Role of algae in sustainable Food, Health and Nutritional Security: An Overview

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Introduction

The fast growing human population, widespread malnutrition are directly imposing pressure on agricultural system which in turn poses serious threat to the biodiversity. Therefore, the goals of providing universal food security and protecting biodiversity seem to be two incompatible actions (Chappell and Lavalle, 2011). The world population is expected to reach nine billion by 2050 and by then global food production need to rise by about 60%. About 7,000 species of plants have been cultivated or collected for consumption throughout human civilization. However, at present only about 30 crops provide 95% of human food requirements of which 5 cereal crops are known to be staple (rice, wheat, maize, millet and sorghum). Due to increasing food demand man has already started exploring other agriculture systems and innovative food sources like algae. Some of the microalgae are able to enhance the nutritional content of conventional food and feed, and hence to positively affect humans and animal health with their original chemical composition such as high protein content, balanced amino acids, carotenoids, fatty acids, vitamins, polysaccharides, sterols, phycobilins and other biologically active compounds, more efficiently than traditional crops.

Algal diversity

There are more than 25,000 species of algae reported from the world. They range in size from a single cell to giant kelp over 150 feet long. There are blue-green microalgae like *Spirulina* and *Aphanizomenon*, green algae like *Chlorella* and *Scenedesmus, Dunaliella*, red algae and also brown, purple, pink, yellow and black microalgae. They occur everywhere in water, soils, on rocks and on plants. Blue-green algae are the most primitive, and contain no nucleus or chloroplast. Larger algae like seaweeds are already have an important economic role. In addition to the fact that algae are responsible for consuming most of the CO_2 and releasing the most amount of oxygen that keeps us alive, the vast diversity of algae also lends itself to being the feedstock and labeled as primary producer in any food chain. About 70 species of algae are used for food, food additives, animal feed, fertilizers and biochemicals. They are grown for animal and aquaculture feeds, human foods, biochemicals and pharmaceuticals. Microalgae in the ocean, called phytoplankton, are the base of the food chain and support all higher life.

Role of algae in food, health and nutrition

Companies involved in the algal fuels domain have started to realize that it could take much longer than originally expected to derive fuels from algae. Hence, as a starting point, many of these companies are venturing into high value, non-fuel products from algae. This allows them to generate profits fairly early into their venture while at the same time ensuring that they are able to continue with their efforts in sustainable fuel production.

Recognizing this trend and the need for a comprehensive resource on algal products, India-based Oilgae has come up with a "Comprehensive Report on Attractive Algae Product Opportunities." This report provides an overview of the wide range of non-fuel applications of algae - both current and

future prospects. It is intended to provide entrepreneurs with an idea of how to derive more benefits from their algal energy ventures. Over 50 algae products were discussed in detail in the report, including: methane, ethanol, biodiesel, protein, astaxanthin, lutein, anti-fungal agents, agar, carrageenan, anti-cellulite, dyes and colorants, solvents, chemicals, lubricants and pigments.

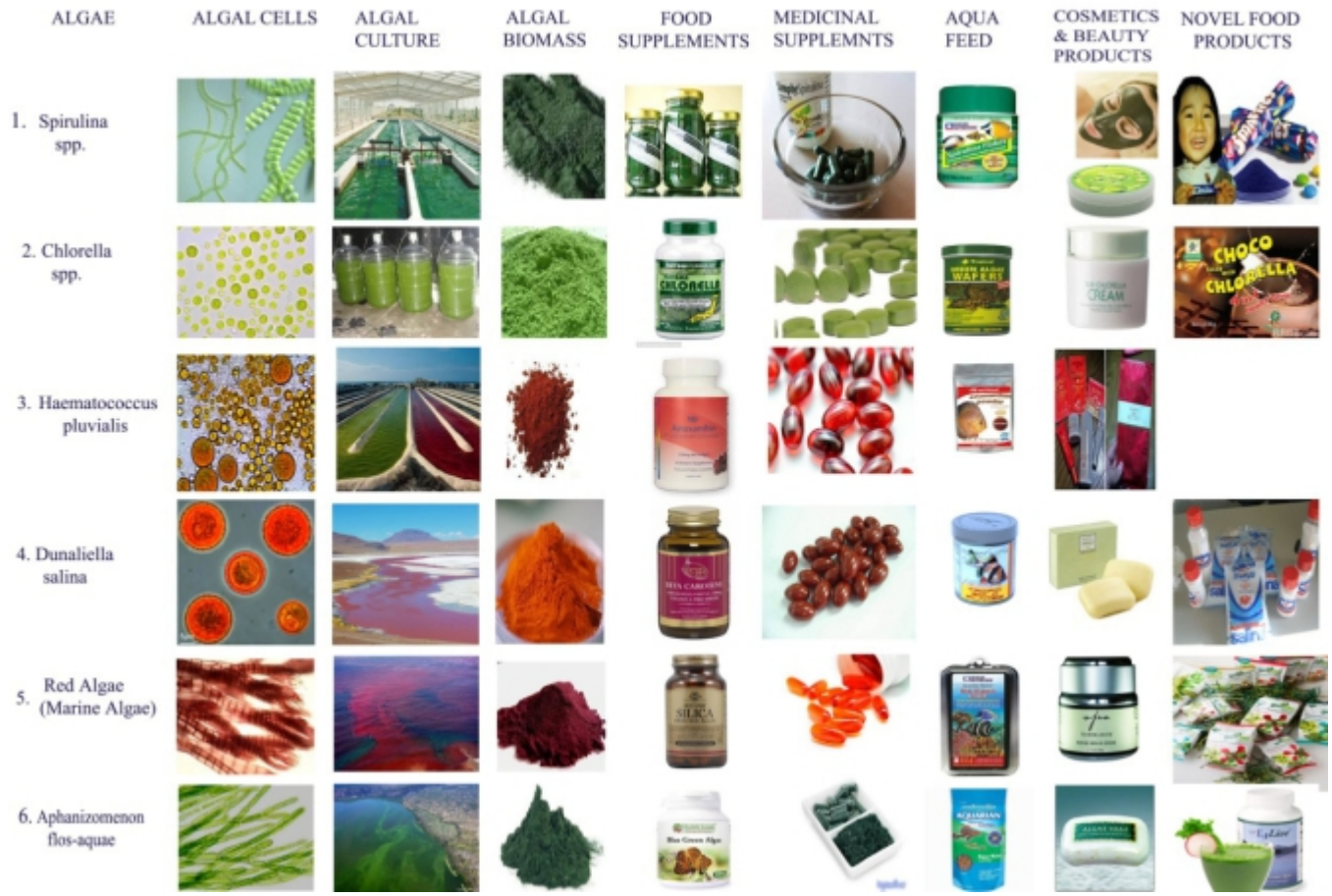
Most people have no idea how many daily use products contain algae. Algae are an ingredient in thousands of products for food, feed, color, nutraceutical, medicinal, personal care, biofertilizer, fine chemical and biofuel. Over 15,000 individual compounds have been identified in microalgae that are responsible for producing numerous useful products. For example the market value of lutein was around $233 million in 2010 and is expected to reach $309 million by 2018. Algae based value added commodities such as lactic acid, PHAs and butanol price ranges from $1300 to $7000 per ton. Around 35,000 tons of microalgal dry mass are processed in the three market segments, "diet", "food" and "cosmetics". More than 85% of biomass is used in the application areas as "functional foods" and "food supplements". A large market for aquaculture feeds could be developed from microalgal biomass containing long chain omega-3 fatty acids replacing fish-meal and oil, but production costs must be reduced from the current $50-$100 to $1-2 per kg. Pharmaceuticals are the fastest growing section of the market, but as of now there are only two approved omega-3 based pharmaceuticals in the world, which together account for 1.6% of consumption with nearly $1.5 billion in sales. Other EPA and DHA based triglyceride reduction products are under development, but it will take some time before these achieve regulatory approval and eventual commercialization. The current wholesale market price for algae omega-3 oil is about $140 per kg, which is higher than the pricing for fish oil derived products. The Global Organization for EPA and DHA, and Frost and Sullivan estimated that the global market for EPA and DHA omega-3 oils exceeded 85,000 tons in 2009 and was estimated to grow to 135,000-190,000 tons by 2015. Although >95% of the astaxanthin market consumes synthetically derived astaxanthin, consumer demand for natural products makes the synthetic pigments much less desirable and provides an opportunity for the production of natural astaxanthin by *Haematococcus*.

The 2011 International Algae Competition witnessed participation of various countries like Australia, Canada, China, France, Germany, Hong kong, India, Italy, New Zealand, Singapore, Spain, Thailand, United Kingdom, USA, and Zimbabwe. The participants submitted recipes, menus, new foods and food products incorporating algae as a featured ingredient. Innovative food preparations were made by using microalgae like Spirulina, Chlorella and macroalgae like nori, wakame, dulse, kombu, kelp and algal ingredients like agar and carrageenan. There were recipes for main course, dessert, ice cream, cookies, chips, snacks, appetizers, pasta, noodles, soup, stew, dips, drinks, shakes, cereals and more. This was an initiative to highlight the algalicious foods with the thought "How will growing algae change the world and improve our lives?".

Apart from food and health products microalgae extracts can be found in face and skin care products. Microalgae extracts are also employed in making anti-aging cream, refreshing or regenerant care products, emollient and as an anti-irritant in peelers. They are also present in sun protection and hair care products. In cosmetics, algae act as thickening, water-binding agents and antioxidants. Carrageenans are extracted from red algae and alginates from the brown algae. Other forms of algae such as Irish moss contain proteins, vitamin A, sugar, starch, vitamin B1, iron, sodium, phosphorus, magnesium, copper and calcium. These are all beneficial for skin either as emollients or antioxidants.

Some Important Algae

Some important microalgae strains used in food applications are discussed below;



- ***Spirulina* P.J.F. Turpin ex M. Gomont** is a blue-green algae that is rich in protein, vitamins, minerals, and carotenoids, antioxidants that can help protect cells from damage. Some of the key health benefits of using *Spirulina* are; boosts the immune system, improve digestion, reduce fatigue, build endurance, detoxifier - cleanses the body, boosts energy levels, controls appetite, improved cardiovascular function, better liver and kidney functioning, reduces inflammation and allergies (Gouveia *et. al*, 2008).
- ***Chlorella* Beyerinck** is a single-celled green algae that has the highest source of chlorophyll compared to any other existing plant species. *Chlorella* is considered as a complete food, because of its important role in detoxification and its high content of protein, vitamins, and minerals including carotenoids (astaxanthin, canthaxanthin, flavoxanthin, loraxanthin, neoxanthin and violaxanthin) and enzymes (pepsin). *Chlorella* is now widely available as a food supplement in tablet, granule or liquid form and as colourants (Gouveia L. *et. al*, 2008).
- Haematococcus pluvialis Flotow is a green algae which can accumulate the highest level of astaxanthin in nature (1.5-3.0% dry weight). This high-value ketocarotenoid pigment is a potent free-radical scavenger and singlet oxygen quencher, with increasing amount of evidence suggesting that it surpasses the antioxidant benefits of b-carotene, vitamin C and vitamin *E*. *Haematococcus* is currently the prime natural source of this pigment for

commercial exploitation, particularly in aquaculture salmon and trout farming (Lorenz and Cysewski, 2000). Astaxanthin is also used in cosmeceutical applications in protection against skin aging.

- ***Dunaliella salina* Teodoresco** is an halo-tolerant microalga, naturally occurring in salted lakes, that is able to accumulate large amounts of b-carotene, a valuable chemical mainly used as natural food colouring and provitamin A (retinol) for the fortification of multivitamin juices, beverages for athletes, food supplement preparations and health foods. *D. salina* community in Pink Lake, Victoria (Australia) was estimated to contain up to 14% of this carotenoid in their dry weight (Aasen *et al.*, 1969) and in culture some *Dunaliella strains* may also contain up to 10% and more b-carotene, under nutrient-stressed, high salt and high light conditions (Ben-Amotz and Avron, 1980; Oren, 2005). Apart from b-carotene *Dunaliella* produces another valuable chemical, glycerol.
- **Red algae (Marine algae)** have been used for thousands of years as a source of food and for treating medical conditions. Red marine algae contain pigment phycoerythrin that gives red color to this sea plant. It is high in vitamins, minerals and antioxidants that are easily utilized by our body. The main benefits of red algae is its ability to promote healthy circulation in our body, regulate our blood sugar levels and lower bad cholesterol levels since it is high in dietary fiber. It is also a rich source of calcium and magnesium so it contributes to bone health and since it is loaded with antioxidants it helps boost our immune system and nourishes our skin.
- ***Aphanizomenon-flos-aquae* Ralfs ex Bornet & Flahault** is a prokaryotic cyanobacterium commonly found in freshwater systems throughout the world. Approximately 500 tons of dried *Aphanizomenon* is produced annually for use in food and pharmaceutical products. The dominant production source of *Aphanizomenon* in North America is Upper Klamath Lake, Oregon and currently constitutes a significant part of the health food supplement industry throughout North America. *Aphanizomenon* contains a signi-ficant amount of chlorophyll (1-2% dry weight) which is shown to stimulate liver function and increase bile secretion. It contains C-Phycocyanin another light-harvesting pigment has antioxidant and anti-inflammatory properties. *Aphanizomenon* also has high hypo cholesterolemic activity, significantly greater than soybean oil, which causes a decrease in blood cholesterol and triglyceride levels. *Aphanizomenon* is a large producer of polyunsaturated fatty acids (*i.e.*, omega-3 and omega-6), a deficiency of which has been linked to immune suppression, arthritis, cardiovascular diseases, mental health issues and dermatological problems. Additionally, components of this alga have been shown to decrease certain cancer risks, inflammation and prevent platelet accumulation (Bishop and Zubeck, 2012).

Conclusion

The global algae biomass market is worth between $ 5- 7 billion of which the health food sector accounts for $2 billion and the aquaculture applications account for $ 0.7 billion. Algal products such as *Spirulina* and *Chlorella*, have significant benefits as potential single cell protein sources. But the market value of these products is not very high; *Spirulina* was sold at a price of $20 per kg in 2010 and *Chlorella* at a price of $44 per kg. Beta-carotene has the largest share of the carotenoids market valued at $247 million in 2007, this segment is expected to be worth $285 million by 2015. This proves algae is playing vital and valuable role in the world market.

The combination of the exceptional nutritional value of microalgae with colouring and therapeutical properties, associated with an increase demand of natural products, make microalgae worth exploring for utilization in the future in feed, food,

cosmetic and pharmaceutical industries. In the actual scenario with multiple pharmacological treatments, many believe that simple dietary interventions or nutritional supplements may be more natural, acceptable and feasible method of providing benefits. Choice of the right food to eat in an early stage of life associated with a healthy lifestyle can have important benefits in future life. A healthy diet based on microalgae can have important benefits for all age groups.

References

Aasen, A.J., Eimhjellen, K.E. and Liaaen-Jensen, S. (1969). An extreme source of b-carotene. Acta Chemica Scandinavica, 23: 2544-2545.

Ben-Amotz, A. and Avron, M. (1980). Glicerol, b-carotene and dry algal meal production by commercial cultivation of Dunaliella. In G. Shelef, and C.J. Soeder (Eds), Algal Biomass. pp. 603-6010.

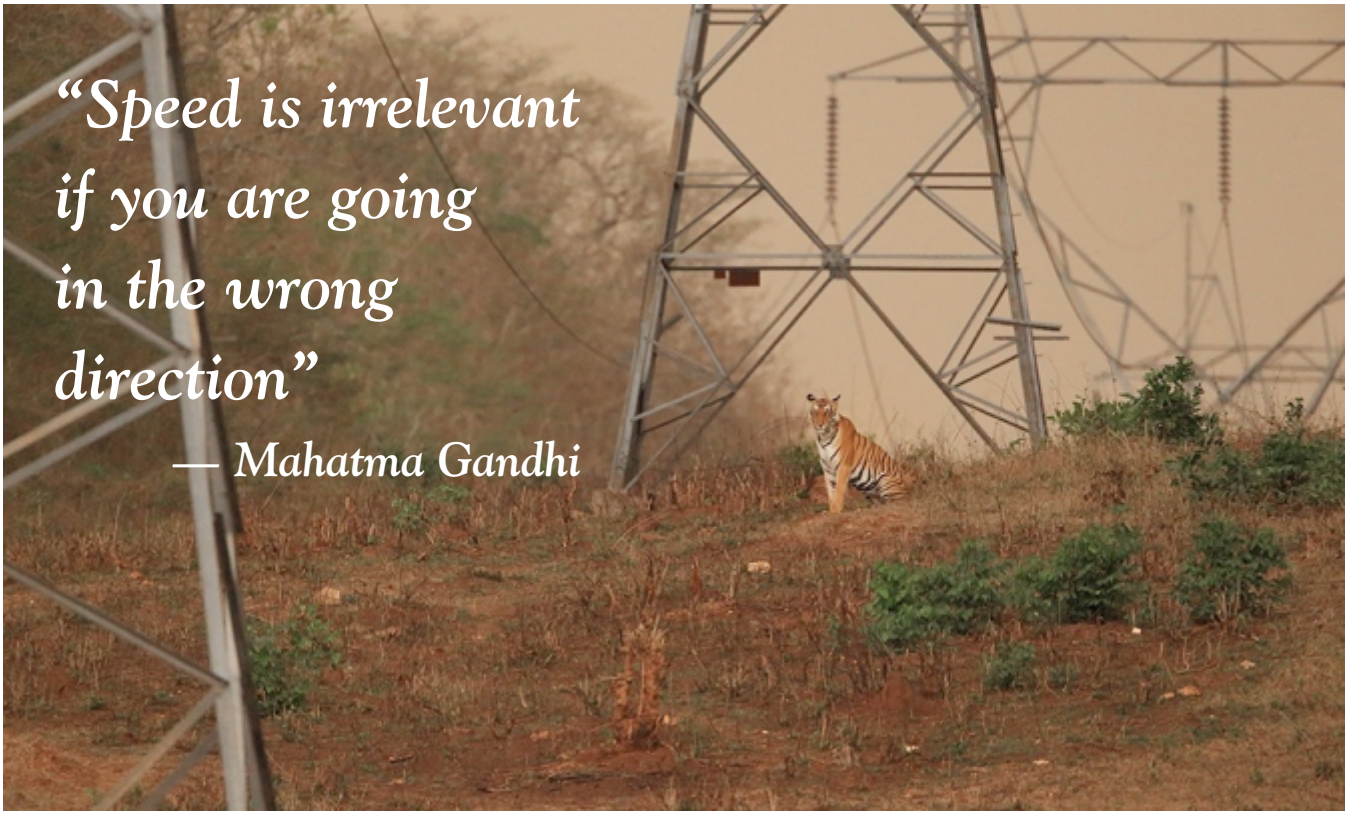
Bishop, W.M, Zubeck, H.M (2012). Evaluation of Microalgae for use as Nutraceuticals and Nutritional Supplements. J Nutr Food Sci. 2:147.

Chappell, M. J., Lavalle L.A. (2011). Food Security and Biodiversity: Can We Have Both? An Agroecological Analysis. Agriculture and Human. 28: 3-26.

Gouveia, L., Batista, A.P., Sousa, I., Raymundo, A. and Bandarra, N.M. (2008). Microalgae in novel food products. In Papadopoulos, K.N. (Ed.), Food Chemistry Research Developments, Nova Science Publishers. Inc. pp. 1-37.

Lorenz, R.T., and Cysewski, G.R. (2000). Commercial potential for Haematococcus microalgae as a natural source of astaxanthin. Trends in Biotechnology. 18:160-167.

Oren, A. (2005). A hundred years of Dunaliella research: 1905-2005. Saline Systems. 1: 2.



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