a wide variety of activities [56]. Seaweed derived polysaccharides have many applications like they are used in food, beverages, pharmaceuticals stabilizers, emulsifiers, thickeners, feed etc. and other products for human consumption [57,58]. Polysaccharides can act as prebiotics (substances that stimulate the growth of beneficial bacteria in the digestive track) and exert growth-promoting and health- improving effects [59]. Many of them are soluble dietary fibers which have positive effect on the digestive tract of animals (i.e. alginic acid), and are non-toxic antioxidants. The total levels of these compounds in seaweeds are up to 76% of dry weight. Among many different algal polysaccharides, the most important are galactans, fucoidan, laminarin, alginates and Carrageenan [60,58].

Galactans

Sulfated galactans are found both in the intercellular matrix and in the cell wall. Galactan is a macromolecule containing disaccharide-based repeating units. Galactans have anti-tumor and antiviral properties [59]. Sulfated polysaccharides isolated from marine algae also have been shown to exert radical scavenging activities in vitro and in vivo [56,57,61] (Figure 3).

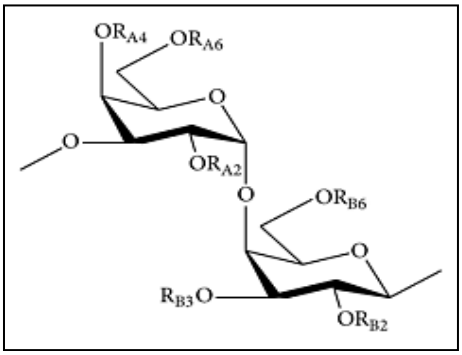

Figure 3: Structure of Galactans

Fucoidan

Fucoidan is a sulfated polysaccharide found in brown seaweeds. The macromolecule contains α-1, 3-linked sulphated L-fucose as main sugar unit and sulfate ester groups. The chemical composition depends on the algal source and harvesting time. The amount of fucoidan in algae is about 10% of dry mass. The absorption and bioavailability of fucoidan depends on its molecular weight. Compared to high molecular fucoidan, low molecular fucoidan is bioavailable in the highest degree. It has anti-inflammatory, antiviral, anti-tumor and antioxidative activities. Antiviral properties of fucoidan participate in inhibition of viral-induced syncytium formation [62] (Figure 4).

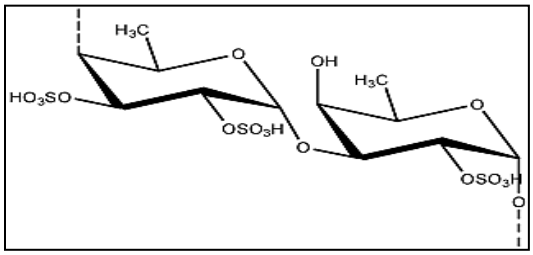

Figure 4: Structure of fucoidan

Laminarin

It is one of the major polysaccharides found in brown algae. The content of laminarin in seaweeds is about 10% of dry weight, but seasonally it can reach up to 32%. Laminarin is a dietary fiber, can act as a probiotic, and has antiviral and antibacterial properties. Antioxidant activity of laminarin depends on its molecular weight and chemical structure [59, 56]. Laminarin composed of (1, 3)-b-D-glucopyranose residues and its structural features are species dependent. Laminarin is a modulator of intestinal metabolism and activator of immune function [60] (Figure 5).

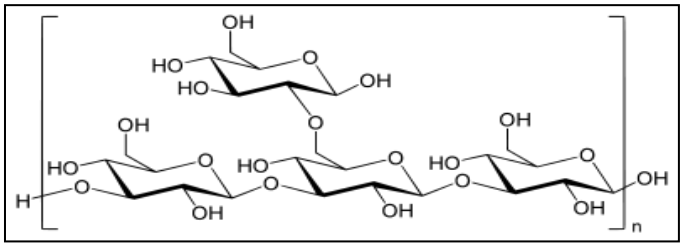

Figure 5: Structure of Laminarin

Alginates

Alginates are absent in terrestrial plants, but they can be extracted from brown seaweeds, in which they constitute up to 47% of their dry biomass. Alginates can be found both in acidic and salt forms. The acid form, known as an alginic acid, is a polymer consisting of two types of hexuronic acid monomers linked by 1–4 bonds, β-D-mannuronic acid and α-L-guluronic acid. They have thickening, stabilizing and general colloidal properties in addition to strong antibacterial and anti-inflammatory activities [56,63] (Figure 6).

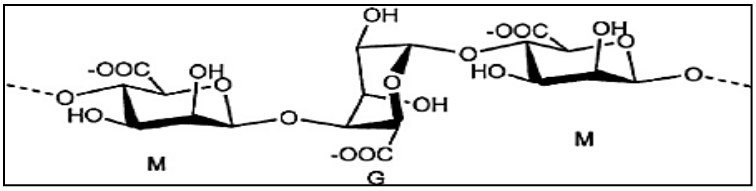

Figure 6: Structure of alginate

Carrageenan

Carrageenan was originally isolated by simply boiling red seaweeds to recover thick mucilaginous liquid and used for soups. It can be taken as a soothing treatment for sore mouths and throats and for constipation relief. Carrageenan is also used in many industries like food, health and beauty products as a thickener, gelling agent, sugar extender, medicines, and paints. It can provide sugar molecules for glycoprotein secreted by mucous membranes and for cell surface aminoglycan labeling (Figure 71).

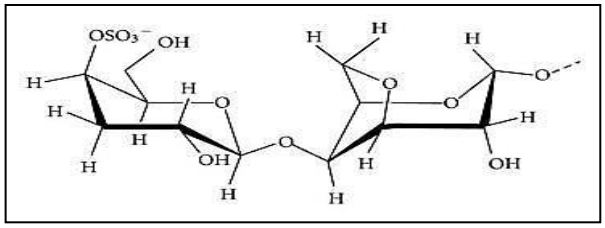

Figure 7: Structure of Carrageenan

Pharmaceutical Uses of Seaweeds

Seaweeds are used in the pharmaceutical industry with great significance. Some components like carrageen is used as a suspension agent and stabilizer in drugs, lotions, and medicinal creams. It has also been used as an anticoagulant in blood products and for the treatment of bowel problems such as diarrhoea, constipation, dysentery and utilized to make internal poultices for the control of stomach ulcers [64]. In the last few decades, discovery of pharmacologically active metabolites from the seaweeds has increased tremendously so that it can be used against several diseases like cancer, diabetes and many infectious diseases [65]. Carrageenan and alginate are used as antibiotics, laxatives, anticoagulants, anti-tumor, anti-ulcer products and suspending agents in radiological preparations have been used for a long time [66-68] Fibers from sea weeds too perform varied range of anti-mutagenic properties and also play an important role in modification of lipid metabolism in the human body [69,70] High intake of calcium, potassium and sodium in diet are associated with lower mean systolic pressure and lower risk of hypertension. Ghislain *et al.* [71] reported about the anticancer effects of different seaweeds on Human Colon and Breast Cancers. Seaweeds or seafood are the most important reservoirs of new therapeutic compounds for humans. Various compounds extracted from seaweeds that have been shown to eradicate or reduce the progression of cancer. Fucoidan extracted from the brown algae Fucus spp. has shown activity against both colorectal and breast cancers. Some other applications like acetone extract of *Gracilaria crassa* and *Laurencia papillosa* reduced the total volume of gastric juice and total acidity of gastric secretion. Species like *G. crassa* and *L. papillosa* possesses alkaloids, flavonoids, saponins, tannins and cardiac glycosides, sulfated algal polysaccharides which may provide an effective protection against gastric damage. The fats, the precursors of prostaglandins play a protecting role by increase the mucosal resistance. Gracilaria also contain abundant amino acids, fatty acids, vitamins, minerals, polyphenolic compounds and carbohydrates which play a role in the defense against oxidative tissue damage wound healing activities. The SGPT (Serum glutamine-pyruvic transaminase) level was prominently reduced by all extract concentrations than that by standard drug [72]. The anti-inflammatory property for methanolic extracts of four seaweeds namely *Padina tertastomatica, Sargassum wightii, Gracilaria edulis* and *Caulerpa racemosa* were evaluated by paw edema test and the percentage inhibition of paw edema volume was compare to standard drug Diclofenac. Maximum inhibition of 35.38% was found in the first hour after carrageenan injection in *Caulerpa racemosa* methanolic extract [73]. The evaluation of the extracts from *Ulva* species with low phenolic content, also has anti-diabetic effects in animal models. Presence of phlorotannins has shown hypoglycemic effects in genetically diabetic mice. In addition, recent, but limited, information suggests potential anti-diabetic effects of seaweed phenolic components in humans. Extracts from *Ulva*, with presumably low phenolic content, have anti-diabetic effects in animal models [74]. As reported some seaweeds species were screened against mosquito larvae (*Culex pipiens*). Different dried seaweeds of red and brown seaweeds including *Caulerpa prolifera, Caulerpa serrulata, Jania rubens,Cystoseira myrica* and *Padina pavonica* were applied into the mosquito larvae rearing jars and measured the survival, larval development and growth rate of the mosquito *Culex pipiens* larvae.

CONCLUSION

Functional foods from sea provide health benefits above normal nutrition as these foods are different from medicinal supplement diets. In this aspect, seaweeds could be the substitute to solve the problems of protein, carbohydrate and mineral deficiency in human nutrition by consuming on daily basis. It can be a dietary alternative due to its high nutritional property which also can be enhanced by improving the quality in all seaweed based products for consumption. Even a mixture of different species or combinations with other food may also open up many possibilities. The fatty acid content and other proximate composition of seaweeds gives an idea of using as feed for livestock, which can also compensate the usage of other expensive feeds. In addition these are viewed as potential source of bioactive compounds with immense pharmaceutical, biomedical, cosmeceutical and nutraceutical importance and can be used in drug discovery to treat many infectious diseases.

Due to composition of high calcium, magnesium and sulphur it enhance the plant cell division and development and in turn seaweed manures can be used in acid leached soil to increase the soil fertility and will be instrumental in replacing many hazardous chemical fertilizers and make significant contribution in the era of green agriculture particularly pertaining to Island ecosystem. In respect of the seaweed resources from the Andaman and Nicobar Islands earlier 206 species of seaweeds were reported and during this study 82 species have been recorded from South Andaman only of which two of the species *Trichogloe requienii and Trichogloeopsis pedicellata* from Rhodophyceae are new records. However exploitation and proper utilization of these seaweed resources from Andaman Sea are scanty. But it has tremendous potential and it will bring golden opportunity to the Island farmers to generate economy out of these seaweed resources. An extensive study of the seaweeds from the Andaman Sea is very much required towards its proper mutilation as a major source of nutritive diet to overcome any malnutrition and also a probable source of therapeutic application. In addition cultivation of seaweeds needs to be promoted using improved techniques for proper seaweed resource utilization and conservation for future.

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REFERENCES

[1] C Dawczynski; R Schubert; G Jahreis. *Food Chem.* **2007**, 103, 891-899.
[2] RM Oza; SH Zaidi. A Revised Checklist of Indian Marine Algae, Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat, India, **2000**, 296.
[3] P Kumari; M Kumar; V Gupta; CRK Reddy; B Jha. *Food Chem*. **2010**, 120, 749-757.
[4] SE Marinho; PC Fonseca; MAA Carneiro; Moreira. *Bioresource Technol*. **2006**, 97, 2402-2406.
[5] J Fleurence. *Trends Food Sci Tech*. **1999**, 10, 25-28.
[6] VJ Chapman, DJ Chapman. Seaweeds and their uses, Springer Netherlands, **1980**.
[7] M Lahaye. *J Sci Food Agr*. **1991**, 54, 587-594.
[8] SV Khotimchenko; VE Vaskovsky; TV Titlyanova. *Botanica Marina*. **2002**, 45, 17-22.
[9] VK Mishra; F Temelli; PF OoraikulShacklock; JS Craigie. *Botanica Marina*. **1993**, 36(2), 169-174.
[10] RJ Shields; I Lupatsch. *J Anim Sci*. **2012**, 21, 23-37.
[11] MG Mustafa; H Nakagawa. *ISR J Aquacult-Bamid*. **1995**, 47, 155-162.
[12] S Mabeau; J Fleurence. *Trends Food Sci Tech*.**1993**, 4, 103-107
[13] P Ruperez. *Food Chem*. **2002**, 79, 23-26.
[14] AJ Smith. *J Appl Phycol*. **2004**, 16, 245-262.
[15] B Kılınç, S Cirik, G Turan, H Tekogul, E Koru. Seaweeds for food and industrial applications, In: Food Industry, InTech, **2013**.
[16] M Jansi; V Ramadhas. *Indian J Mar Sci*. **2009**, 38, 470-473.
[17] SI Khan, SB Satam. *Aquaculture Asia*. **2003**, 8(4), 26-29.
[18] G Karthidevi; K Manivannan; G Thirumaran; P Anantharaman, T Balasubramanian. *Glob J Pharmacol*. **2009**, 3, 107- 112.
[19] https://gec.gujarat.gov.in/downloads/towards_green_guj_n.pdf
[20] D Mohanty; SP Adhikary. *J Water Res Protect*. **2013**, 5, 611-623.
[21] MP Chander; S Veeraragavam; P Vijayachari. *Int J Curr Microbiol Appl Sci.* **2014**, 3, 364-369.
[22] J Valentina; TV Poonguzhali; LNLL Josmin. *Int J Adv Res.* **2015**, 3, 972-976.
[23] Seaweed cultivation and utilization, National Academy of Biological Sciences, India, **2003**, 22, 1-6.
[24] MH Norziah; ChY Ching. *Food Chem*. **2000**, 68, 69-76.
[25] C Denis; M Morançais; E Li M Deniaud; P Gaudin; G Wielgosz Collin. *Food Chem.* **2010**, 119-913.
[26] http://www.sandiegouniontribune.com/news/health/sdut-seaweed-provides-vitamins-minerals-and-2012sep25-story.html
[27] A Habtamu; Z Wei; Y Rujin; AAG Maohammed; A Elmuez. *Int J Sci Technol.* **2015**, 4(9), 108-115.
[28] M Jaspars; F Folmer. Sea Vegetables for Health. Food and Health Innovation Service, **2013**.
[29] L Bellows, R Moore, J Anderson, L Young. Water-soluble vitamins: B-complex and vitamin C. Food and nutrition series. Health, no. 9.312, **2012**.
[30] http://www.lpi.oregonstate.edu.infocenter
[31] K Ito; K Hori. *Food Rev Int*. **1989**, 5, 101-144.

[32] K Nisizawa; H Noda; R Kikuchi; T Watanabe. *Hydrobiologia*. **1987**, 5(29), 151-152.
[33] P Insel, D Ross, K Mc Mahon, M Bernstein. Nutrition, 3rd edition, Jones & Bartlett Publishers, Sudbury, Canada. **2007**.
[34] P Ruperez; F Saura-Calixto. *Eur Food Res Technol*. **2001**, 212, 349-354.
[35] M Elleuch; D Bedigian; O Roiseux; S Besbes; C Blecker; H Attia. *Food Chem.* **2011**, 124, 411-421.
[36] B Halliwell; CE Cross. *Environ Health Persp*. **1994**, 102, 5-12.
[37] MP Cervantes-Cervantes; JV Calderón-Salinas; A Albores; JL Munoz-Sanchez. *Biol Trace Elem Res*, **2005**, 103, 229-248.
[38] DJ Betteridge. *Metabolis*. **2000**, 49, 3-8.
[39] YJ Wu; CY Hong; SJ Lin; P Wu; MS Shiao. *Arterioscl Throm Vas*. **1998**, 18(3), 481-486.
[40] M Valko; D Leibfritz; J Moncol; MTD Cronin; M Mazur; J Telser. *Int J Biochem Cell Biol*. **2007**, 39, 44-84.
[41] P Burtin. *Electron J Environ Agri Food Chem*. **2003**, 2, 498-503.
[42] PM Lesser. *Annu Rev Physiol*. **2006**, 68, 253-278.
[43] F Shahidi. *Trends Food Sci Tech*. **2009**, 20, 376-387.
[44] P Matanjun; S Mohamed; NM Mustapha; K Muhammad; CH Ming. *J Appl Phycol*. **2008**, 20, 367-373.
[45] J Santoso; Y Yoshie; T Suzuki. *Dev Food Sci.* **2004**, 42, 169-178.
[46] SK Chandini; P Ganesan. N Bhaskar. *Food Chem*. **2008**, 107, 707-713.
[47] S Heo; E Park; K Lee; Y Jeon. *Bioresource Technol*. **2005**, 96, 1613-1623.
[48] R Matsukawa; Z Dubinsky; E Kishimoto; K Masaki; Y Masuda; T Takeuchi; M Chihara; Y Yamamoto; E Niki; I Karube. *J Appl Phycol*. **1997**, 9, 29-35.
[49] M Yangthong; N Hutadilok-Towatana; W Phromkunthong. *Plant Food Hum Nutr*. **2009**, 64, 218-223.
[50] D Amornlerdpison; Y Peerapornpisal; C Rujjanawate; T Taesotikul; M Nualchareon; D Kanjanapothi. *Sci Technol*. **2007**, 7, 1-7.
[51] Y Peerapornpisal; D Amornlerdpison; U Jamjai; T Taesotikul; Y Pongpaibul; M Nualchareon; D Kanjanapothi. *Chiang Mai J Sci*. **2010**, 37, 507-516.
[52] CD Funk. *Science*. **2001**, 294, 1871-1875.
[53] JA Napier; LV Michaelson; AK Stobart. *Curr Opin Plant Biol*. **1999**, 2, 123-127.
[54] JA Nettleton. Omega-3 Fatty Acids and Health. Chapman & Hall, New York, **1995**.
[55] Z Wen; F Chen. *Biotechnol Adv*. **2003**, 21, 273-294.
[56] S Gupta; N Abu Ghannam. *Trends Food Sci Tech*. **2011**, 22, 315-326.
[57] WAJP Wijesinghe; YJ Jeon. *Carbohyd Polym*. **2012**, 88, 13-20.
[58] A Pal; MC Kamthania; A Kumar. *Open Access Library J*. **2014**, 1, 1-17.
[59] K Chojnacka, A Saeid, Z Witkowska, L Tuhy. Biologically active compounds in seaweed extracts-the prospects for the application. In: The Open Conference Proceedings Journal **2012**, 3(1), 20-28.
[60] EM Balboa; E Conde; A Moure; E Falque; H Dominguez. *Food Chem.* **2013**, 138, 1764-1785.
[61] Y Athukorala, KN Kim; YJ Jeon. *Food Chem Toxicol.* **2006**, 44(7), 1065-1074.
[62] S Lordan; RP Ross; C Stanton. *Marine Drugs.* **2011**, 9, 1056-1100.
[63] HK Handral; A Pandith; SD Shruthi. *Asian J Pharm Clin Res*. **2012**, 5(4), 5-14.
[64] J Morrissey; S Kraan; MD Guir. A guide to commercially important seaweeds on the Irish coast. Irish Bord Iascaigh Mhara/irish Sea Fisheries Board, **2001**.
[65] YW Zeng; S Yang; M Yang; JZ Zhu; WH Pu; XY Du Juan; Yang; Tao. *Asian Pac J Cancer Prevent*. **2013**, 14(3), 1585-1592.
[66] L Mohapatra; P Pati; R Panigrahy; SK Bhattamisra. *Indian J Geo-Marine Sci*. **2013**, 42(5), 538-546.
[67] F Namvar; S Mohamed; SG Fard; J Behravan; NM Mustapha; NBM Alitheen; F Othman. *Food Chem.* **2012**, 130, 376-382.
[68] G Moussavou; DH Kwak; BW Obiang Obonou; CA Maranguy; SD Dinzouna Boutamba; DH Lee; OG Pissibanganga; JI Ko K Seo; YK Choo. *Marine Drugs*. **2014**, 12, 4898-4911.
[69] VK Dhargalkar; N Pereira. *Sci Cult.* **2005**, 71, 3-4.
[70] S Mohamed; SN Hashim; HA Rahman. *Trends Food Sci Tech*. **2012**, 23, 83-96.
[71] M Ghislain; DH Kwak; WO Brice; CA Maranguy; DB Sylvatrie; DH Lee; GM Pissibanganga; K Kisung; J Seo; KC Young. *Maraine Drugs*. **2014**, 12, 4898-4911.
[72] AS Kulandhaisamy; A Murugan. *Braz J Pharm Sci*. **2013**, 49.
[73] D Radhika; C Veerabahu; R Priya. *Int J Pharm Biol Sci.* **2013**, 4(1), 39-44.
[74] F Nwosu; J Morris; A Victoria; S Derek; AR Heather; J Gordon; M Dougall. *Food Chem.* **2011**, 126, 1006-1012.