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Algae as Source of Functional Ingredients for Health Benefits

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Abstract

Algae produce a number of important functional ingredients for health benefits which are incorporated into foods consumed on daily basis, such as energy bars, breads, cookies, cereals, desserts, ice creams, pastas, and emulsions etc to improve human health and reduce the risk of chronic disease. Further, algal powders and extracts are used in nutraceutical, pharmaceutical and food industry as tablets, capsules, crystals, gels and dietary supplements etc. This review focusses on the recent advancements in this field and projects the opportunities that exists in the industrial production of the functional ingredients.

Keywords: Microalgae; Functional ingredients; Health benefits; Recent developments

Introduction

Functional food is defined as food which contains more functional ingredients that provides additional health benefits [1]. The increased interest in functional food ingredients and other natural food products has been recognized to promote excellent health, decrease the risk of mainly non communicable diseases and enhance cost effective care by promoting a quality of life [2]. The positive impact of nutritious foods on the human health has been long realized, which has led to the development of several innovative functional ingredients and functional food products. Functional foods have been linked with health improvement, quality of life, and decrease illnessrisk [3]. Algae derived nutrients and bioactive compounds are being investigated for their potential biological activities [4,5]. The algal metabolites are promising source of ingredients for the development of novel food products they are also good source of proteins, minerals, vitamins, amino acids, lipids, fatty acids, polysaccharides, nucleic acid, and carotenoids etc which are of immense value as nutritional supplements [6,7]. In view of this in recent years a lot of research has been carried out on the development of novel health foods from algal biomass. Algal biomass and extracts are used extensively in the formulations of gels, capsules, tablets, gums, bars, snacks, pastas, drinks, and beverages [8]. Algal biomass production can be improved through adopting innovative methods of enhancing biomass coupled to technological interventions for functional food applications. The main focus of this review is to provide an overview of functional ingredients from algae for food and health applications.

Functional ingredients from algae for health benefits

The main objective of functional food is to identify the health benefits of the specific ingredient(s). The functional attributes must be investigated using suitable *in vitro* or *in vivo* models and through human trials. A functional food needs though evaluation of biological activity at molecular level also based on the specific target sites as well. The science of interactions between genes and food ingredients also called as nutrigenomic is receiving attention to enhance the efficacy [9].

The design of a functional food should aim at increasing the benefits and reduce the risk. The benefit involves evaluation of physiological effects, enhanced bioavailability and efficacy. However the toxicity evaluation is to be made for determining the upper limits of administration or to set minimal effective levels (Figure 1).

Algae contain a large number of bioactive molecules with wide biological activities such as anti-oxidant, anti-bacterial, anti-viral, anti-carcinogenic etc. Some algae contain high fiber content in the form of sulphated galactans or carragenates in red algae, fucans, alginates, and laminarin etc. The consumption of high fiber containing diet has a progressive effect on human

health which reduces The risks of cancer, diabetes, obesity, and hypercholesterolemia. The high fiber content diet showed a good immunological activity [10,11]. Alginate in *Undaria pinnatifida* showed positive effect on cardiovascular disease, and alginic acid demonstrated to reduce hypertension in hypertensive rats [12]. Alginic acid, xyloglucans in *Sargassum vulgare* and sulphated fucans in *Undaria pinnatifida* have been shown to exhibit a powerful anti-viral activity against herpes type-1 and cytomegalovirus in humans [13,14]. The fucoidans from algae acts as anti-coagulant, anti-thrombotics agents and also showed anti-tumoral properties in rat model studies [15-17]. A sulphated polysaccharide from the red alga *Porphyra sp*. showed some apoptotic property in carcinogenic cells [16,18].

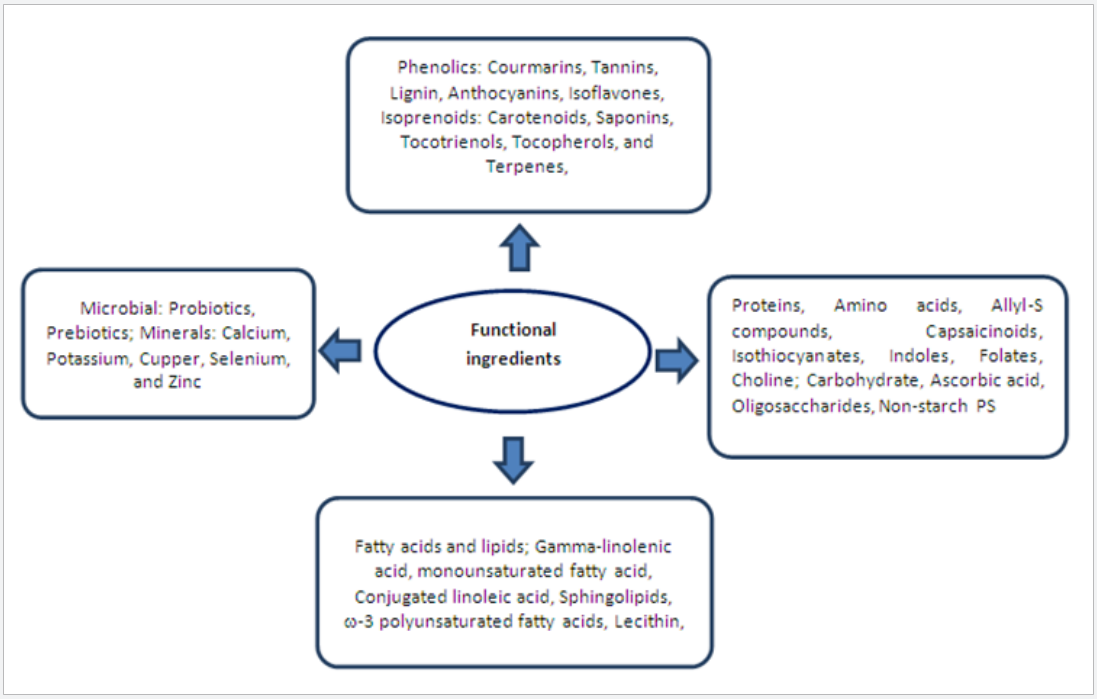

Figure 1: Common functional ingredients (Information obtained from Wildman 2007).

Antioxidants are the substances that have attracted major interest. Algae are exposed to various combinations of light and oxygen Which induces the formation of free radicals and oxidative reagents. The absence of structural damage in the algae may suggest that these organisms are able to generate the necessary compounds to protect themselves against oxidation. The most powerful antioxidants found in algae are carotenoids (astaxanthin, lutein, and β-carotene), polyphenols, phycobiliproteins and vitamins found in the algae. Thus algae are considered as an important source of antioxidant compounds for protecting cells against the reactive oxygen species formed by light or pollutions or other factors. The most important vitamin-E found in *Himanthalia elongata* (brown alga) is very stable to acids , heat, and unstable to alkali, oxygen and UV radiation. Algae also produce various carotenoids and xanthophylls. Several studies were conducted on carotenoids which unraveled the potential anti-oxidant and anti-cancer properties [19-23]. Xanthophylls obtained from *Undaria pinnatifida* have showed activity against cerebrovascular disease [12]. Algae are also a wonderful source of eicosapentanoic acid (EPA) reported in *Himanthalia elongata, Undaria pinnatifida* and *Porphyra sp*. These essential fatty acids such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) have demonstrated their effect on the reduction of coronary heart diseases, thrombosis and arteriosclerosis (Several clinical studies have been conducted using diets with sterols from algae which showed reduction in cholesterol levels in blood. Further, they have shown anti-inflammatory, anti-fungal, anti-ulcer, anti-ulcerative and anti-tumor activities in *in vitro* and *in vivo* studies [24-27]. The biochemical composition and biological activity of algae plays a major role in the selection of specific novel functional food ingredient for human health benefits. Many of the manufacturing companies are producing algal biomass for health food products for nutritional purpose (Table 1). Bioactive molecules such as phycocyanin, phycoerythrin, astaxanthin, β-carotene, polysaccharide from various micro algal species used in health food, dietary supplements, feed, pharmaceuticals, and cosmetics applications (Table 2). Bioactive molecules from algae show a potential as natural source of ingredients with diverse biological activities. However, once their importance is known there is a requirement to sustainable development of production system coupled to ecofriendly Downstream processing methods. Since algae are largely unexplored for biodiversity and biological activities, they hold tremendous promise for bioprospecting and to find novel biotechnological applications of functional ingredients for health benefits [31-34].

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Table 1: Some companies producing algal products for nutritional purpose.

Microalgae	Major Producers	Products
Spirulina	Earthrise Nutritionals, California, USA; Cyanotech, USA; Myanmar Spirulina factory, Myanmar; Bluebio Bio-Pharmaceutical Co. Ltd., China; Jiangsu Cibainian Nutrition Food Co. Ltd., China; Far East Bio-Tech Co. Ltd., Taiwan; Fuqing King Dnarmsa Spirulina Co. Ltd., China; Hainan Simai Pharmacy Co. Ltd., China; Nanjing General Spirulina Developing Corporation, China; Wuhan Sunrise Biotech Co. Ltd., China; Parry Nutraceuticals, India; Wellisen Nutraceuticals, India	Powders, extracts, Tablets, beverages, chips, pasta, liquid extract , biomass
Chlorella	Taiwan Chlorella Manufacturing Co. Taiwan; Bluebio Bio-Pharmaceutical Co. Ltd., China; Jiangsu Cibainian Nutrition Food Co. Ltd., China; Klotze, Germany; Wellisen Nutraceuticals, India	Tablets, powders, nectar, noodles
	Far East Bio-Tech Co. Ltd., Taiwan; Ocean Nutrition, Canada; Wudi Xinhui Chlorella Co. Ltd., China	Cosmetics, health care products
Dunaliella salina	Cognis Nutrition health, Australia	Powders and β-carotene
Aphanizomenon flos-aquae	Blue Green Foods, USA; Vision, USA	Capsules, crystals, powder, capsules, crystals

(Information obtained from Pulz & Gross [28]; Spolaore et al. [29]; Hallmann [30].

Table 2: Utilization of algae for food and health applications.

Algal species	Applications
Spirulina platensis	Phycocyanin, phycoerythrin, and biomass for health food, pharmaceuticals, feed, and cosmetics
Chlorella vulgaris; Chlorella spp.	Polysaccharides for dietary supplements, extracts for cosmetics; Biomass for health food, feed,
Dunaliella salina	β-carotene for health food, feed, dietary supplements, and cosmetics
Haematococcus pluvialis	Astaxanthin for health food, pharmaceuticals and feed additives
Chlamydomonas Reinhardtii	Biomass for animal health and feed; environmental monitoring; bioremediation, production of recombinant proteins
Isochrysis galbana	Fatty acids for animal nutrition
Nannochloropsis oculata	Lipids and fatty acids for animal nutrition; extracts for cosmetics
Porphyra spp.	Biomass for feed, food; extracts for cosmetics
Porphyridium spp.	Polysaccharides for nutrition, pharmaceuticals, and cosmetics, phycocyanin and phycoerythrin for pharmaceuticals, cosmetics and food
Phaeodactylum tricornutum	Lipids and fatty acids for nutrition

(Information obtained from Hallmann [30].

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