CHAPTER 3

Marine Edible Algae as Disease Preventers

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Abstract

As modern lifestyles and new feeding habits settle in the world, noncommunicable diseases (NCDs) have evolved to be major causes of disability in developing as well as developed countries. As a concomitant effect, there is a growing interest in natural, healthy food and an increasing awareness of risk factors and determinants of disease. This chapter describes some nutritional facts about seaweeds, which have been used as food since ancient times in China, Japan, Egypt, and India and comments on the potential utilization of marine algae as functional foods.

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This concept and the description of metabolic syndrome are used as a basis to comprehension of seaweeds against two dreadful illnesses of our times: high blood pressure and cancer.

I. INTRODUCTION

For centuries, mankind has relied on food as a main source of well-being and health. An improved nutrition and better healthcare are among major factors determining life expectancy, which has increased all over the world (WHO, 2011). However, modern lifestyle and current feeding behavior have fostered the development of illnesses due to physical inactivity; overweight and obesity, and other diet-related factors; and tobacco and alcohol-related risks. The evolution of the human diet over the past years has adversely affected health, and chronic diseases cause substantial disability and death, disease prevalence being one major challenge. Chronic diseases, including obesity, diabetes mellitus, cardiovascular disease (CVD), hypertension and stroke, and some types of cancer, have become the target in a fight where marine algae may play a major role.

II. MARINE ALGAE AS FOOD HEALTH PROMOTERS

Ancient times witnessed the health benefits linked to seaweed consumption by Eastern countries. This utilization of marine algae can be traced back to the fourth century in Japan and the sixth century in China, although archeological evidences also indicate that seaweeds were included in folk medicine for many thousands of years in Japan, China, Egypt, and India (Fakoya *et al.*, 2011). Today, Japan, China, and the Republic of Korea are the largest consumers of seaweeds as food (FAO, 2003).

Despite the scarce knowledge on composition and nutritional value of marine algae, oriental communities included them in their dietetic habits centuries ago, and nowadays, they have a long traditional use of marine algae as food. As more information about algae components is being accumulated, more people around the world are becoming familiarized with ''sea vegetables'' as part of a regular diet and, slow but steadily, cooking recipes are incorporated in Western countries.

In the past three decades, many authors have published on the chemical composition of diverse species of algae; however, there is still a lack of studies on the nutritional properties of a great variety of species, and even the most popular edible seaweeds are incompletely known which is understandable, given the enormous number of species that occur worldwide, around 12,000. Despite this incompleteness, data on major edible seaweeds might be used to point out some representative nutritional facts to make some statements on their value as foodstuff. A comparison can be made using published data on the composition of edible seaweeds and the amounts of typical intakes through both western and eastern diets, applying typical nutritional indicators. Daily consumption of seaweed is difficult to establish since they are used in a variety of ways: noodles, soups, snacks, salads are some of the dishes that can be prepared. However, some approaches are useful to determine a common measure and be able to compare on a portion basis. According to the third Korean National Health and Nutrition Survey, the daily intake of seaweed is 8.5 g/d. In Japan, a daily typical consumption in that country is up to 10 g/d (Teas *et al.*, 2004). For Koreans, diet is based on *Porphyra* sp., *Undaria pinnatifida*, and *Laminaria* sp. seaweeds which constitute over 95% of seaweed consumption in Korea. In Japan and China, *Monostroma* sp., *Hizikia fusiformis*, *Ulva* sp., and *Palmaria palmata* are also used as food, and all of them are among the most commonly consumed algae which are being incorporated into Western dietetic habits (FAO, 2003). Well known are also species of *Gracilaria*, *Gellidium*, *Sargassum*, *Caulerpa*, and *Ascophyllum*. Using this information, a comparison is made using common measures (portions) of usual foods in an occidental diet (Table 3.1).

III. ALGAE AS FUNCTIONAL FOOD: THE PREVENTING DISEASE POTENTIAL

Experts around the world have joined efforts to provide tools for international organisms as the Food and Agriculture Organization of the United Nations and the World Health Organization to make recommendations regarding the prevention of chronic diseases and the reduction of their impact. Information has been gathered, reviewed, and systematized in order to have an overview of the so-called noncommunicable diseases (NCD) (WHO, 2003). According to their report, changes in dietary and lifestyle patterns, chronic NCDs—including obesity, diabetes mellitus, CVD, hypertension and stroke, and some types of cancer—are becoming increasingly significant causes of disability and premature death. According to WHO statistics, in 2008, NCDs caused an estimated 36 million deaths worldwide, up from 35 million in 2004 (WHO, 2011). Among the causes of main chronic disease epidemics, unhealthy diet, excessive energy intake, over weight, and obesity are widely documented as major modifiable factors. As the global burden of chronic diseases have steadily increasing, there is growing interest on prevention to keep the world far from the leading global risks for mortality in the world: high blood pressure (BP), tobacco use, high blood glucose, physical inactivity,

TABLE 3.1 Nutrition facts about edible seaweeds

Nutrient	Nutritional facts [a,b]	Reference
Fiber	Fiber in *Ulva lactuca* (5.3 g) is as high as one of papaya (5.2 g) and in *Ulva rigida* (4 g) is similar to bananas (3.9 g). *Laminaria digitata* and *Enteromorpha* sp. contain (3.6 g) slightly more fiber than a portion of rice brown (3.5 g), blueberries (3.5 g), or cooked mushrooms (3.4 g). Fiber in a portion of *Porphyra umbilicalis*, *Porphyra tenera*, *Palmaria palmata*, *Ascophyllum nodosum*, or *Undaria pinnatifida* is almost the same (3.3 g) as a portion of raw carrots (3.1 g), raw mangos (3.3 g), oranges (3.1 g), strawberries (3.3 g), or dates (3.3 g). In these algae, fiber content is higher than in a portion of nuts (2.8 g), wheat bran muffin (2.8 g), or a slice of both wheat and rye bread (2.8 g) or multigrain bread (1.9 g).	Wong and Cheung (2000), Taboada (2002)
Calcium	A portion of *Caulerpa veravelensis* provides 395 mg of calcium, an amount similar to the amount provided by a portion of a milk shake with thick chocolate (396 mg) or one portion of low fat milk (305 mg). *Sargassum polycystum* contains (360 mg) more calcium than a portion of low fat yogurt with fruit (345 mg), one of low fat milk enriched with A and D vitamins (305 mg) or one of plain yogurt made of whole milk (275 mg). *Ulva lactuca*, in one portion, has more calcium (257 mg) than a portion of cheese: swiss (224 mg), provolone (214 mg), (207 mg) or cheddar (204 mg).	Mac Artain *et al*. (2007), Matanjun *et al*. (2009), Kumar *et al*. (2011)
Vitamin C	*Gelidiella aerosa* has a vitamin C content (311 mg) higher than a glass of concentrated, undiluted, orange juice, which is the highest reported content of vitamin C (293.7 mg). *Padina pavonica* and *Ulva reticulata* have 242.25 and 232 mg respectively, higher than other raw juices: papaya (185 mg), orange(124 mg), grapefruit (94 mg), or a portion of strawberries (97.6 mg).	Chang *et al*., 1997, Matanjun *et al*. (2009), Mac Artain (2007), Anantharaman *et al*. (2011)

ω-3 PUFA	Seaweeds have small levels of lipids (1–5%), but they have high contents of n-3 and n-6 fatty acids; also have an n-6:n-3 ratio around 1. *Sargassum polycystum* provides 77.5 mg of ω-3 and 75.6 of ω-6; in a portion of *Eucheuma cottoni*, 256 and 26 mg of n-3 and n-6 respectively. *Ulva lobata* has 95 mg of n-3, 4 mg of n-6, and a 0.04 ratio. *Palmaria palmate* provides 85.5 mg of n-3 and 1.2 mg of n-6.	Matanjun *et al*. (2009), Nelson *et al*. (2002), van Ginneken *et al*., 2011
Potassium/ Sodium Ratio	Seaweeds with a ratio (K/Na) equal to or higher than 2.0 and high potassium content (K): *Laminaria digitata* (3.2; K, 1159 mg), *Himanthalia elongata* (2.25; K, 360 mg), *Porphyra umbilicalis* (2.5; K, 252 mg), *Palmaria palmata* (4.6; K, 694 mg), *Enteromorpha* sp. (6.8; K, 257 mg), *Gracilaria corticata* (3.3; K, 1334 mg), *G. pudumadensis* (1.9; K, 1087 mg), *Sargassum myriocystum* (2.2; K, 1153 mg) and *S. polycystum* (6.1; K, 8371 mg).	Sivakumar and Arunkumar (2009), Matanjun *et al.* (2009)

[a] A Portion 9.5 g/d (dry matter) for seaweed.
[b] For terrestrial foods, each portion is equivalent to standard food portions. U.S. Department of Agriculture, Agricultural Research Service 2010. USDA National Nutrient Database for Standard Reference, Release 23. Nutrient Data Laboratory Home Page. Available at: http:/www.ars.usda.gov/ba/bhnrc/ndl.

and overweight and obesity since they are considered to be responsible for raising the risk of chronic diseases, such as heart disease and cancers.

A. Risk factors for chronic disease: The metabolic syndrome (MetS)

The metabolic syndrome (MetS) is a combination of medical disorders integrated to have a useful description of related cardiovascular risk factors which also predict the risk of developing diabetes. Although there have been arguments against the use of a minimalistic view for these diseases, there is currently a unifying definition for the MetS (Fig. 3.1). According to this (Alberti *et al.*, 2006), obesity and insulin resistance appear to be the causative factors in the development of the MetS. General features include obesity, insulin resistance (correlated with the risk of Type 2 diabetes and CVD), atherogenic dyslipidemia (increased triglycerides and HDL cholesterol), elevated BP, elevated C-reactive protein (CRP; proinflammatory state), and a prothrombic state, associated with coagulation and fibrinolytic proteins. Scientific effort has been done to clarify associations between MetS factors, and after decades of effort, some facts can be stated:

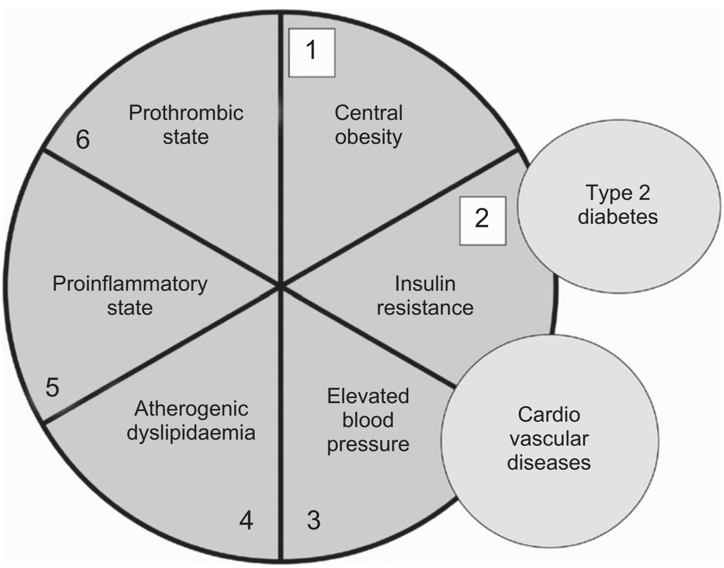

FIGURE 3.1 General features of MetS. Obesity and insulin resistance are causative factors in the development of the MetS. Insulin resistance and elevated blood pressure are related to cardiovascular diseases.

- Causes of atherosclerosis include obesity, age, smoking, hypertension, hypotension, abnormalities of bone and mineral homeostasis, and disturbances of lipid metabolism and insulin resistance.
- Insulin resistance is part of the natural history of Type 2 diabetes and may be present years before the clinical diagnosis; cardiovascular risk factors are strongly related to insulin resistance.
- Atherogenic dislipidemia, characterized by high triglycerides and low high density lipoprotein, leads to coronary heart disease (CHD).
- BP and cardiovascular risk related; elevated BP is one of the major risk factors of CVDs worldwide.
- BP and CVD (CHD, stroke, heart failure, etc.) are strongly related.
- A proinflammatory state means elevated CRP values, and this strongly predicts future coronary events.
- Inflammation and thrombosis influence the pathogenesis of CHD. The inflammation may favor blood clot formation.

B. Metabolic syndrome prevention

The WHO, in the 2009 report, states that high BP ranked first in the list of leading global risks for mortality and accounted for 7.5 million deaths in the world in 2004. According to MetS concept, elevated BP is clustered with other symptoms, including obesity, dyslipidemia, and glucose dysregulation. For treating these disorders, clinical guidelines such as the National High Blood Pressure Education Program recommend, among others, weight loss, dietary sodium reduction (no more than 2.4 g/d), adequate potassium intake (more than 3.5 g/d), and consumption of a diet rich in fruit and vegetables. In its initial stage, one of the major concerns is on preventing disease worsening, and shifting to more adequate foods is crucial. In this context, functional foods play a relevant role if they supply what is needed to comply with dietary guidelines.

Several pieces of knowledge support the importance of marine algae as a functional food, defined this as a food that provides a health benefit beyond basic nutrition, that is, that has health-promoting benefits and/or prevent diseases (Barker and Meletis, 2004), by offering health benefits to reduce the risk of chronic diseases. Probably, the best illustration of marine algae as functional foods is the case of wakame, brown seaweed widely consumed by oriental people.

Undaria pinnatifida (wakame) is a very popular food in the Asiatic countries (Suetsuna *et al.*, 2004). Wakame has a fiber content similar to rice (3.4% wet weight) and proportionate the same beneficial sensation of satiety and aid digestive transit through their bulking capacity without the starchy carbohydrate (Mac Artain *et al.*, 2007). Besides, wakame has antihypertensive effect through inhibition of angiotensin I-converting enzyme (ACE-I) by peptides isolated from hot water extracts (Suetsuna *et al.*, 2004; Suetsuna and Nakano, 2000). Inhibition of ACE-I is considered to be a useful therapeutic approach in the treatment of hypertension and inhibitors such as captopril, enalapril, alcacepril, and lisinopril, which are currently used in the treatment of essential hypertension and heart failure in humans. Peptides from wakame can be a better alternative, as natural products might have less secondary effects. Another beneficial effect of wakame has been reported to be against the development of stroke in stroke-prone spontaneously hypertensive rats putatively due to fucoxanthin (Ikeda *et al.*, 2003). Other studies suggest that wakame and dietary fish oil synergistically decrease rat serum and liver triacylglycerol (Murata *et al.*, 2002), effect attributable to stimulation of enzymes involved in hepatic fatty acid oxidation (Murata *et al.*, 1999). Of particular interest in clinical studies are dose dependency investigations, which are reported for sodium alginate, polysaccharide obtained from brown seaweeds. The results of this study indicated that the optimum dose would be 1.25–2.5 g/day (Takamitsu *et al.*, 2006). Another potential therapeutic application is the reduction of increased uptake cholesterol and glucose on individuals with high body mass index by fibers of alginate in treatments with 1.5 g dose, which was demonstrated by Paxman *et al.* (2008). More recently, in a randomized double-blinded placebo-controlled trial, Teas *et al.* (2009) achieved excellent results on systolic pressure decrease by 10.5 mm Hg and waist circumference reduction of 3.9 cm after consecutive treatments of 4 g/d for 1 month and 6 g/d of *Undaria pinnatifida* in 14 women (aged 45.6 $\pm$ 12.2 year) with at least one symptom of the MetS.

C. Cancer prevention

Another evidence to prove seaweeds as functional foods comes from the studies on the role of nutrition in cancer etiology, a line of research that converges with the use of seaweeds as a breast cancer anticarcinogen. Both lines can be traced back to first recommendations of using seaweeds as remedies to treat tumors by ancient Egyptians in the Ebers Papyrus (1500 BC), to the more recently suggestions on the use of seaweeds as a breast cancer anticarcinogen and the conclusive results of cause–effect relationships on cancer matters. Today, there is evidence of an inverse association between endometrial cancer and dietary fiber through epidemiological studies as the one by Bandera *et al.* (2007). In this study, authors performed the first systematic literature review and made an analysis of the role of dietary fiber intake on endometrial cancer, concluding that current evidence supports the idea of reducing risks in endometrial cancer through fiber intake. Other findings were obtained from a cohort study of more than 180,000 postmenopausal women, which suggests that dietary fiber also can play a role in preventing breast cancer, the most common cancer in women worldwide (Park *et al.*, 2009). Fiber consumption, in turn, is associated to seaweed intake in a study of pattern of dietary habits among the Japanese general population where it was demonstrated the high contribution of seaweed to dietary fiber intake (Fukuda *et al.*, 2007). Japanese women with a traditional consumption of fiber from seaweeds have a good excretion of estradiol, which in serum high level increases the risk of developing breast cancer. It has been shown that *Alaria esculenta*, a brown seaweed related to *Undaria pinnatifida*, modulates serum estradiol levels and urinary excretion of estrogen metabolites and phytoestrogens. This investigation led to the conclusion that seaweed fiber reaching the colon may be a prebiotic, providing substrate for specific bacteria favoring the healthy ones (Teas *et al.*, 2009). Recently, a case–control study investigated 362 women with confirmed breast cancer, concluded that high intake of gim (*Porphyra* sp.) may decrease the risk of breast cancer (Yang *et al.*, 2010). Evidence for polysaccharides from marine algae as prebiotics has provided and there are claims that fucoidan, laminarin, alginate, and their derivatives could be exploited as prebiotic functional ingredients for human health applications since they have demonstrated in a specific manner an antiproliferative activity against several cellular lines of cancer, among them, human colon adenocarcinoma, human neuroblastoma, rat basophylic leukemia, and Chinese hamster fibroblasts (O'Sullivan *et al.*, 2010).

IV. CONCLUSION

As research is being performed and results are presented, the possibility for marine algae as functional food is increasing. Wakame and alginate studies are only a small piece of knowledge showing us that sea remains until now as an untapped reservoir of raw materials for a better health in a variety of ways.

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