CHAPTER 1

Present and Future Prospects of Seaweeds in Developing Functional Foods

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Abstract

There has been a combined effort among scientists to explore and utilize varying food sources to develop functional foods to cater the ever-increasing demand from the consumers, who seek health-promoting roles of dietary compounds. Considering the diversity of biochemicals in seaweeds that are capable of exerting bioactivities,

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a growing trend is developing across globe to employ seaweeds in functional food development. Proteins, peptides, amino acids, polysaccharides, phenolics, lipids, vitamins, and minerals in seaweeds and their functional properties provide insights into the success of potential functional food products that can be developed utilizing seaweeds. However, several factors need to be taken into consideration in designing seaweed-based functional foods to obtain the market success. This chapter elaborates on the prospects of seaweeds in developing seaweed-based functional food products.

I. FUNCTIONAL FOODS AND DISEASE PREVENTION

"Let food be thy medicine and medicine be thy food" Hippocrates, 460 BC. Identification of the relationship of foods and prevention from a range of diseases in human goes back to several centuries. It is noteworthy to comprehend that along with the ever-increasing consumer expectations toward convenient foods, the desire to maintain and improve health remains the key driver in the consumer goods market. Apparently, consumer awareness on the diet is gradually improving, and increasing health consciousness of modern consumers emphasizes on the broader idea of "wellness" obtained through optimum nutrition. Further, health challenges coming in the mode of chronic diseases that prevail mainly among the aging population compel the consumers to reevaluate their nutrition and life style choices they adapted for years. Dietary transitions are becoming common as a result of this reevaluation process where consumers become proactive in reducing risk of the occurrence of chronic diseases and trying to manage the diseases without medical interventions. In this context, consumers are becoming highly receptive for functional foods and beverages seeking health-promoting roles of dietary compounds. Consequently, food industry has ramped up the development and marketing of diverse group of functional food products using different sources of foods on which biological assays have confirmed their beneficial effects related to the disease prevention and health promotion (Gray *et al*., 2003).

Functional foods can be developed in many forms. Conventional foods with bioactive components can be presented claiming positive health outcomes. Some may be fortified or enhanced foods, specifically created to reduce disease risk associated with a certain group of people. Although most foods have its own function, in this chapter "functionality" is ascribed to a specific phenomenon widely accepted by the scientific community involved in this field which is defined as "functional foods are foods and food components that provide a health benefit beyond basic nutrition for the intended population. These substances provide essential nutrients often beyond quantities necessary for normal maintenance, growth and development, and/or other biologically active components that impart health benefits or desirable physiological effects'' (Anonymous, 2005). Further, this definition emphasizes the positive health benefits of food components not considered nutrients in the traditional definition.

A. Emerging trends in the functional food industry

When surveying the world market for functional foods, it is evident that distinct trends are emerging in different parts of the world. Apparently, some functional food categories common to most regions are emerging faster and will significantly outperform during the years ahead (Farkas, 2000). Analyzing trends across globe, it is predicted that digestive health and heart health will be key areas of focus in developing functional food products for the years to come. Based on worldwide analysis of new introductions of functional food categories, products that are focused on digestive health are capturing the interest of a broader audience than products with a narrow focus such as products targeting specific illnesses. In parallel to the ramped up need for the improvement of dietary health, foods with probiotics, prebiotics, and dietary fiber are capturing the interest of consumers and food manufacturers. Similarly, a great industry emphasis is given to development of designer beverages such as energy and sports drinks. This has a link to consumer preference to go for wide range of food or beverage products that claim ''energy boosters,'' ''high vitamins,'' ''high minerals,'' and ''high antioxidants,'' and products promoting their antioxidant capacity specifically are getting flooded to the consumer markets to meet this demand. There are products in the market claiming that they are made out of ''super fruits,'' fruits which are having higher antioxidant power as they contain phytochemicals responsible for antioxidative mechanisms. Further, among claims relating minerals, in food products ''with calcium,'' ''high in calcium'' type of health claims are increasingly exploited.

Though it is a focus of a narrow audience to look for products focusing heart health, products with low saturated fats and cholesterol are admired by the majority of the consumers. In the same arena, ω-3 fatty acids are still maintaining its recognition among consumers having identified its effects including protection against cardiovascular disease, various inflammatory and autoimmune conditions, and enhanced cognitive health. In recent years, there was concentration toward products targeting the women population composed of active ingredients capable of fighting against bone-related complications, pregnancy, or menopause-related issues. Wider coverage in research is given for phytoestrogens and phytosterols available in this category of products among other phytochemicals. Further, soy protein inclusions are getting highly recognized by women population due to their ability to reduce the risk of heart diseases by lowering blood cholesterol levels, promoting bone health, and easing symptoms of menopause. Further, there is an increasing demand for products targeting children. Active ingredients are added in these products and are capable of supporting brain development of infants, immunity enhancement, and acting against allergy reactions in the body. Also some of these products are aiming at promoting healthier eating habits and active life styles among children to prevent the unprecedented growth of obesity and related complications. Functional protein, peptides, and amino acids from different food sources are also renowned, and among them, soy protein concentrates are gaining much popularity attributed to the functional properties specifically toward women population. Other than that, there are products that are becoming popular for their functional effects relating development of healthier skin, energy supplements, weight management, cognitive boosters, antihypertension, anticarcinogenic and antiallergic properties.

II. POTENTIAL OF SEAWEEDS AS A SOURCE TO DEVELOP FUNCTIONAL FOODS

There has been a combined effort among biochemists, biologists, food technologists, and nutritionists to explore and utilize varying food sources of both terrestrial and marine origin to cater the demand from the consumers who eagerly look forward to have optimum nutrition through their dietary interventions. Further, they quest for health benefits associated with these food sources knowing the current need for molecules with novel modes of action to face emerging diseases, seeking proactive approach than ''firefighting'' with medical interventions. When considering the sustainability of different sources, photosynthetic algae are the most heterogeneous group of organisms and considered the true survivors of the planet as they have been capable of facing the dramatic changes in climatic conditions for centuries and to occupy virtually all niches on earth with a ubiquitous distribution. Seaweeds are taxonomically classified as algae and they belong to four major seaweed classes, the rhodophyceae (red algae), the phaeophyceae (brown algae), the cyanophyceae (blue-green algae), and the chlorophyceae (green algae). A greater diversity in biochemical composition of seaweeds paves the path to explore variety of compounds in their bodily composition with a wide range of physiological and biochemical characteristics, many of which are rare or absent in other taxonomic groups (Holdt and Kraan, 2011).

Knowing the benefits associated with the seaweeds through the experience, seaweed has been used as an important dietary component for centuries in countries like China, Japan, and Korea. However, seaweeds are attracting increasing attention as a valuable food source in other parts of Asia, Africa, and also other western parts of the world, and growing interest is developing to explore all possible seaweed interventions including functional food product development. For this purpose, several countries other than China, Japan, and South Korea have commercially exploited open and closed cultivation systems to grow seaweeds at large scale. These countries are expected to increase culturing of seaweeds dramatically over the years to come. Further advances in science and technology have provided researchers the required know-how and powerful analytical tools to better characterize the physiological roles of bioactive compounds from seaweeds in disease prevention and health promotion. Research currently underway at academic, industry, and government facilities will reveal how a myriad of substances from seaweed sources can be used as functional food products. Moreover, growing consumer interest in functional foods developed using marine sources has been seen as a significant business opportunity for the agri-food sector, and among them, greater potentials exists to promote the utilization of seaweeds in the functional food industry. Recognizing the market potential for functional foods, a number of firms all over the world have begun to capitalize on these emerging markets.

III. BIOCHEMICAL COMPOSITIONAL ANALYSIS OF SEAWEEDS THAT CATER TO THE POTENTIAL OF SEAWEEDS AS A SOURCE TO DEVELOP FUNCTIONAL FOODS

Scientific reports dealing with functional effects of seaweed proteins, peptides, amino acids, polysaccharides, phytochemicals, lipids, and minerals greatly endorse the efforts toward development of ''health foods'' using seaweeds. Table 1.1 provides some seaweed species studied and recognized for their richness in functionally important molecular groups. Evaluation of functional properties requires a clear idea about their biochemical composition, and it provides a platform to have an inspiration to decide on the molecules responsible for different biological activities.

A. Seaweed proteins, peptides, and amino acids

Percentage of proteins in seaweeds varies from about 10% to 40% (w/w) per dry weight, and it varies according to the season and the species (Murata and Nakazoe, 2001). Red algae are rich sources of proteins compared to other divisions of algae. Among the proteins present in

TABLE 1.1 Seaweed species studied for their richness in specific bioactive compounds

Bioactive compound(s)	Seaweed species
Total polysaccharides	*Saccharina latissima*, *Sargassum pallidum*
Carrageenan	*Chondrus crispus*, *Eucheuma cottonii*
Agar	*Gracilaria cornea*, *Gracilaria domingensis*
Algins/alginic acid	*Laminaria digitata*, *Laminaria hyperborea*
Fucoidan	*Fucus vesiculosus*, *Ascophyllum nodosum*
Laminarin	*Fucus vesiculosus*, *Laminaria hyperborea*
Ulvan	*Ulva lactuca*, *Ulva rigida*
Total protein	*Undaria* spp., *Sargassum* spp.
Lectins	*Ulva* sp., *Eucheuma amakusaensis*
Phycobilliproteins	*Palmaria palmata*, *Gracilaria tikvahiae*
Taurine	*Saccharina latissima*, *Porphyra tenera*
Kanoids (kainic and domoic acid)	*Palmaria palmata*, *Digenea simplex*
PUFA (ω-3 fatty acids)	*Laminaria digitata*, *Saccharina latissima*
Phlorotannins	*Ascophyllum*, *Fucus* spp.
Carotenoids	*Laminaria digitata*, *Fucus serratus*
Iodine	*Laminaria japonica*, *Laminaria digitata*
Calcium	*Porphyra tenera*, *Ulva lactuca*
Vitamin B_{12}	*Ulva lactuca*, *Porphyra tenera*

Source: Holdt and Kraan (2011).

seaweeds, lectins, a group of hemagglutinin proteins that bind with carbohydrates, have captured the interest of researchers due to their ability to take part in host–pathogen interactions, cell–cell communication, recognizing and binding carbohydrates and to exert functional effects to induce apoptosis, metastasis, and cell differentiation in cancer cells, antibiotic, anti-inflammatory, anti-human immunodeficiency virus (anti-HIV) activity, and human platelet aggregation inhibition (Hori *et al*., 2000; Mori *et al*., 2005; Smit, 2004).

Other than the lectins, phycobilliproteins (phycocyanins and allphycocyanins) are popular for their potency to exert functional effects in the mode of anti-inflammatory, liver protecting, antiviral, antitumor, anti-atherosclerosis, lipase activity inhibitor, serum lipid reducing agent, and antioxidant, and to obstruct absorption of environmental pollutants into the body (Sekar and Chandramohan, 2008). Seaweed peptides obtained through the enzymatic digestion process have shown several biological activities including antioxidant, antimicrobial, antithrombotic, immunomodulatory, and mineral binding activity (Smit, 2004). These peptides are inactive in the amino-acid sequence of the parental protein and become active upon release through the enzymatic digestion. *In vitro* and *in vivo* studies that have been carried out using water extracts of seaweeds have confirmed that dipeptides in extracts are capable of acting against hypertension through inhibition of angiotensin I converting enzyme (Sato *et al.*, 2002).

The free amino-acid fraction of seaweed is a mixture of amino acids and is mainly composed of taurine, alanine, amino butyric acid, omithine, citrulline, and hydroxyproline (Holdt and Kraan, 2011). Taurine is an amino acid present in high concentration in red algae. It also acts as an antioxidant and protects against toxicity of various heavy metals such as lead and cadmium by preventing their absorption in the stomach. Taurine has been shown to be effective in reducing the secretion of serum lipids and apolipoprotein B100, a structural component of low density lipoproteins, thereby reducing the risk of atherosclerosis and coronary heart disease. These finding have been followed and supported by several other research reports that taurine supplementation exerted a hypocholesterolemic effect in young overweight adults. Taurine has also shown its capability to relieve complications in people with congestive heart failure by increasing the force and effectiveness of heart–muscle contractions (Lourenço and Camilo, 2002; Mochizuki *et al.*, 1999). The kainoid amino acids, kainic, and domoic acids have also been found in numerous algal species. They act as central nervous system stimulants upon exceeding the safe levels and become neurotoxins. These compounds are currently used in research associated with neurophysiological disorders such as Alzheimer's and Parkinson's disease and epilepsy (Harnedy and FitzGerald, 2011).

B. Polysaccharides

Presently sulfated polysaccharides are the group which is identified as economically most important among other ingredients found in algae that have been extensively used in the industry for food and medicinal purposes. Red algae and brown algae are the classes that produce these polysaccharides of interest in higher concentrations. These polysaccharides act as dietary fiber as they are not digested in the upper digestive tract but may be degraded by the colonic bacteria to some extent in the colon. Direct comparisons show that, in most of the seaweeds dietary, fiber amounts are similar or slightly elevated than the levels of total fiber in terrestrial foodstuffs. Edible seaweed contain 33–62% total fibers on a dry weight basis, which is higher than the levels found in higher plants, and these fibers are rich in soluble fractions (Dawczynski *et al.*, 2007; Lahaye, 1991). A growing interest can be seen among researchers to study the roles of polysaccharides in the human body particularly how they prevent the occurrence of certain diseases.

Carrageenans are generally identified as carbohydrate antigens and has the potency to promote the growth of connective tissues. Antiviral properties of few algal species have been studied extensively including *Chondrus crispus* and *Gelidium cartilagineum*, the species produce agar and carrageenan in higher concentrations. Researchers have concluded that this property is attributed to the galactan units available in agar and carrageenan of these algal species. Current research develops strong evidences to promote carrageenan as an useful antiviral agent that blocks the transmission of the HIV virus as well as other STD viruses such as gonorrhea, genital warts, and the herpes simplex virus (Buck *et al.*, 2006). Carrageenan is also studied extensively in ulcer therapy, and it has been concluded that carrageenan is involved in developing protective layer by interacting with the mucoid lining of the stomach and thereby preventing enzymes and acid secretion (Emerson and Kerkut, 1974). Agar has similar structural and functional properties as carrageenans. Both agar and carrageenan have the ability to exert effects in modifying the adhesion and proliferation of normal and tumoral human colonic cells thereby affecting the process of metastasis (Zhou *et al.*, 2006).

Other important polysaccharide, alginic acid, is present naturally in seaweeds as calcium or magnesium salts which are insoluble in water. Algins/alginates are extracted from brown seaweeds and are available in both acid and salt forms. Commercially alginic acid is extracted mainly from brown seaweeds as soluble sodium alginate. Sodium alginate is reported to serve as a coadjutor in immunization against strain-specific influenza virus. Sodium alginate also has tried in the treatment of esophagitis and urolithiasis. It has the ability to function as a haemostatic agent which is capable of clotting blood *in situ*. Alginates have the capability to act like fibers and help clearing the digestive system to protect surface membranes of the stomach and intestine from potential carcinogens. Further, this feature has a link with its ability to prevent proliferation of implanted cancer cells in the stomach. Moreover, alginic acid and its derivatives are used for the production of drugs in the treatment of gastritis and gastroduodenal ulcers, as well as alginates are used as antiulcer remedies. The mechanism action of these materials has a link to its ability to effectively suppress postprandial acidic refluxes and binding of bile acids. Alginates are capable of reducing hypertension through several mechanisms including physical binding of sodium in the gastrointestinal tract and calcium channel blocker activity (Draget and Taylor, 2011).

The polysaccharide laminarin is commercially extracted mainly from kelp and fucoids and is a main form of food storage of brown algae. Sulfated laminarins have antilipidemic activities and capable of reducing serum cholesterol levels and total serum lipids (Kiriyama *et al.*, 1969). The anticoagulant activity of this material is attributed to its antithrombotic property, and laminarin only shows anticoagulant activity after structural modifications such as sulfation, reduction, or oxidation (Miao *et al*., 1999). Structural similarity of laminarin to barley, which is potent prebiotic, has prompted the study of laminarin as a prebiotic. Studies have proved that laminarin provides a substrate for prebiotic bacteria and promotes their growth and function in human (Deville *et al*., 2004). Further, laminarin has proved to be involved in modulating the gut environment and act as an immunostimulant. Further studies have revealed the potential of laminarin as a cancer therapeutic and as a tumor inhibiting agent (Miao *et al*., 1999).

Fucoidan, another polysaccharide of brown algae, is not found in other algae or in higher plants. Fucoidan has shown promising antiviral, immunomodulating, and antibacterial activities. Fucoidan inhibits the angiogenesis and promotes apoptosis in human cancer cells. Further, it inhibits the proliferation of tumor cells and thereby reduces the growth and the size of the tumor. Further, this compound has proven its capability to act as anti-inflammatory and anticoagulant agents. Further, fucoidan preparations have been proposed as an alternative to the injectable anticoagulant heparin considering its safety being free of viruses as they originate from plant matter and exert protective effects through direct inhibition of viral replication against HIV, hepatitis, and herpes viruses. Further, fucoidan has reputed for its ability to stimulate the immune system by acting as an immunomodulator directly on macrophage (Li *et al*., 2008).

Ulvan is a water soluble polysaccharide obtained from members of the Ulvales. Bioactive properties of ulvan such as cytoxicity against colonic cancer cells through modification of the adhesion and proliferation of tumoral human colonic cells and modulating the expression of transforming growth factors related to cellular differentiation are reported. Further, there are reports to confirm that ulvan acts as an antiviral and antibacterial agent (Lahaye and Robic, 2007).

C. Phytochemicals

The secondary metabolites of seaweeds have always attracted the interest of biochemists because of their diversity as compared with those present in the leaves of higher plants. Isoprenoids (e.g., terpenes, carotenoids, steroids), polyketides (e.g., phlorotannins), amino-acid-derived natural products (e.g., alkaloids), and shikimates (e.g., flavonoids) are the major groups of secondary metabolites found in algae. Compared to other macroalgae, rhodophyta are richer sources of these secondary metabolites. Exceptionally, Phlorotannins, or polyphenols, are recognized as structural classes of polyketides found exclusively in brown algae. Phlorotannins are constructed through the polymerization of phloroglucinol units to form polyphloroglucinols. These polyphloroglucinols are composed of six major groups: fucols, phlorethols, fucophlorethols, fuhalols, isofuhalols, and eckols. They possess strong antioxidative properties and act against oxidative stress (König and Wright, 1993). Certain polyphenols work as preventative medicines for problems such as cardiovascular diseases, cancers, arthritis, and autoimmune disorders that have a direct link with oxidative stress (Yuan *et al.*, 2005). Further, phlorotannins has bactericidal activity (e.g., anti-*Staphylococcus* activity) together with other therapeutic perspectives.

Flavonoids and their glycosides present in green, brown, and red algae also have exhibited antioxidative properties and have demonstrated their capability to act against atherosclerosis and cancer. Fucoxanthin, β-carotene, and violaxanthin are carotenoids found in seaweeds and exhibit powerful antioxidant properties. Further, fucoxanthin has demonstrated strong anticancer effects and has demonstrated its capability to prevent obesity (Hosokawa *et al.*, 1999). The correlation between a diet rich in carotenoids and a diminishing risk of cardiovascular diseases and ophthalmological diseases has been backed by the recent research carried out using different types of carotenoids in cellular systems and human intervention studies.

Halogenated compounds, another type of metabolites found in algae, are produced mainly by the brown and red algae, and among other halogenated compounds, polyhalogenated monoterpenes found in red algae have exhibited anticancer, antimicrobial, and antitubercular functionalities (Cabrita *et al.*, 2010). A greater number of researches on varying type of secondary metabolites are progressing fast, and their biological mode of actions and efficacies in human dietary interventions are yet to be confirmed (König and Wright, 1993).

D. Lipids

In general, seaweeds are recognized to contain low amounts of lipid, however, polyunsaturated fatty acids (PUFAs) found in algae have attracted the attention due to their biological effects which have implications in human health. However, amounts and concentrations of these PUFAs are greatly varied according to environmental temperature, being the lower temperatures favoring their production. When comparing the two families of PUFAs found in the human diet (ω-6 fatty acid and ω-3 fatty acid), ω-3 PUFAs are of particular interest in the emerging field of functional food development. This is attributed to the properties of ω-3 PUFAs, eicosapentaenoic (EPA), and docosahexaenoic acids (DHA) that are linked to a range of biochemically and physiologically important functions in the human body. However, EPA has been reported as the predominant fatty acid in various seaweeds. A greater number of scientific evidences support the efficacy of ω-3 PUFA as agents possessing antiarteriosclerotic, antihypertensive, anti-inflammatory, and immunoregulatory effects (Khan *et al.*, 2007; Plaza *et al.*, 2008).

Reports provide evidence that the phospholipids are the prominent type in the composition of lipids in seaweeds and they provide better compounds for food applications than fish oil attributed to their greater resistance to oxidation and higher degree of bioavailability. Sterols are also an important part of seaweed lipids due to their different compositional and functional effects in the human body. The predominant types and amounts of sterols in seaweeds vary to a greater extent. Red algae contain primarily the cholesterol, and fucosterol is the predominant sterol type in brown algae. Fucosterol reduces the absorption of cholesterol into the bloodstream by restricting the solubility of cholesterol in bile acid (Ikeda *et al.*, 1988). The sterol composition in green algae varies greatly among species, and isofucocholesterol, cholesterol, 24-methylene-cholesterol, and β-sitosterol are frequently found among others. Prolonged consumption of sterols from marine algae is reported to reduce the tendency to form a fatty liver and excessive fat deposition in the heart of human.

E. Minerals and vitamins

Seaweeds are rich sources of some important minerals and vitamins. In particular, seaweeds contain good amounts of iodine, calcium, and iron among others. Iodine content of seaweeds is incomparable with the highly consumed terrestrial vegetables as seaweeds are much better sources of iodine. However, amounts are varied with phylum, season, and environmental, geographical, and physiological variations. Brown algae have recognized as much important sources of iodine and have utilized extensively for the prevention and treatment of iodine deficiency goiter. Further, scientific reports link the potential of iodine in inhibiting tumorogenesis with the high amount of iodine in some seaweed species (Funahashi *et al.*, 1999). In line with this capability of iodine in seaweeds, epidemiological studies suggest that high dietary seaweed content must have accounted for the low prevalence of breast cancer in some countries of Asia.

Seaweeds are also rich sources of calcium which provides a greater potential to be used in functional food developments attributed to their higher calcium concentration and easy assimilation (in the form of calcium carbonate) in to the body compared to calcium in cow's milk (in the form of calcium phosphate). Further, seaweeds provide good sources of vitamins such as vitamin E, A, and B12 and have a greater potential to be exploited in functional food categories in demand (Berg *et al.*, 1991).

IV. PRESENT SITUATION AND POTENTIAL OF SEAWEEDS FOR NOVEL FUNCTIONAL FOOD PRODUCT DEVELOPMENTS

Seaweeds have long been recognized as potential sources for the phycocolloid industry dealt with agar, carrageenan, furcellaran, and algin to use as food additives in the modes of stabilizers, texture enhancers, viscosity modulators, gelling agents, etc. Seaweeds have gained the popularity in the international trade specifically for these phycocolloids, dried seaweeds, and products of laminarin and fucoidans. With the increased understanding of the health beneficial properties of these seaweed compounds, considerable efforts have been exerted in discovering more direct therapeutic-related food applications, but, despite high expectations, no commercially successful product ranges have yet been developed utilizing these compounds targeting optimum health and nutrition of human. Very few seaweed-based functional food products can be seen covering a narrow market niches such as powder forms of alginates and carrageenans, phytocomplexes fortified with fucoidans, aligns, minerals and vitamins from seaweed sources, β-carotene as vitamin supplements, seaweed protein powders, fiber complexes fortified with phytochemical extractions from seaweeds, etc. However, their success as a functional food product in the market is not up to the expectation. Fortification of food products having higher consumer acceptance with seaweed bioactives would provide an opportune approach to popularize health benefits of seaweeds among consumers and very few such efforts are reported recently (Kadam and Prabhasankar, 2010; López-López *et al*., 2009). It is an agreeable fact that functional foods present major challenges for the food industry as they appear to be a new and unfamiliar territory for product developers in marketing and developing business strategies. This is mainly because translating scientific advances and nutritional innovations into consumer products is a costly and complex process. Sound science must underlie the development, marketing, and regulation of these new functional foods to gain success. Further, one needs to understand that the functional food trends are more heterogeneous than homogeneous, evolving and growing at different rates both within and across countries, owing to sociodemographic and sociocultural differences, and functional food products needs to be developed to match with the interests of the target populations (Wim, 2005).

Successful functional product innovations dealt with other food sources have been mainly launched targeting the markets for nonalcoholic beverages fortified with the vitamins or other functional ingredients, breakfast cereals, cholesterol-lowering spreads, confectionery, biscuits, cereal, cereal bars, soft drinks, probiotic and prebiotic dairy products, isotonic drinks, bakery, and hypoallergenic baby foods. Further, ever-concerning chronic disease-related conditions such as cancer, high cholesterol, coronary heart diseases, atherosclerosis, stroke, hypertension, diabetes (type II), gastrointestinal disorders, osteoporosis, intestinal complications, and immune disorders including allergy have been used as prime focuses when developing these functional food products. When analyzing the supply structure of these functional foods, the main types of successful actors in the commercial functional food segment are multinational food companies with a broad product range and pharmaceutical or dietary products producing companies. Therefore, the combination of consumer acceptance, advances in science and technology, and scientifically backed evidence linking consumption of biochemical compounds in seaweed to disease and disease prevention can be taken as unprecedented opportunity for these food marketers to develop seaweed-based functional products to address nutritional and health-promoting demands of consumers. Hence, they can take the challenge of developing novel food products using seaweeds with their wider experience in handling other functional food categories. Today's science and technology can be used to provide many additional functional foods, and future scientific and technological advances promise an even greater range of health benefits for consumers through seaweed-based functional food innovations. Other than these main factors, the extent of cultivation needs to be expanded to which raw seaweed demands can be met at competitive prices, and further efforts are needed to explore new sources of algae so far neglected. Further, in obtaining the success in the market, strategic planning is required to enhance the knowledge and awareness of the consumers about health effects of seaweeds-related functional ingredients. Moreover, the long-term success of a functional food for health and well-being depends on perspective and the alignment of a number of interests and different stakeholders such as health sector, food industry, technologists, scientists, regulators, and even environmentalists. Therefore, a dialog needs to be initiated among researchers, industry, regulators, and other important stakeholders to initiate strategies to promote this invaluable natural resource of food to develop successful functional food products to the market.

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