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Seaweed: Nutritional and health benefits

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Abstract
Seaweeds are autotrophic plants and grow in the intertidal and sub-tidal regions of the sea. Seaweeds are the only source for the manufacture of colloids like agar; algin and carrageenan. seaweeds are generally used as food and also play a vital role in chemical and pharmaceutical industries. Edible seaweeds are rich in bioactive compounds such as soluble dietary fibers, protein like (glycine alanin, argine and glutamic acid), vitamins, minerals and trace elements. Seaweeds are also the types of novel food have been shown to have therapeutic properties for health and disease management, such as anticancer, antiobesity, antiviral, antifungal, antibacterial antidiabetic, antihy- pertensive, immuno- modulatory antihyperlipidemic, antioxidant, anticoagulant, anti-inflammatory, antiestrogenic, thyroid stimulating, neuroprotective, and tissue healing properties. Seaweed contains Carotenoids which Nutraceuticals are effectively able to reduce the atherosclerosis process and coronary heart disease progression. The consumption of seaweed is useful in expectant mothers, adolescents and elderly who are exposed to risk of calcium deficiency.

Keywords: Seaweed, marine algae, novel food

Introduction
Today Consumer interest has been increased towards the health food and healthy food is the prime source for healthy life. Nutrition is the prime focus in formulating the food products. Algae are the organisms capable of providing bioactive compounds for producing novel medicinal and as a source of food and a number of pharmaceutical and industrial products for humans. Algae are widely studied for human nutritional purpose and correspondingly utilized as functional foods. The study of algae is called phycology.

The term marine algae are generally referred as marine macroalgae or seaweeds. The first living organisms have appeared in the sea more than 3,500 million years ago (Argulis *et al*., 1982) [1]. The oceans are full of living organisms and contain more flora and fauna compared to the land. Marine organisms encompass a complex and diverse assemblage of life forms, which occur throughout the oceans. These organisms live in complex communities and in close association with other organisms both macro (e.g. algae, sponges, ascidians etc.,) and micro (e.g. bacteria, fungi, actinomycetes etc.,) organisms (Maudougall, 1996) [16]. Seaweeds are living resources found notably in littoral habitats or attached to rocks. They grow in shallow coastal waters as well as in deep sea areas up to a depth of 180 m. These macroscopic algae relatively occur in river mouth and saline waters. Seaweeds constitute the basis of the marine food chain and are subdivided in to three divisions, namely, brown algae, red algae and green algae. Globally, 96 percent of the harvested seaweeds are produced by aquaculture which had an economic value of 6.4 billion US dollar in 2013 (FAO, 2016a) [6]. The annual macroalgae harvest from wild and cultivated crops was 28.4 million tons in 2014 (FAO, 2016b) [7]. This is a rise of 43% compared to 2010 where 19.9 million of tons of seaweeds were harvested. Forty percent of the global harvest in 2014 represents seaweeds traditionally eaten in Japanese culture. Seaweeds are found in the coastal region between high tide to low tide and in the sub tidal region up to a depth where 0.01percent availability of photosynthetic light. Nearly 5,000,000 species available in the sea are virtually untapped source of secondary metabolites. Seaweeds are the extraordinary sustainable resources of marine ecosystem and man has been using the seaweeds as food, feed and medicine. It was estimated that about 90 % of the plant species of marine are algae and about 50 percent of the global photosynthesis is contributed from algae (Dhargalkar, 2005) [4]. About 271 genera and 1153 species of marine algae have been reported from Indian coast (Kaliaperumal, 2002).

Types of Seaweeds
Algae are considered a big group of autotrophic organisms, algae are divided in to four domains: Bacteria, Plantae, Chromista and Protozoa.

Which ranges from unicellular to multicellular forms. Seaweeds or benthic marine algae are the group of plants that live either in marine or brackish water environment. Like the land plants, seaweeds contain photosynthetic pigments and with the help of sunlight and nutrient present in the seawater, they photosynthesize and produce food.

Microalgae constitute a polyphyletic group of prokaryotic and eukaryotic microscopic organisms with a simple cellular structure. This group of unicellular microorganisms live individually or in groups and is known as phytoplankton. Among the most common microalgae, are the Cyanophyceae (blue green algae), Bacillariophyceae (diatoms) and Chrysophyceae (golden algae). Among these, diatoms are the dominant life form in phytoplankton and represent the largest group of biomass producers on earth.

The green algae (Chlorophyta) are truely green with no pigments to mask the chlorophyll. The green algae are very diverse and range from microscopic free-swimming single cells to large membranous, tubular and bushy plants. Bladderwrack (*Fucus vesiculosus*) Channelled wrack (*Pelvetia canaliculata*) Hijiki (*Sargassum fusiforme*) Limu Kala (*Sargassum echinocarpum*) Sargassum (*Sargassum sp.*) these are the example of green algae. Brownalgae (Phaeophyta) are multi-cellular and are found in a variety of different physical forms including crusts and filaments. Like all photosynthetic organisms, brown algae contain thegreen pigment chlorophyll. They also contain other gold an d brown pigments, which mask the green colour of chlorophyll. The dominant pigment found in brown algae is called fucoxanthin. In brown seaweed, alginate may be isolated and found at concentrations up to 40% according to the seaweed species (Moe, Draget, Skjåk-Braek, & Smidsrød, 1995; Whistler & BeMiller, 1997) [17]. Alginate is extracted from several brown algae including *Ascophyllum nodosum*, *Laminaria digitata*, *Laminaria hyperborea*, *Laminaria saccharina*, *Laminaria japonica*, *Ecklonia maxima*, *Macrocystis pyrifera*, *Lessonia nigrescens*, *Lessonia trabeculata* (Helgerud, *et al*., 2009; McHugh, 2003) [12]. The red algae (Rhodophyta) in addition to chlorophyll contain the pigments phycocyanin and phycoerythrin which give the red colouration. Red algae are found in a variety of physical forms, including simple and branched filaments.

Bioactive compounds from different seaweeds

Seaweeds	Bioactive compounds
Undaria pinnatifida	Fucoxanthin
Porphyra sp.	Phycoerythrobilin
Phaeophyceae	Sulfated fucoidans
Rhodophyceae	Sulfated galactans
Codium fragile	Xyloarabinogalactans
Codium cylindricum	Sulfated galactan
Sargassum thunbergii	Phlorotannins
Corallina pilulifera	Ethanolic extract

(**Source:** Khalid, *et al.*, chapter intechopen)

Seaweed utilization in food formulation

The recent popularity of sushi and Asian cuisine in Western countries has stimulated the seaweed economy. The migration of Asian population across the world has promoted the discovery of new ingredients from seaweeds and has fuelled the creation of new dishes by chefs in restaurants. Among the macroalgae traditionally consumed by Asian population, Ulva, Laminaria and Porphyra (Atlas & Bartha, 1998) [2] are well known. Emad (2011) [5] noted that marine algae have been used as a novel food with potential nutritional benefits in food and pharmaceutical industry. The mean intake of seaweeds in Japanese diet has been reported to be approximately 7 gram per person per day (Center for Food Safety and Applied Nutrition, 2013). The seaweed species used in Asian cuisine and their common uses as found in the literature. These are grouped under three seaweed phylum: Chlorophyta (green), Ochrophyta (brown) and Rhodophyta (red) based on their pigmentation.

Species such as Wakame or Kombu requires cooking to overcome their chewy texture while others can be eaten raw (Nori and sea lettuce) (Mouritsen, 2009) [18]. The valorization of seaweed as sea vegetables generally involves drying or salting processing treatments. Seaweed drying is one of the primary steps to allow transportation. They are either sun dried, air dried or dehydrated by salt addition (Fleurence, 2016; Venugopal, 2011) [10]. Seaweed can also be macerated with specific enzymes to improve protein bioaccessibility through hydrolysis of dietary fibers resistant to human digestion but this process hasn't reach any commercial application yet (Fleurence, 1999a) [9];

Nutrional profile

The benefits of seaweeds are numerous and profound. Harvested in pure seawater, seaweeds can be considered as nature's most complete and balanced nutrient food source. (Woodhouse, 2003). Seaweeds can help to build and sustain the broad nutritional balance of vitamins, minerals and vital nutrition like:- carbohydrates, protein, essential amino acid, dietary fibers. On which optimal health and vitality depend. Seaweed contains protein which is rich in glycine alanin, argine and glutamic acid and also contains other essential amino acid. Seaweed containing high amount of ash which indicating appreciable amount of minerals like:- iodine, calcium sodium mahnesium, zinc, magnesium potassium.

Carbohydrates

Seaweed polysaccharides are mostly found within the algae cell-wall with exception of the storage polysaccharides which are located in the plastid. The seaweed cell-wall (extracellular matrix) has an important structural role. The storage carbohydrates are equivalent to the human glycogen and serve as the principal energy source. Biochemical constituents of eighteen species of marine macroalgae belonging to Chlorophyta, Phaeophyta and Rhodophyta collected from Okha coast, Gulf of Kutch, India and compared their biochemical composition are Carbohydrate 16-45 percent, Amino acid 9-20 percent, Protein 10-35 percent, Lipid 8-34 percent and Ash content 0.4-14 percent on fresh weight basis (Nirmal *et al.* (2010) [19].

Fiber composition

Seaweeds are richest sources of fibers, they contain valuable carbohydrates undigested by the human gastrointestinal track. Dietary fibers (refers to fibers from food source) remain intact in the small intestine they are known to increase the viscosity in the gastro-intestinal track and they are partially or sometimes completely fermented by the microbiota in the gut (FAO/WHO, 2013) [8].

Protein

The protein content is variable according to the species, season, geographic distribution, population, cultivation conditions and nutrient supply during growth phase. In

general, the red and green species contain relatively high protein levels, with an average value of 4-50% (w/w) dry weight, compared to brown species, which contain between 1 and 29% (w/w) dry weight (Harnedy & Fitz Gerald, 2011). Nutritional qualities of two edible green seaweeds, *Caulerpa lentillifera* and *Ulva reticulate* contains Protein 12.49 & 21.06 percent and Ash content 24.21 & 17.58 percent on dry weight basis of *Caulerpa lentillifera* and *Ulva reticulata* respectively. *Caulerpa lentillifera* rich in phosphorus, calcium, magnesium and copper *Ulva reticulata* rich in potassium, manganese and iron. Some variety of seaweeds are even richer in calcium than milk and the human body can utilize nutrients from seaweed without wastage (Soja, 2006).

Lipids

Seaweeds contain relatively low levels of lipids (1-5%) when compared to other plant seeds such as soy and sunflower, but majority of those lipids are polyunsaturated fatty acids (PUFAs) (MacArtain, Gill, Brooks, Campbell, & Rowland, 2007; Makkar, *et al.*, 2016) [14, 15]. PUFAs health benefits are well documented for fish and seaweeds may also provide a sustainable source of these compounds. Algal PUFAs are under the form of ω-3 fatty acids such as eicosapentaenoic acid (EPA, C20:5) or docosahexaenoic acid (DHA; C22:6).

Seaweed contains several mineral elements required in human nutrition such as Na, K, Ca, Mg, Fe, Zn, Mn and Cu. Seaweed contains a valuable source of polyphenols. Values, expressed in gallic acid, ranging from 4-59 mg per gram of dry seaweed may be found (Tibbetts, Milley, & Lall, 2016) [20].

Functional food and therapeutic uses

Seaweeds are an everyday miracle. Seaweeds offer a wide range of therapeutic possibilities both internally and externally. Eating unprocessed dried seaweeds can yield many healing benefits. Many physical ailments in humans can be regularly resolved with the simple addition of seaweeds to their respective diets. The metabolic active compounds already isolated from seaweeds have helped in the development of new drugs against cancer, microbial infections and inflammation (Francisco, M *et al.*, 2001) [11]. Preventing disease outbreaks or treating the disease with drugs or chemicals tackles these problems. Nowadays, there is an increase in use of antibiotics due to heavy infections and the pathogenic bacteria becoming resistant because of indiscriminate usage of antibiotics.

Study on rats has shown that simultaneous consumption of fish (fish oil) and brown seaweeds decreases the concentration of triacylglycerol in the serum and liver (Murata *et al.*, 2002). Burtin (2013) found 34% dry weight of calcium in seaweeds whose consumption is useful in expectant mothers, adolescents and elderly who are exposed to risk of calcium deficiency.

Dyslipidemia is a main cardiovascular risk factor for coronary heart disease incidence and mortality. Lipid disorders can accelerate the atherosclerosis process and result could be chronic heart failure. Nutraceuticals are effectively able to reduce the atherosclerosis process and coronary heart disease progression. Carotenoids are produced by seaweeds, plants and microorganisms. Solibami *et al.*, (1985) explains that brown algae contain α, β and δ tocopherol while the green and red algae contain only the α tocopherol where the α and δ tocopherol help in the prevention of cardiovascular disease.

Conclusion

Seaweeds are very important marine plants that constitute flora of our coastal habitats. However information on its diversity is still in a state of infancy when compared with the land plants. A number of civilizations around the world have been using seaweeds as a food since time immemorial and recently these marine plants have been showcased as a food for future. Seaweed contains a various nutritional compounds also possessing several functional properties that may lead to many culinary innovations. For example, seaweeds may be used as a flavoring agent to promote the umami taste or as a texturizing agent. Edible seaweeds are rich in bioactive compounds such as soluble dietary fibers, proteins, peptides, minerals, vitamins, polyunsaturated fatty acids and antioxidants. seaweeds have been shown to have therapeutic properties for health and disease management, such as anticancer, antiobesity, antiviral, antifungal, antibacterial antidiabetic, antihy- pertensive, immuno- modulatory antihyperlipidemic, antioxidant, anticoagulant, anti-inflammatory, antiestrogenic, thyroid stimulating, neuroprotective, and tissue healing properties.

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