

Review Article

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Importance of Some Algal Species as a Source of Food and Supplement

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ABSTRACT

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The waters of the world, oceans, seas, rivers, creeks, lakes and even ice, host a large variety of organisms which are able to use light as the only energy source for their metabolic processes. Algae are a group of relatively simple, plant-like organisms, most of which are capable of performing photosynthesis. They capture light and use its energy to convert CO₂ into sugars and oxygen. There are 80,000 to 100,000 different algae species with widely varying characteristics; many of which have been investigated. Algae size ranges from micrometres of unicellular micro-algae to macro-algae, seaweeds of tens of metres. Globally, there is growing interest in algae as production organisms. Algae contain lipids (oil), proteins and carbohydrates (sugars), and especially marine algae have been used as food, feed and fertilisers for centuries. Commercial farming of macro-algae (seaweeds) has a long history, especially in Asia. In the 1950s algae were considered a candidate for protein supply for the increasing world population on a search for biologically active substances began. Algae have been used in as human diets since very early times. In coastal regions seaweeds are used for human food from ancient times, population boom in the last decades has forced man to depend upon seaweeds and other algae to supplement his diet. Researchers in Japan, Germany and USA have shown that nutritive value and per unit area yield of algae is much more than conventional crops. The use of algae for the food and feed market is increasingly relevant as the components of micro-algae (such as fatty acids, colourants, and vitamins) have the potential to be competitive with the same components from other sources. Some important algal species that are used for human food and nutritional supplement are reviewed in this paper.

Introduction

Algae comprise a group of chlorophyll containing plant of the simplest type, having no true roots, stems, leaves or leaf like organ. Although most of the algae are autotrophic i.e., they synthesize their food

by themselves, yet heterotrophic and holozoic forms are not uncommon, they occur in variety of habitats but majority of them are aquatic which are found in freshwater like Spirogyra and marine forms like Polysiphonia. They are commonly

known as pond scum and seaweeds (Singh *et al.*, 2014). Most people don't realize how important marine macro algae are both ecologically and commercially. In fact, seaweeds are crucial primary producer in oceanic aquatic food webs. They are rich both in minerals and essential trace elements and raw materials for the pharmaceutical and cosmetics industry (Chapman, 1970). The use of seaweeds as animal and human food is a very old and widespread practice, especially in Japan and South Eastern Asia where macro algae represent an important economic resource and are largely used in human nutrition (Perez *et al.*, 2007). Seaweeds can contain high amounts of carbohydrates, proteins and minerals (Ruperez, 2002). On the other hand, as seaweed polysaccharides cannot be entirely digested by human intestinal enzymes, they are considered to be a source of dietary fiber. However, seaweed dietary fiber differs in composition, chemical structure, physicochemical properties and biological effects from those of land plants (Singh *et al.*, 2014). Also, they are a rich source of minerals, especially macro and micronutrients necessary for human nutrition. The mineral fraction of some seaweeds accounts for up to 40% of dry matter and in some cases even higher percentages than that of land plants and animal products are recorded. Evaluation of minerals in any edible seaweed is important from both the nutritional and the toxicological point of view (Rao *et al.*, 2007). Seaweeds are found growing throughout the world oceans and seas none is found to be poisonous (Guiry, 2009). Seaweed is a very versatile product widely used for food in direct human consumption. It is classified taxonomically as algae and they represent a food group that is not normally ingested in unprocessed form to any great extent in Western societies. Humankind is no strangers to the use of

algae as a food source. Even if seaweeds have been used as a human food since ancient times, particularly in the region bounded by China, Korean Peninsula and Japan but the commercial exploitation of this resource is only a few decades old, after World War II, when the focus was set on a possible insufficient protein supply due to the rapid increase of the world population. Today those countries are the largest consumers of marine algae as food. However, as nationals from these countries have migrated to other parts of the Earth, the demand for seaweed for food has followed them, for example, in some parts of the North and South America. Nowadays, seaweeds are major coastal resources which are valuable to human consumption and environment in many countries. Edible seaweeds were widely consumed, especially in Asian countries (e.g., Japan, China, Korea, Taiwan, Singapore, Thailand, Brunei, Cambodia, and Vietnam, but also in South Africa, Indonesia, Malaysia, Belize, Peru, Chile, the Canadian Maritimes, Scandinavia, South West England, Ireland, Wales, California, Philippines, and Scotland) as fresh, dried, or ingredients in prepared foods.

Seaweed can be collected from the wild but is now increasingly cultivated. It falls into three broad groups based on pigmentation; brown, red and green seaweed. Use of seaweed as food has strong roots in Asian countries such as China, Japan and the Republic Of Korea, but demand for seaweed as food has now also spread to North America, South America and Europe. China is By far the largest seaweed producer followed by the Republic of Korea and Japan but seaweeds are today produced in all continents (Manivannan *et al.*, 2009). In recent years there has been a strong movement in France to introduce seaweed into the European cuisine, with some

success, although it is still regarded as an exotic component of the menu. It has gained more acceptance in regions like California and Hawaii, where communities of Japanese are larger and the taste for seaweeds spreads out into the surrounding population through finding them on restaurant menus and supermarket shelves (Christien Enzing *et al.*, 2014).

Edible Algae

Algae contain several high-value molecules, such as lipids (oil), proteins and carbohydrates (sugars), and Protein, for this reason there is a growing interest in algae as production organisms. Algae, especially marine algae, have been already used as food, feed and fertilizers for centuries, and nowadays approximately 200 species are used worldwide in different sectors. Recently, algae have been used for the production of ethanol or biodiesel and research is on-going on genetic engineering of micro-algae, especially for the production of pharmaceuticals and cosmetics (Mabeau *et al.*, 1993; Novaczek, 2001; Ortiz *et al.*, 2006).

Nori or Purple Laver (*Porphyra* spp.)

This is the purplish-black seaweed often seen wrapped around a small handful of rice in sushi. It comes largely from cultivation in Japan, the Republic of Korea and China. In Japan's list of products from marine culture, nori has the highest production, followed by oysters, yellowtails and wakame, the last being another seaweed used as food. *P. columbina* the red edible seaweed has a considerable protein content, better chemical score than cereals and protein digestibility similar to that of plant foods. *P. columbina* has a high mineral content with medium value of potential mineral accessibility (except for iron), low phytic acid content

and good Na/K relationship. Also, *P. columbina* has bioactive compounds, which are good electron donors and could act as antioxidant. This fact and the high dietary fiber level make *P. columbina* a healthy low-fat food (Raul *et al.*, 2013). Nori grows as a very thin, flat, reddish blade, and is found in most temperate intertidal zones around the world, illustrated by its history of being eaten by the indigenous peoples of northwest America and Canada, Hawaii, New Zealand and parts of the British Isles. It is among the most nutritious seaweeds, with a protein content of 30-50 percent, and about 75 percent of that is digestible. Sugars are low (0.1 percent), and the vitamin content very high, with significant amounts of Vitamins A, C, niacin and folic acid, but the shelf life of vitamin C can be short in the dried product. During processing to produce the familiar sheets of nori, most salt is washed away, so the sodium content is low. The characteristic taste of nori is caused by the large amounts of three amino acids: alanine, glutamic acid and glycine (Dennis, 2003). This is perhaps the most widely domesticated marine seaweeds (Mumford and Muira, 1988). It is among the most nutritious seaweeds with a protein content of 30-50%, and about 75% of that is digestible. Sugar is low (0.1%), and vitamin content high, with significant amount of vitamin A, C, niacin and folic acid, While *Porphyra* can be collected by hand from natural sources, most is now derived from cultivation this specie is largely cultivated in Japan, republic of Korea and China.

Spirulina- A Super Algal Food

Spirulina a microscopic blue-green algae is one of such functional food and dietary supplement which is 100% natural product with all the good qualities that nature has to offer. It is a single celled alga that lives in warm fresh water bodies. *Spirulina* is almost

a complete functional food and dietary supplement, it contains almost all vital nutrients that are required by our body for it is health and fitness. Spirulina has a long history as food source in east Africa and Mexico, one of the largest production is lake Tecoco in central Mexico (Christien Enzing *et al.*, 2014). The algae was named Spirulina because of its spiral filament-like appearance under microscope, it is one of the most concentrated natural sources of nutrition known; it contains all the essential amino acids. The US FDA has registered Spirulina as 'GRAS' (Generally recognised as safe) that liberates its use as food. In India, at CTFRI, Mysore, research is being conducted on the use of blue green algae, Spirulina as a supplement to diet. The algae is cultured, dried, powdered and then used in the form of tablets. It contains 60% protein, essential vitamins and unsaturated fatty acids.

Chlorella

Chlorella is green alga and more useful than Porphyra in terms of nutritive value. Its nutritional value is comparable to that of a mixture of soybean (*Glycine max*) and Spinach. They can be cultured easily in the presence of light, carbon dioxide and mineral nutrients. They grow rapidly hence many crops can be obtained in a limited period. Several species of Chlorella are high producers of lipids and proteins. It contains about 30% carbohydrates, 30% proteins and 15% lipids.

Chlorella is another popular microalgae, it has similar nutritional value to Spirulina. Chlorella is very popular in Japan, it is also used as nutritional supplement with possible effects on metabolic rates; some allege Chlorella can reduce mercury level in humans supposedly by chelation of the mercury to the cell wall of the organism (Manivannan *et al.*, 2009).

Laminaria (kombu)

Kombu is the Japanese name for the dried seaweed that is derived from a mixture of Laminaria species. These include *L. longissima*, *L. japonica*, *L. angustata*, *L. coriacea* and *L. ochotensis*. These are all harvested from natural sources, mainly on the northern island of Hokkaido, with about 10 percent coming from the northern shores of Honshu. The first three of the above are the main components of the harvest. The plants grow on rocks and reefs in the sublittoral zone, from 2-15 m deep. They prefer calm water at temperatures between 3° and 20°C. Laminaria species contain about 10 percent protein, 2 percent fat and useful amounts of minerals and vitamins, though generally lower than those found in nori. For example, it has one-tenth the amounts of vitamins and niacin, half the amount of B1 but three times the amount of iron compared with nori. Brown seaweeds also contain iodine, which is lacking in nori and other red seaweeds.

Nutritional Value

For the last couple of decades, nutritionists and food scientists have given much more concentrations on nutritional evaluation of edible seaweeds. Most of the studies were focused on red seaweeds due to their higher nutritional value compared to other edible seaweeds (Wong and Cheung, 2000). Seaweeds have been used as a part of human diet in China, Japan, Thailand and South Korea for many years. Depends on species, some seaweeds are generally suitable for making cool, gelatinous dishes or concoctions. In general, seaweeds are considered as low calorie food item, but rich in vitamin, mineral and dietary fibre. Seaweeds are also utilized as animal feed ingredient, raw material for fertilizer and as well as various industrial applications.

Some seaweed is used in preparing creams, puddings, bears, wines, canned fishes etc. Several studies showed that seaweeds are valuable sources of dietary protein, lipid, fiber, vitamin and some essential minerals (Mabeau and Fleurence, 1993). Although it has always been realized that nutritional fact study has prime importance to make the species edible and commercially viable to the consumers. Several studies showed that red seaweed contains higher amount of protein and dietary fiber than that of some other green and brown algae. *Porphyra* is red alga which grows in shallow sea water, it is very rich in protein (30-35%) and carbohydrates (40-45%) it is also a good source of vitamin B and C. Food obtained by *Laminaria saccharina* is known as kombu, it is highly rich in carbohydrates (57%) (Singh *et al* 2014). The mean percentage of protein content ($11.31 \pm 1.02\%$ DW) recorded from *Gelidium pusillum* is higher than the concentrations found in higher plants (Siddique *et al.*, 2003).

Dietary Supplement

Traditionally, micro-algae such as *Spirulina* and *Chlorella* are directly sold as dietary supplements, without any kind of processing except drying. The development of these products is relatively mature and they are produced by a relatively large number of producers. *Spirulina* production is concentrated in Asia and the USA, *Chlorella* mostly in Asia, although both are also produced in a small number of other countries with warm climates (Marinho-Soriano *et al.*, 2006).

Besides the sales of the whole dried algae, nowadays also specific high-value components from micro-algae are being produced. In general, micro-algae based molecules are less competitive than standard synthetic and traditional alternatives.

However, some micro-algae based molecules have specific advantages over their conventional alternatives which make their use commercially viable. For instance, from a chemical point of view, synthetic molecules are only available in specific isomers, which are generally much less effective than natural variants for specific applications, such as in infant formula, fish pigment enhancers or dietary supplements. Astaxanthin (a carotenoid used as pigment) from dried *Haematococcus Pluvialis* is the most developed product in this domain. Astaxanthin is either available as dietary supplement (mostly USA-produced), or as food additive.

Global Production

Globally, there is growing interest in algae as production organisms. Algae contain lipids (oil), proteins and carbohydrates (sugars), and especially marine algae have been used as food, feed and fertilisers for centuries. Commercial farming of macro-algae (seaweeds) has a long history, especially in Asia, Commercial large scale cultures of the micro-algae species *Chlorella* started in the early 1960s followed by *Arthrospira* (*Spirulina*) in the 1970. Seaweeds and aquatic plants are broadly classified into brown, red, green seaweeds and miscellaneous plants. This red and brown seaweed are the most important commercially. In 1988, the total seaweed production was about 4 million MT (wet weight). The main groups were produced in the following order: brown seaweeds (2.5 million MT, 66.5%), red seaweeds (1.25 million MT, 33%) and green seaweeds (15 000 MT, 0.4%) (Dennis, 2003).

While traditionally seaweed was collected from the wild, virtually all brown seaweed, 63% of red seaweed and 68% of green seaweed are now maricultured. The main species maricultured are *Laminaria*

japonicus, (Phaeophyceae), *Undaria pinnatifida*, (brown seaweeds), *Euclima* spp, *Gracilaria* spp, *Porphyra tenera*, (red seaweeds) and *Monostroma nitidum* (green seaweed) (Arasaki and Arasaki, 1983).

Leading producers of seaweed in 1988 were China, Japan, Republic of Korea followed by the Philippines, USSR, Norway and Chile. The Asia-Pacific region, accounts for the production of some 3 million MT (80%) of the world's total production mainly for the colloid industry while seaweed for human consumption is mainly produced in the 3 major consuming countries - China, Japan, Republic of Korea and Taiwan. World seaweed demand grows at about 10% per year. World trade in seaweed and seaweed products was valued at US\$ 50 million in 1970, and five times that in 1980 (ITC/UNCTAD/GATT 1981). In 1988, an estimated US\$ 250 million worth of seaweed and seaweed products were exported from the Asia-Pacific region alone.

The international demand for phycocolloids (agar, alginates, carrageenan and furcellaran) has grown much more rapidly. The world seaweed colloid market was estimated at US\$ 1 billion and to have grown around 10% to 30% per year during the 1980s (Bung-Orn, 1989). While world supply of seaweeds is mainly from developing countries, the seaweed colloid manufacturing industry is concentrated in a few developed nations: Denmark, France, Japan, Norway, Spain, the United Kingdom and the United States. Colloid manufacture is slowly developing in a few seaweed producing countries in Asia.

Potential producers from developing countries wishing to enter the seaweed and seaweed colloid trade will face very stiff competition from the established producers. Often, since colloids are made up

specifically and marketed with technical support for its use, market preference and confidence in a particular performing brand or grade of colloid is difficult to dislodge despite their higher price. Similarly, since the quantity and quality of derivatives from seaweeds vary and are characteristic for a particular geographical area or season, market acceptance of seaweeds from new sources may be difficult and prices offered somewhat low.

In India, at CTFRI, Mysore, research is being conducted on the use of blue green algae, *Spirulina* as a supplement to diet. The algae is cultured, dried, powdered and then used in the form of tablets. It contains 60% protein, essential vitamins and unsaturated fatty acids. *Scenedesmus* besides being rich in proteins is also a rich source of threonine.

Seaweed Varieties and Culinary Uses

Because Japan is the leading producer and exporter of sea vegetables, most varieties are known in the U.S. market by their Japanese names. The mildest among seaweeds, nori is best known as the dark green wrapping on sushi rolls. Since nori is high in omega-3 fatty acids (about three sheets contain 0.01 grams of ALA), it helps protect the skin and prevent dryness. It is also rich in B12 and vitamin C. Sushi lovers will be happy to hear that nori is lower in iodine than other seaweeds, so eating a few rolls a week should not impact thyroid health.

The most widely consumed seaweed, kelp comes in many varieties — usually dried into sheets that are added directly to a dish during cooking or soaked in water to make it pliable for eating. Kombu is brown kelp popularly used as a hearty, mineral rich flavoring for broths and soups, and in Japan it is sometimes eaten fresh. Arame, another species of kelp that is characterized by its

dark brown strands, has a mildly sweet flavor and firm texture that makes it an appealing addition to many dishes, from soups and casseroles to baked goods. In Korea and Japan, chefs prepare fresh arame by tossing it with sesame oil and serving it over chopped lettuce. Kelp also comes in flake or granulated form and is used as a salt substitute and a shakable mineral supplement. Kelp noodles, which do not require cooking, are tasty and do not contain sugar or fat; a 1-cup serving has fewer than 10 calories. They are cholesterol- and gluten free, and contain 15 percent of the daily recommended intake of calcium. Kelp is very high in iodine — a quarter of a teaspoon contains 2,000 percent of the RDA. It can be a welcome addition to a diet if more iodine is needed, but steer clear if there are medical reasons to limit iodine. Dulse is a red seaweed that grows abundantly along the rocky North Atlantic and Northwest Pacific Coasts. Dulse has a soft, chewy texture. One way to enjoy fresh dulse is to sauté it with butter and garlic. Most dulse is consumed in dried flake form as a flavoring for soups. Dulse has considerably less iodine than kombu, and it is a good source of magnesium and calcium. Seaweed snacks, such as roasted seaweed, offer a healthy alternative to chips by providing a salty crunch that's low in both calories and fat.

Prospect

The seaweeds eaten in large quantities in China, the Republic of Korea and Japan (nori, kombu nad wakame) are all in a state of full supply, if not oversupply, in those countries. Nori producers in Japan are looking for exports to United States of America and other countries to absorb their surplus production. This, taken with the experiences of the two companies that attempted nori production in United States

of America, means it would not be advisable to invest in new production facilities for nori in the near future. Certainly any prospective investors in developed countries would first need to secure rights to all the cultivation areas they propose to use.

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