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Algae as a functional food

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Abstract
Plants are everywhere and they are primary producers which is a source of many nutrients. Seaweeds are traditionally used in human and animal nutrition. Their protein contents differ according to the species and seasonal conditions. Globally, the demand for algae are growing and increasing for consumption because of its functional benefits beyond the traditional considerations of nutrition and health. Algae are a very large and diverse group of autotrophic organisms which ranges from unicellular to multicellular forms with a very high protein content. Algae are also important producers of vitamins, minerals and fatty acids. Nowadays, Algae is not only used as food but also used as extracts in food, dairy, cosmetics and industrial uses thereby creating new opportunities for the food industry. Edible algae are recognized as complete foods which provide correct balance of proteins, carbohydrates, vitamins, and minerals. Therapeutic properties of algae are used for promotion of health status and maintenance. Algae contain some antioxidant, anticancer, antiviral properties which are used as medical resources.

Keywords: Algae, food, nutrient, spirullina

Introduction
Algae are a very diverse group of generally simple unicellular or multicellular eukaryotic organisms' plantlike species. The various single-celled strains are microscopic (Upton, J. 2014**)** [35]. Algae are of excellent nutritional value since they contain complete proteins, fiber and high levels of omega 3-fatty acids, vitamins and minerals. Algae is becoming be one of the most promising and long term source of food, animal feed, medicines, cosmetics other co-products and most importantly oil for fuel and because they are found in a large quantity, a wide variety of benefits are associated with them which makes them so attractive. Some microalgae are cultivated for foods and food additives (Chacón-Lee and González-Mariño 2010; FAO 2016) [8, 18].
In addition to their nutritional value, algae increasingly are being marketed as functional foods that benefit health beyond the role of basic nutrition (Hafting *et al*., 2012) [23]. Energy in algae is stored in form of oils and carbohydrates which when multiplied with its number give us a very large amount. Since algae are plant they are autotrophs, they can harvest carbon dioxide from the atmosphere and convert it to organic matter and releases oxygen as it grows. The more the amount of carbon dioxide, the more is its productivity.
The widespread interest in algal foods and/or their functional food potential is evident in numerous recent reviews (Cornish *et al*. 2015) [12]. Different food components of Algae will be discussed such as proteins, polysaccharides, lipids, vitamins, minerals, and antioxidants in the context of improving knowledge about the efficacy of algal foods.

Proteins
Protein content differs widely across groups of algae, Chlorella have an amino acid profile that compares well with egg and contains up to 70 % dry weight protein. It contains all of the essential amino acids (EAA) that humans cannot synthesize from the body but can only be obtained from foods. Spirulinais harvested as a protein-rich whole food in many cultures outside Europe and North America (Gantar and Svircev 2008) [20]. By weight, Spirulina is about 60% protein, making it an excellent source of the all-important nutrient that the body needs to function properly. Further, the protein contained in Spirulina is a perfect protein, which means it contains all of the essential amino acids. That's rather uncommon in plant-derived proteins, because most are lacking some of the essentials.

Spirulina as a plant-based source of complete protein makes it an ideal dietary supplement choice for vegetarians, but it's also an excellent option for those who are interested in upping their protein intake without taking on excessive calories in the process. In general, protein in most algae is digested less completely than reference proteins such as casein, a milk protein containing digestive enzymes such as pepsin, proteinase and pancreatin which are contributing to inhibitory soluble fibers (De Marco *et al*. 2014) [15].

Lipids

Lipids are nutrients which are essential for all living organisms as components of membranes, energy storage compounds, and as cell signaling molecules (Eyster 2007) [16]. Although humans and other mammals synthesize lipids, some essential lipids must be obtained from dietary oils or fats. Algal lipids consist of phospholipids, glycolipids (glycosylglycerides) and non-polar glycerolipids (neutral lipids). Phospholipids and glycolipids are important for membrane function and they contain a polar head group with two fatty acid chains, while the triacylglyceroles (TAGs) are important energy stores in the cell and they contain non-polar (neutral) group with three fatty acid chains. Lipid membranes contain sterols such as fucosterol and β-sitosterol (Fahy *et al*. 2005) [17] that have shown their health benefits (Arul *et al*. 2012) [4]. Algae contain many of the major lipids of plants, such as the glycosylglycerides and the usual phosphoglycerides. In addition, more unusual compounds such as the betaine lipids, chlorosulfolipids or various other sulfolipids may be major components of some species or orders. These acyl lipids have characteristic fatty acid compositions and are often highly enriched in polyunsaturated fatty acids which may contain as many as six double bonds.

Sterols

Algae vary in their total sterol content and in the variety of sterols present (Holdt and Kraan 2011) [24]. The algal sterols consist of cholesterol, fucosterol, isofucosterol, clionosterol, dihydroxysterols. Algal sterols are not as cholesterol but Fucosterol which occurs in many algae, especially red and brown macroalgae (Pereira *et al*. 2016) [33]. This compound may have value in treating complications of diabetes and hypertension, as well as other major health concerns (Abdul *et al*. 2016) [1].

The seasonal, environmental and species-specific factors that alter the abundance and composition of algal sterols, such as in the recent studies in Antarctic seaweeds must be well understood in their potential effects in human diets (Pereira *et al*. 2016) [33]. These algal sterols possess beneficial health promoting effects such as hypercholesterolemic, antioxidant, anticancer, antidiabetic, antihypertensive, anti-inflammatory responses (Kim and Ta, 2011) [30].

Polysaccharides

Polysaccharides are used for energy storage and as structural elements in marine algae and terrestrial plants. Humans possess enzymes that degrade algal starches to mono-and di-saccharides for transport across the gut lumen, but generally cannot digest the more complex polysaccharides. These resistant polysaccharides, known as dietary fiber, may be fermented in the large intestine to varying degrees depending on the enzymatic competence of the micro biome (Cian *et al*. 2015 [9] These algae produce various bioactive compounds including sulphated polysaccharides as in complex composite cell walls consisting of cellulose, sulfated galactans, xylan or mannan fibrils. Both sulphated and carboxylated algal polysaccharides are known to exhibit biological activities such as anti-herpetic, anti-coagulant, anti-inflammatory, anti-tumor, anti-microbial, immune modulatory, anti-viral activities (Karnjanapratum *et al*, 2012) [29]. It is fair to say that algal polysaccharides are the most widely, and often unknowingly, consumed food of algal origin. Edible macroalgae contain unusually high amounts of dietary fiber, ranging from 23.5%to 64.0%of dry weight, values that frequently exceed those for wheat bran (Benjama and Masniyom 2012) [5]. These beneficial responses may include reduced risk of diabetes, hypertension and cardiac heart disease (Institute-of- Medicine 2005) [26].

Vitamins

Algal foods are rich in vitamins. Certain marine microalgae contain water-and lipid-soluble vitamins and can be used as food supplements or food ingredients. A number of vitamins are present in higher concentrations in the microalgae than in conventional foods which are traditionally considered rich in them. Ingestion of relatively small quantities of microalgae can cover the requirements for some vitamins in animal nutrition, including human nutrition, while supplementing others. Marine microalgae can thus be considered to represent a non-conventional source of vitamins or a vitamin supplement for animal or human nutrition. Several sea vegetables contain levels of vitamin C comparable to common vegetables such as tomatoes and lettuce (Ferraces-Casais *et al*. 2012) [19]. Sea vegetables also are a good source of B-group vitamins (particularly B1, B12), as well as the lipophilic vitamin A (derived from the carotenoid β-carotene) and vitamin E (tocopherol). Algal foods can be an excellent source for a wide range of these essential micronutrients. But differences also can be due to environmental and seasonal factors.

Algal foods offer one of the few vegetarian alternatives for cobalamin (vitamin B12) in the diet. Cobalamin is synthesized only by prokaryotes (Warren *et al*. 2002) [37], and it has been shown that B12-synthesizing bacteria are closely associated with or reside on eukaryotic algal surfaces (Wagner-Döbler *et al*., 2010) [36]. Thus, sea vegetables are likely to be a more reliable source of the appropriate form of this vitamin, although again this will be determined by the prokaryotic community associated with the algae.

Antioxidants

Marine algae are sources of antioxidant compounds for human diets. Microalgae and macroalgaecontain antioxidant organic compounds and enzymes that limit the oxidative damage, which results primarily from the reduced states of oxygen (Cornish and Garbary 2010) [11]. There are two broad categories of antioxidant activity of algae and they are decreasing oxidative stress on the gut micro biome by limiting reactive oxygen species within the digestive tract and transportation of epithelial cells into the blood for distribution throughout the body (Gobler *et al*. 2011) [22]. Natural antioxidants, found in many algae, are important bioactive compounds that play an important role against various diseases and ageing processes through protection of cells from oxidative damage. The detected antioxidant compounds in algae from these genera and others have potential anti-aging, dietary, anti-inflammatory, antibacterial, antifungal, cytotoxic, anti-malarial, anti-proliferative, and anticancer properties (Zubia *et al*., 2007) [39].

Inorganic elements

Processed seaweeds are widely used as mineral and metal nutritional supplements (Kay 1991) [28]. There is a comparatively small literature describing mineral contents of macro algal and micro algal foods (Cabrita *et al*. 2016) [7], and very little information about seasonal variations for naturally harvested sea vegetables. The human nutritional benefits of sea vegetable inorganic elements are more found in iodine and iron, which can be highly enriched in marine macroalgae.

Seaweeds are a good nutritional source for iodine, there is a long history linking seaweed consumption by humans and the reduced incidence of goiter and other thyroid disorders. Macroalgae are rich source of iron for human diets because they enhance total dietary iron content. High levels of ascorbic acid (vitamin C) convert iron to the more readily absorbed ferrous form (Garcia-Casal *et al*. 2007) [21]. Various strains of the green microalga another main source of carotenoids is the green alga Haematococcuspluvialis, whose cultures have developed industrially in several countries (Cysewski and Lorenz 2004) [14].

Omega-3 fatty acids are the well-known PUFAs and are usually obtained from the fish oil. But fishes cannot produce PUFAs, these get accumulated in their body when they eat algae and hence algae are their true sources. In present time, the unpleasant fish odour is eliminated PUFAs directly produced by algae, it is easily purified and in a better way and there is reduction in the risk of contamination and reaction. PUFAs are important for our body as they help in fighting many diseases like cardiovascular diseases, reduce obesity, regulate membrane fluidity, and also regulate oxygen transport and improve thermal adaption ability.

Benefits of Algae as a Functional Food

Seaweeds are edible algae that have been used for centuries as food all over the world. Algae are of excellent nutritional value since they contain complete protein, fiber, and sometimes high levels of omega-3 fatty acids. In fact, the omega-3 acids in fish come from the microalgae consumed at the bottom of the food pyramid and gradually passed up to the fish at the top. Algae are also rich in many vitamins, such as A, C, B_1, B_2, B_3 and B_6, as well as minerals, such as iodine, calcium, potassium, magnesium and iron. They can be consumed from cooked to dried or raw (Siva Kiran *et al*., 2015) [34]. Algae are used for some production such as Medicines, vitamins, vaccines, nutraceuticals and other nutrients. Many types of algae and the products derived from them have shown medicinal values and nutritional applications.

Spirulina is a form of blue green Algae that springs from warm, fresh water bodies. It is often confused with chorella, but the fundamental difference between them is that spirulina does not possess the hard cell wall while chlorella possess a hard cell which makesit closer to being a plant than algae. Spirulina is renowned for its intense flavor and even more powerful nutrition profile. Spirulina benefits are so amazing that when taken on a daily basis they could restore and revitalize the health (Nicoletti M. 2016) [32]. Spirullina is being seriously discussed as a sustainable source of food with its potential to end world hunger it is different from most plants, because it is able to withstand extreme temperature variations and still thrive. It has been found in studies to successfully treat a wide range of ailment, including arsenic poisoning, candida overgrowth, and allergic rhinitis. It has also been seen to potentially lower stroke and cancer risks.

Spirulina as a super food is a plant that can nourish the body by providing most of the protein require by the body. It helps to prevent the annoying sniffling and sneezing of allergies, reinforces the immune system, helps to control high blood pressure and cholesterol and helps to protect against cancer. The recommended daily dose is typically 3-5 grams, which can be spread out twice to thrice a day. It is a powerhouse of essential vitamins and minerals, it is also a potent.

Mostly people take availability of healthy clean water for granted, unfortunately in some countries like Bangladesh, it is a luxury. Bangladesh water supply is loaded with arsenic. Bangladeshi researchers conducted a three-month-hospital-based study, where spirulina was given to 33 patients while 17 received placebo doses. 82 percent of those taking spirulina showed tremendous improvement.

According to one study, Cingi *et al*., 2008 [10], patients treated with spirulina reported relief of symptoms commonly associated with allergic rhinitis, such as nasal discharge and congestion, sneezing and itching. Spirulina helps to regulate blood pressure among both women and men ages 18-65 years with no other dietary changes and lower cholesterol levels. Spirulina is healthy for vegetarian because it contains 65-71 percent complete protein compared to beef, which is only 22 percent, and lentils, which is only 26 percent. In addition to being protein-rich, spirulina is an excellent source of vital amino acids and minerals easily assimilated by the body. There are many types of spirulina out there so it is important to choose organic spirulina from a reputable source. Spirulina comes in capsules, tablets, powders and flakes.

Spirulina is a safe source of protein, nutrients, vitamins, and minerals that has been used for centuries, though there are no known side effects associated with spirulina, the body may react to it based on individual current state of health. The reactions can be reduced by increasing the water intake, reducing stress levels, eating according to nutritional type and getting plenty of rest. Some major benefits of Spirullina include;

- It helps in detoxification of Heavy Metals especially Arsenic. According to the World Health Organization 2016, the United States is one of the countries affected by inorganic arsenic that is naturally present at high levels. Millions of people in Bangladesh, India, Taiwan and Chile are consuming high concentration of arsenic through drinking water, and thousands of them have already developed chronic arsenic poisoning. After giving 24 patients affected by chronic arsenic poisoning spirulina extract (250 mg) plus zinc (2 mg) twice daily, they compared the results with 17 patients who took a placebo and found that the spirulina-zinc combination worked wonderfully. Ultimately, the participants experienced a 47% decrease of arsenic in their body.
- It helps in eliminating Candida with its effective anti-microbial agent. Specifically, the immune-strengthening properties of spirulina help to promote the growth of healthy bacterial flora in the intestines, which in turn inhibits Candida from thriving.
- It helps to lower the Blood pressure; Phycocyanin is a pigment found in the spirulina that scientists have discovered possesses antihypertensive effects (Ichimura M *et al*., 2013) [25]. Japanese researchers claim that this is because consuming the blue-green algae reverses endothelial dysfunction in metabolic syndrome because metabolic syndrome has rapidly become one of the main causes of preventable disease today, as it raises one's risk of developing heart disease, diabetes and stroke.
- It helps to lower Cholesterol and reduce chances

of Stroke spirulina have shown to prevent atherosclerosis and reduce elevated blood cholesterol levels.

- It helps to boost Energy When spirulina and lime are combined it enhances energy performance because they unlock sugar from the cells and, when frozen, the cold from the ice boosts metabolic energy while it gives the body a "wake-up call."
- It speeds up weight loss spirulina promotes weight loss and low-fat stores through a variety of mechanism because it takes more energy to metabolize and they are high nutrient-dense protein-rich foods.
- Spirulina benefits the body by reducing the inflammation that causes people to experience sinus problems known as allergic rhinitis and it is effective at reducing itching, nasal discharge, nasal congestion and sneezing.

An average of one ounce of different spirulina species contains the following nutritional content:
Calories (81), Protein (39g), Dietary fiber (1g), Sugars (.9g), Fats: Total fat (3% Daily Value), saturated fat (4%), Omega-3 fatty acids (230 mg), Omega-6 fatty acids (351 mg).
Precautions of high consumption of Algae
Consumption of any food is not without risk, so the precaution of high algal consumption must also be considered t consumes to prevent potential harm. Possible risks associated with algae include excess intake of toxic metals, allergenicity, cyanotoxins, and certainly secondary metabolites (e.g., prostaglandins, kainoids) as well as contamination with pathogens, radioisotopes, and toxic synthetic compounds. Algae are being grown in waters enriched with carbon dioxide, climate-changing waste gases that can be pumped into algae ponds from mines, power plants, and factories. Spirullina is a strong detoxifier that why it is best to start with a small dose and allow the body adapt to it.
Heterotrophic microalgae are grown in large fermenters using sugar or starch, similar to the corn ethanol fermentation already providing almost 10 percent of our liquid transportation fuels. Seaweeds (macroalgae) are cultivated in seawater, typically in near-shore systems, though open ocean cultivation has been studied in the past and are again of interest, and even on-shore cultivation of seaweeds is a possibility. A number of algae production technologies are currently under development, from open ponds and closed photo bioreactors, from fermentation tanks to hybrid systems, to some that combine these various methods. Simply put, there is no one single way to grow algae at commercial scale, and this versatility is one of algae's strengths.
The most prominent reactions from spirullina can be; Slight Fever due to high protein content, Dark Green Waste Matter due to high chlorophyll, Hyper-activeness due to conversion process of protein into heat energy and Sleepiness from the detoxification process and may indicate your body is exhausted and needs better rest.

Conclusion

This review emphasizes the relevance of algae as a functional food, which is not known by some countries due to ignorance despite the abundance of the edible algal species. Even though spirulina is entirely natural and generally considered a healthy food, there are some contraindications to be aware of such as allergy to seafood or iodine and pregnant or nursing women. *Spirulina* is generally considered safe for human consumption supported by its long history of use as food source. Quality control in the growth and process of Spirulina to avoid contamination is mandatory to guarantee the safety of the products. The use of algae should be encouraged because it will help solve so many environmental problems like purification of water and enhance usage of barren land.

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