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Health Benefits of Sea Vegetables — Learn About Their Culinary Uses, Including How Clients Can Incorporate Them Into Their Diets

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Sea vegetables, commonly called edible seaweed, are a class of marine algae packed with healthful nutritional value. Used for centuries around the world with documented use in Asian and Aztec civilizations, edible seaweed was called one of the hottest food trends in 2015 as it gained popularity in American cuisine. It's an ingredient now used in mainstream dishes such as chips, snacks, pizza, and desserts in addition to more traditional cuisine including sushi and salads.[1] Now that it's known as a functional food used for complementary and alternative therapies, it isn't surprising that edible seaweed is catching the attention of chefs, health providers, and environmentalists alike.

In vitro and mammal studies have revealed promising health benefits of sea vegetables including antioxidant capacity, antitumor and anticancer effects, immune and endocrine modulating potential, and therapeutic properties for degenerative diseases such as Alzheimer's disease, dementia, obesity, dyslipidemia, diabetes, and hypertension.[2-5] Studies on the nutritional benefits of sea vegetables show their high level of soluble and insoluble fibers, protein content, polyunsaturated fats including essential fatty acids, and various bioactive compounds such as antioxidant polyphenols and carotenoids. Further, sea vegetables have proven to be high in vitamins and minerals, including vitamins A, B class, C, and E, calcium, magnesium, sodium, potassium, zinc, iodine, iron, and manganese.[2,5-7]

Keep in mind that not all sea vegetables can be consumed. For example, *Gracilaria*, a type of red algae that grows in tropical waters, has been linked to foodborne gastrointestinal illness.[8,9] Some varieties of red algae, such as *Asparogopsis* and *Bonnemaisonia*, produce volatile compounds such as halogenated iodine and bromine. *Desmarestia ligulata* and *D. viridis* are brown kelp varieties that store sulfuric acid and maintain a very low pH, therefore not utilized as a food source due to an unpleasant taste.[10,11] These sea vegetables have developed defense mechanisms against marine animals that may eat them, resulting in limited culinary uses for humans.

This continuing education course reviews the health benefits and culinary uses of edible sea vegetables and includes strategies your clients can use to incorporate them into their diets.

Classification

Edible seaweeds are classified as macroalgae including brown, red, and green, and single-celled, chlorophyll-containing microalgae such as spirulina or chlorella.[6] Brown seaweeds (*Phaeophyta*) get their color from the carotenoid fucoxanthin.

The primary polysaccharides in brown seaweed include alginate, laminarin, fucan, and cellulose. Familiar edible brown seaweeds include wakame, kombu, and hijiki. Red seaweed (Rhodophyta) is pigmented with phycoerythrin and phycocyanin.

The primary polysaccharides in red seaweed are agar and carrageenan. Nori and dulse are well-known red seaweeds. Like brown seaweeds, red sea vegetables grow in deeper environments where the exposure to sunlight is more limited.

Green seaweeds (*Chlorophyta*) get their pigment from chlorophyll, and their primary polysaccharide is ulvan. They can absorb the largest amount of light energy and are found in coastal waters.[12,13] Edible forms of green seaweed are sometimes referred to as sea lettuce. Single-celled microalgae also can be referred to as blue-green algae and includes spirulina and chlorella, which are rich in protein. Microalgae play a crucial role in the marine food chain and contribute to oceanic health.[13]

Nutrition Composition of Sea Vegetables

Edible seaweeds are a low-calorie food with high dietary fiber, protein, vitamins, minerals, and bioactive phenolic compounds.[14] Studies have shown that they contain a high concentration of polyphenolic compounds including catechin, epicatechin, epigallocatechin galate, and gallic acid.[4] The marine environment in which sea vegetables live contributes to the bioactive compounds they contain, such as phycocyanin, terpenes, fuctosterol, and polysaccharides.[15] Studies show that a unique compound in edible brown algae called fucoidan provides many of the health benefits proven in vitro and in vivo. Fucoidan, a fucose-containing sulfated polysaccharide, has proven antiangiogenic, antitumor, and immunity enhancing properties.[15]

Edible seaweeds are high in soluble and insoluble fiber and have a fiber content similar to that of lentils, a well-known high-fiber food. In a 2007 study on the nutritional content of edible sea vegetables, the fiber in 100 g of wet-weight edible seaweed compared favorably to a 100 g measurement of lentils, yielding 8.8 and 8.9 g of fiber, respectively.[16,17] Fiber ranges in edible seaweeds generally fall between 29.3 to 62.3 g per 100 g dry weight.[13] Studies have found that the high level of both soluble and insoluble fibers in sea vegetables support gut health by decreasing colon transit times and fecal bulking. The low level of digestibility negates the high carbohydrate content of sea vegetables, making edible seaweed a low-energy food.[13]

Sea vegetables contain protein, as much as 47% of the dry weight, though levels vary among samples and species tested in some studies.[16] The red seaweed nori has tested among the highest in protein content, while brown seaweeds typically test among the lowest.[9,17] Most sea vegetables test low in the nonessential amino acid cysteine, but many varieties do contain all of the essential amino acids including histidine, leucine, isoleucine, and valine.[13,16] It's estimated that protein content in seaweed varies by season and environment, with some studies showing higher protein levels in plants tested at the end of the winter and spring periods and with lower protein levels in the summer.[17] Because of the high phenolic content of sea vegetables, there's some question regarding the digestibility and absorption of the nutrients they contain. Some studies have shown a high rate of protein degradation in vitro by proteolytic enzymes (up to 70%), but the assimilation through normal human digestion is yet undetermined.[13]

Though relatively low in fat content at 1% to 5% dry weight, the predominant fatty acid in edible seaweeds are polyunsaturated fatty acids, with nearly equal parts omega-3 to omega-6 fatty acids.[9,13,16,18] Omega-3 content includes both essential fatty acids EPA and DHA. Nonanimal vegetarian or vegan supplementation of omega-3 is commonly derived from blue-green algae such as spirulina or chlorella, which are the omega-3 sources that fish consume and assimilate into their own fatty acid composition. Many people take fish oil for omega-3 EPA/DHA supplementation, but it's possible to get these essential fatty acids from algae instead.

Because of the marine environment in which seaweed grows, its mineral content is very high, particularly in calcium, iron, copper, magnesium, and iodine. Testing has shown that some seaweed has a mineral content of up to 36% of its dry matter.[13] Brown seaweeds such as kombu, which often are used in soups or bean dishes, meet 65% of the reference nutrient intake for magnesium in an 8 g serving.[16] Sea vegetables, which are exposed to direct sunlight in their natural growing habitat, are high in vitamins A, B (1, 2, 3, 6, 9, 12), C, and E. Uniquely, red and certain green sea vegetables can be a source of B_{12}. Generally, only animal products contain B_{12}. One study found that an 8-g portion of the red seaweed nori contained 5 mcg B_{12}.[16] Seaweed also is a rich source of iron; an 8-g serving of dried dulse tested higher in this mineral than did 100 g of raw sirloin steak.[13]

Anti-Inflammatory Properties

Sea vegetables have proven to be powerful for blocking inflammatory pathways including proinflammatory cytokines tumor necrosis factor (TNFa), interleukin 1b (IL-1b), and interleukin 6 (IL-6), which are modulated by the nuclear factor kappa B (NF-kB) pathway.[19] In this way, the consumption of edible seaweeds could be beneficial for clients with chronic diseases linked to inflammation, such as insulin resistance, type 2 diabetes, cardiovascular disease, metabolic syndrome, and nonalcoholic fatty liver disease.[19] Antioxidants in certain edible sea vegetables also block the cyclooxygenase-2 enzyme (COX-2), which reduces inflammatory prostaglandin E2 (PEG2).[3] The polyunsaturated fatty acid content, including essential fatty acids EPA and DHA, also may contribute to the anti-inflammatory effects.[20]

Studies of animal models to further evaluate the compounds responsible for this free radical scavenging activity have found that phenolic compounds, carotenoids including fucoxanthin, and even sulfated polysaccharides in sea vegetables all may play a role in the beneficial antioxidant capacity of these functional foods.[5,21] Carotenoids such as fucoxanthin are rich in electrons and can quench singlet oxygen molecules, which stabilizes the long central chain of conjugated double bonds in a carotenoid molecule.[3] The antioxidant capacity of sea vegetables has been found to have neuroprotective effects, including antineuroinflammation and neuronal cell death inhibition.[21] Neural tissue is sensitive to oxidative stress because of its high oxygen consumption and lipid content. Some studies even suggest that the lower rate of neurodegenerative diseases in people in East Asian countries compared with Europeans ($p<0.0004$) may be partially attributed to high fish and marine algae consumption of those populations.[21]

Antioxidant Capacity

The antioxidant capacity of fucoxanthin, the carotenoid found in brown seaweed, has been studied in conjunction with its free-radical scavenging ability as well as its anti-inflammatory, anticancer/antiangiogenic, antiobesity, antidiabetic, and antimalarial properties.[15,22] Studies have shown that even very high doses of fucoxanthin in vitro and in vivo are safe and without

toxic effects because it acts as an antioxidant by quenching singlet oxygen molecules. Studies also have found that fucoxanthin inhibits tumor cells through induction of apoptosis, or programmed cell death. Research has been done on this antioxidant and its role in breast cancer, colon cancer, adult T-cell leukemia, nonsmall-cell lung cancer cells, prostate cancer, hepatocellular carcinoma cells, gastric cancer, neuroblastomas, and lymphoma cells, as it inhibits cancer cell growth and suppresses tumorigenesis.[3,22,23] In in vitro and in vivo studies, fucoxanthin has demonstrated direct anticancer and antiangiogenic effects, showing potential for use in complementary cancer treatment.[15]

Cancer

In addition to the antioxidant effects of the carotenoids in edible sea vegetables, studies have provided promising evidence that sea vegetables in general can induce apoptosis and necrosis and inhibit cell cycle replication, proving potential to destroy prostate cancer, human leukemia, glioblastomas, and colon cancer cells.[3,23] Sea vegetable extracts have been studied in relation to breast cancer because populations consuming typical Asian diets have been observed to have a lower incidence of hormone-dependent cancers than do populations who follow traditional Western diets.[24] A 2012 study on hormone-dependent breast cancer cells in vitro found that edible red seaweed extract proved nontoxic to normal cells but inhibited proliferation of estrogen-dependent as well as independent human breast cancer cells. Researchers observed cytotoxic effects to cancer cell lines including cancer-associated receptors, cancer cell signaling molecules, and gene expression triggering apoptosis.[24]

The unsaturated fatty acids in some sea vegetables also may be chemopreventive when consumed in the diet.[25] Other studies have shown that polyphenols extracted from edible brown seaweed decrease major tumor progression molecular targets in human pancreatic cancer cells in vivo, including NF-kB, EGFR, kRAS, STAT3, VEGF, AKT, TERT, FGFA, BC12, and PDGFA.[4] Edible red seaweed extract showed strong anticancer effects on human glioblastoma cells in vitro in a 2014 study published in the ***Journal of Microbiology and Biotechnology***.[23] Seaweed polyphenols have been shown to inhibit pancreatic cancer cell proliferation, induce apoptotic death, regulate tumor progression molecules, and suppress tumor activity.[15] A 2006 study on the antiproliferative activities of common edible species of brown seaweed found that extracts of three tested kelp species and dulse were effective free radical scavengers and exhibited dose-dependent inhibition against the proliferation of human cervical epithelial adenocarcinoma cells, likely related to the polyphenol content.[26]

Notably, the sulfated polysaccharide fucoidan in edible seaweeds has proven antitumor, anticancer, antimetastatic, and fibrinolytic properties in mice as well as promise for reduction of cell proliferation. Bioactive secondary metabolites terpene and chondriamide A extracted from edible seaweeds also have shown promise for cytotoxicity against human nasopharyngeal and colorectal cancer cells.[20] Though studies are ongoing, it appears safe to suggest that including edible seaweed in the diet of anyone wanting to focus on cancer prevention is advisable in light of the research that has been done. At this time, extracts and supplementation are still being studied for potential anticancer benefits. Note that most anticancer studies have involved the use of edible seaweed extracts rather than normal dietary intake.

Digestive Health

Sea vegetables are rich in complex carbohydrates, polysaccharides, and oligosaccharides that function as prebiotics, or nondigestible compounds that gut bacteria can ferment and from

which they receive benefit.[12,13] Seaweed prebiotics are resistant to digestive enzymes so they can reach the lower intestine where they undergo selective fermentation by intestinal microbiota. Prebiotics in sea vegetables have been studied in vitro, in farm animals as an alternative to antibiotics, and in lab animals. Studies show that the nonmetabolized fiber in edible seaweed helps to reduce colonic transit times, supporting gut health and detoxification.[16] Some sea vegetables also can be used to increase the digestibility of legumes because they help break down the fibers in these foods. For example, one can cook dried beans with a strip of kombu seaweed, which lends minerals to the beans and breaks down some of the hard-to-digest fibers before being discarded.

Cardiovascular Health

Sea vegetables appear to have potential to protect against cardiovascular disease, an effect likely based on their anti-inflammatory and antioxidant capacity. Reactive oxygen species can damage endothelial cells, leading to dysfunction and arteriosclerotic damage, worsened by a hypercoagulative state. An eight-week human trial studying erectile function as a sign of cardiovascular health found that 400 mg six times daily of standardized edible brown seaweed extract saw significant improvement in five separate domains by the study's end ($p<0.01$).[27] The researchers hypothesized that the polyphenolic compound in the supplement significantly contributed to neutralizing oxidative damage, improving peripheral blood circulation. Studies also show that the ion quotient values between 1.4 and 4.0 for seaweed tested can reduce hypertension.[7]

Moreover, studies have found that rodents fed the carotenoid fucoxanthin increased production of DHA in the liver, which has potential to improve lipid profiles.[3] In one animal study, rats were divided into groups: one received a normal diet; the other a diet including brown seaweed wakame powder. The intervention group saw a delayed incidence of stroke signs and increased life span.[28] Polysaccharides from edible sea vegetables including alginate, carrageenan, funoran, fucoidan, laminaran, porphyran, and ulvan have shown promise in reducing cholesterol absorption in the gut and increasing fecal cholesterol content.[20]

The sulfated polysaccharide fucoidan found in sea vegetables has shown heparinlike antithrombic and anticoagulant properties both in vitro and in vivo similar to those of the medication heparin. This compound may have cardiovascular and circulatory benefits because it inhibits thrombin generation from platelets.[20] Though sea vegetables have proven promising for cardiovascular health, clients must be aware that they may interact with certain blood thinning medications due to their antithrombotic effects.

Obesity, Weight Loss, Blood Sugar Control

Some animal studies have shown that the sea vegetable antioxidant fucoxanthin may help decrease body weight, body fat accumulation, and the size of adipocytes in mice.[22,29] In a review of the function of fucoxantin, a 2012 study found that this antioxidant increases thermogenesis and whole body energy expenditure, potentially contributing to weight management.[3] An animal study using lipids extracted from commonly consumed wakame found that the intervention group had significantly lower body weight than did the control mice ($p<0.05$). These researchers hypothesized that these changes in body weight were a result of antiobesity activity of fucoxanthin through upregulation of mitochondrial uncoupling protein 1 in white adipose tissue.[29]

Because of its link to weight reduction, fucoxanthin and other compounds in sea vegetables also have been studied in relation to antidiabetic effects and blood sugar control.[3] These effects may be due in part to the anti-inflammatory and antioxidant capacity of carotenoids. A large 2005 Korean study found that after adjustments for age, family history of diabetes, education, smoking, alcohol intake, physical activity level, BMI, waist circumference, triglyceride levels, and total energy intake, algae consumption in the diet may decrease diabetes risk. This study hypothesized that the high levels of dietary fiber coupled with nondigestible carbohydrate as well as potentially hypoglycemic properties of polyphenolic compounds may contribute to the antidiabetic properties.[14] Researchers also found that as algae consumption increased, so did intake of legumes, fruit, fish, and dairy products ($p<0.001$) while proportions of cereal and fast food significantly decreased, suggesting that people who incorporate seaweed into their diets may have more healthful diets in general.[14] The positive effects in people with diabetes are theorized to be associated with healthful compounds in seaweed including fiber and polyphenols.[14]

Detoxification

The fiber or polysaccharides in sea vegetables, particularly alginates, bind heavy metals, making them ideal for detoxification support.[16] Further, there's some promise that certain immunostimulating beta-glucans in sea vegetables may provide protective substances for patients with radiation illness.[20] A 2013 study found that the monounsaturated fatty acids in edible green seaweed *Ulva lactuca*, commonly called sea lettuce, had antioxidant effects, activating phase II detoxification enzymes.[30]

Culinary Use of Sea Vegetables

People have consumed brown, red, and green seaweed since prehistoric times. Currently, red seaweeds nori and dulse are popular and have documented use for generations in Ireland; Brittany, France; Iceland; Maine; and Nova Scotia, Canada.[31] In culinary practices, sea vegetables are included in main dishes, used as a wrap for sushi or rice rolls, as condiments and seasonings, and as a source of phycocolloid thickening and gelling agents such as alginate, carrageenan, and agar.[6] Consumed in whole form as part of a normal diet in Eastern cultures, sea vegetables are more commonly included in Western cuisine as extracts, additives, and stabilizers. Food labels will reveal alginate, carrageenan, and agar in a variety of foods used for their properties of gelling, water-retention, and ability to emulsify.[9,13,20] Interest in seaweed was stimulated by the macrobiotic diet movement, popular in the 1960s and '70s, which calls for daily intake of sea vegetables. With the introduction and popularization of sushi in the United States starting in the 1960s, many Americans are now familiar with nori for sushi roll wraps or maki or seaweed salads served in Japanese restaurants.

Sea vegetables remain common in traditional Asian cuisine, specifically in China, Korea, and Polynesia, as well as Japan and the Philippines. Studies estimate that sea vegetables constitute 10% to 25% of food intake by Japanese people.[26] The brown seaweed wakame is the most commonly consumed seaweed in Japan and can be made into salads, used as sushi wrapping, eaten as a vegetable, or added to foods as a condiment.[15,26] Sea vegetables are associated with a strong flavor because of the presence of aspartic and glutamic acids. Glutamic acid is closely related to the flavor enhancer monosodium glutamate, which contributes to an "umami" or savory flavor.[9]

Microalgae including spirulina and chlorella are commonly used as a supplement in smoothies or beverages due to their high protein, essential fatty acid, vitamin, mineral, and antioxidant content. Referred to as blue-green algae, this product often is consumed in powdered form and touted as a concentrated source of nutrients, essential fatty acids, and protein.[9] There's evidence that blue-green algae, like other types of edible sea vegetables, exerts antioxidative and anti-inflammatory effects.[14]

There are some simple ways to incorporate sea vegetables into American cuisine. Remind clients that familiar foods they enjoy, such as sushi, are wrapped in seaweed. To increase minerals in the diet or support calcium intake, they can eat a simple seaweed salad that involves soaking and reconstituting dried seaweed such as wakame in water for about 10 to 15 minutes. Pair it with cucumber to make it more familiar and add tamari, which can give the salad an Asian-influenced flair that many clients will enjoy. Toasted nori strips or chips provide a crunchy texture and salty flavor perfect for snacking on.

The following are other ways clients can incorporate sea vegetables into their diet:
• Garnish with strips in miso soup.
• Wrap rice, vegetables, and fish in nori as maki sushi.
• Eat toasted nori strips as a snack.
• Cook kombu strips with beans or soup for flavor and added minerals.
• Use dulse flakes as a salt substitute, sprinkling it on breads or salad.
• Eat a wakame seaweed salad.
• Add rehydrated arame, a species of kelp, to a stir fry.
• Add spirulina or chlorella powder to a smoothie.
• Use kelp noodles instead of grain pasta.
• Blend dulse or kelp into a salad dressing.

Safety

Microalgae such as chlorella are contraindicated for individuals using medications such as warfarin (Coumadin) because of their blood thinning capacity and vitamin K content, and for those taking immunosuppressants, as blue-green algae can stimulate the immune system. Clients with autoimmune diseases such as lupus or rheumatoid arthritis should use microalgae with caution for the same reason.[32] RDs should advise clients to work with a knowledgeable medical provider who can help them decide how much seaweed is safe for them to include based on their unique needs, medical history, and medication use.

Keep in mind that not all seaweeds are edible, and some even produce toxic metabolites that can cause neurodegeneration, acute toxicity, or tumor promotion, namely kainoids, aplysiatoxin, and polycavernosides.[5,20] The compounds may act as neural agonists, or stimulators to neurons.[20] Studies have shown that sea vegetables such as dulse contain low levels of kainic acid, but to experience the negative gastrointestinal adverse conditions or neurodegenerative effects including encephalopathy noted in animal research, a human would need to consume 150 kg of this compound.[31] For common edible sea vegetables consumed in normal amounts, these toxins shouldn't be a concern.

Because seaweed does absorb minerals from the environment, toxic compounds such as arsenic are sometimes an issue. Studies have shown that some types of arsenic aren't metabolized and may not pose as serious a health threat as inorganic arsenic, which the World

Health Organization (WHO) labels as acutely toxic.[33,34] Further, the level of arsenic may vary between types of sea vegetables and the environment in which they were grown and harvested.[31,33] Some studies have found inorganic arsenic concentrated in seaweed supplements and samples.[31,34,3]5 In particular, two seaweed species that have tested very high in arsenic include invasive brown seaweed species *Sargassum muticum*/Wireweed and *Sargassum fusiforme*/hijiki.[31,36] It's advisable to avoid concentrated sources of sea vegetables including supplements given the potential for compounded toxins. For the majority of edible sea vegetables, the level of heavy metals and potentially hazardous trace minerals including iodine, arsenic, mercury, cadmium, and lead are naturally below the set WHO food safety limits.[16,31,33] Aside from naturally occurring contaminants, environmental contamination is a fear for many consumers. It should be noted that seaweed can be sustainably farmed and tested for environmental toxins. Information on how and where seaweed was grown should be accessible on a company's website. To ensure safety, source your edible sea vegetables from a reliable distributor who participates in testing for environmental toxins and contaminants.

Finally, there has been some concern over potentially carcinogenic properties of the common food additive carrageenan, but a 2014 review of the literature shows that the majority of carrageenan consumed isn't absorbed or metabolized; rather it's excreted in the feces due to the high molecular weight. In rodent, baboon, and human studies, it also didn't disrupt the immune system or cause any other toxic effects.[37] That review found neither carcinogenic, tumor promoting, genotoxic, developmental, nor reproductive effects in animal studies through dietary intake.[37]

Putting It Into Practice

Many clients may be unfamiliar with or intimidated by the idea of including sea vegetables into their diets for health or culinary flavor. Edible seaweed is predicted to trend strongly in 2016,[38] so dietitians are sure to get questions about the health benefits and how best to include seaweed into their diets. RDs can guide clients toward appropriate incorporation, for example, including kombu in soup or bean dishes, ordering seaweed salad or nori wrapped around sushi when eating out, or making arame chips at home. They may be most comfortable starting by using seaweed as a condiment or seasoning instead of a main dish. Clients should be instructed to choose seaweed that has been sourced from a reliable company and select whole food dietary sources over supplementation due to increased dangers of toxins in this concentrated form. Dietitians can guide patients to include this nutritious functional food to optimize health and culinary pleasure. By including sea vegetables in their diets, clients may experience health benefits from a variety of minerals and antioxidants that have anticancer properties, that help support cardiovascular health, blood sugar stabilization, and provide antioxidant and anti-inflammatory support.

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References

1. Seaweed named among top food craze trends for 2015. http://seagreensonline.com/seaweed-named-among-top-food-craze-trends-for-2015/. Published November 3, 2014. Accessed June 8, 2015.

2. Mohamed S, Hashim SN, Rahman HA. Seaweeds: a sustainable functional food for complementary and alternative therapy. ***Trend Food Sci Tech***. 2012;23(2):83-96.

3. D'Orazio N, Gemello E, Gammone MA, de Girolamo M, Ficoneri C, Riccioni G. Fucoxantin: a treasure from the sea. ***Mar Drugs***. 2012;10(3):604-616.

4. Aravindan S, Delma CR, Thirugnanasambandan SS, Herman TS, Aravindan N. Anti-pancreatic cancer deliverables from sea: first-hand evidence on the efficacy, molecular targets and mode of action for multifarious polyphenols from five different brown-algae. ***PLoS One***. 2013;8(4):e61977.

5. Lee JC, Hou MF, Huang HW, et al. Marine algal natural products with anti-oxidative, anti-inflammatory, and anti-cancer properties. ***Cancer Cell Int***. 2013;13:55.

6. Burtin P. Nutritional value of seaweeds. ***Electron J Environ Agric Food Chem***. 2003;2(4):498-502.

7. El-Said GF, El-Sikaily A. Chemical composition of some seaweed from Mediterranean sea coast, Egypt. ***Environ Monit Assess***. 2013;185(7):6089-6099.

8. Centers for Disease Control and Prevention. Outbreak of gastrointestinal illness associated with consumption of seaweed — Hawaii, 1994. http://www.cdc.gov/mmwr/preview/mmwrhtml/00039077.htm. Published October 1995. Accessed November 1, 2015.

9. Mouritsen OG. The emerging science of gastrophysics and its application to the algal cuisine. ***Flavour***. 2012;1(6):1-9.

10. Desmaresia ligulata. Seaweed Industry Association website. https://seaweedindustry.com/seaweed/type/desmarestia-ligulata. Accessed November 1, 2015.

11. Nylund GM, Enge S, Pavia H. Costs and benefits of chemical defence in the red alga Bonnemaisonia hamifera. ***PLoS One***. 2013;8(4):e61291.
12. O'Sullivan L, Murphy B, McLoughlin P, et al. Prebiotics from marine macroalgae for human and animal health applications. ***Mar Drugs***. 2010;8(7):2038-2064.

13. Lordan S, Ross RP, Stanton C. Marine bioactives as functional food ingredients: potential to reduce the incidence of chronic diseases. ***Mar Drugs***. 2011;9(6):1056-1100.

14. Lee HJ, Kim HC, Vitek L, Nam CM. Algae consumption and risk of type 2 diabetes: Korean National Health and Nutrition Examination Survey in 2005. ***J Nutr Sci Vitaminol***. 2010;56(1):13-18.

15. Zorofchian Moghadamtousi S, Karimian H, Khanabdali R, et al. Anticancer and antitumor potential of fucoidan and fucoxanthin, two main metabolites isolated from brown algae. ***ScientificWorldJournal***. 2014;2014:768323.

16. MacArtain P, Gill CI, Brooks M, Campbell R, Rowland IR. Nutritional value of edible seaweeds. ***Nutr Rev***. 2007;65(12 Pt 1):535-543.

17. Patarra RF, Paiva L, Neto AI, Lima E, Baptista J. Nutritional value of selected macroalgae. ***J Appl Phycol***. 2011;23(2):205-208.

18. Polat S, Ozogul Y. Fatty acid, mineral and proximate composition of some seaweeds from the northeastern Mediterranean coast. ***Ital J Food Sci***. 2009;21(3):317-324.

19. Ku CS, Pham TX, Park Y, et al. Edible blue-green algae reduce the production of pro-inflammatory cytokines by inhibiting NF-kB pathway in macrophages and splenocytes. ***Biochim Biophys Acta***. 2013;1830(4):2981-2988.

20. Smit AJ. Medicinal and pharmaceutical uses of seaweed natural products: a review. ***J Appl Phycol***. 2004;16(4):245-262.

21. Pangestuti R, Kim SK. Neuroprotective effects of marine algae. ***Mar Drugs***. 2011;9(5):803-818.

22. Peng J, Yuan JP, Wu CF, Wang JH. Fucoxanthin, a marine carotenoid present in brown seaweeds and diatoms: metabolism and bioactivities relevant to human health. ***Mar Drugs***. 2011;9(10):1806-1828.

23. Cho M, Park GM, Kim SN, Amna T, Lee S, Shin WS. Glioblastoma-specific anticancer activity of pheophorbide a from the edible red seaweed Grateloupia elliptica. ***J Microbiol Biotechnol***. 2014;24(3):346-353.

24. Namvar F, Mohamed S, Fard SG, et al. Polyphenol-rich seaweed (*Eucheuma cottonii*) extract suppresses breast tumour via hormone modulation and apoptosis induction. ***Food Chem***. 2012;130(2):376-382.

25. Wang R, Paul VJ, Luesch H. Seaweed extracts and unsaturated fatty acid constituents from the green alga *Ulva lactuca* as activators of the cytoprotective Nrf2-ARE pathway. ***Free Radic Biol Med***. 2013;57:141-153.

26. Yuan YV, Walsh NA. Antioxidant and antiproliferative activities of extracts from a variety of edible seaweeds. ***Food Chem Toxicol***. 2006;44(7):1144-1150.

27. Kang K, Park Y, Hwang HJ, Kim SH, Lee JG, Shin HC. Antioxidative properties of brown algae polyphenolics and their perspectives as chemopreventive agents against vascular risk factors. ***Arch Pharm Res***. 2003;26(4):286-293.

28. Ikeda K, Kitamura A, Machida H, et al. Effect of Undaria pinnatifida (Wakame) on the development of cerebrovascular diseases in stroke-prone spontaneously hypertensive rats. ***Clin Exp Pharmacol Physiol***. 2003;30(1-2):44-48.

29. Maeda H, Hosokawa M, Sashima T, Funayama K, Miyashita K. Fucoxanthin from edible seaweed, Undaria pinnatifida, shows antiobesity effect through UCP1 expression in white adipose tissues. ***Biochem Biophys Research Commun***. 2005;332(2):392-397.

30. Lee JC, Hou MF, Huang HW, et al. Marine algal natural products with anti-oxidative, anti-inflammatory, and anti-cancer properties. ***Cancer Cell Intl***. 2013;13:55.

31. Mouritsen OG, Dawczynski C, Duelund L, Jahreis G, Vetter W, Schröder M. On the human consumption of the red seaweed dulse (*Palmaria palmata* (L.) Weber & Mohr). ***J Appl Phycol***. 2013;25:1777-1791.

32. Chlorella. Natural Medicines Database website. http://naturaldatabase.therapeuticresearch.com/nd/search.aspx?cs=cepda~mbr&s=nd&pt=100&id=907&ds=&name=chlorella&searchid=52089342. Updated December 10, 2015. Accessed December 20, 2015.

33. Bouga M, Combet E. Emergence of seaweed and seaweed-containing foods in the UK: focus on labeling, iodine content, toxicity, and nutrition. ***Foods***. 2015;4(2):240-253.

34. Avula B, Wang YH, Khan IA. Arsenic speciation and fucoxanthin analysis from seaweed dietary supplements using LC-MS. ***J AOAC Int***. 2015;98(2):321-329.

35. Rose M, Lewis J, Langford N, et al. Arsenic in seaweed — forms, concentration and dietary exposure. ***Food Chem Toxicol***. 2007;45(7):1263-1267.

36. Yokoi K, Konomi A. Toxicity of so-called edible hijiki seaweed (Sargassum fusiforme) containing inorganic arsenic. ***Regul Toxicol Pharmacol***. 2012;63(2):291-297.

37. Weiner ML. Food additive carrageenan: part II: a critical review of carrageenan in vivo safety studies. ***Crit Rev Toxicol***. 2014;44(3):244-269.

38. Watson E. The top 10 specialty food trends for 2016: from seaweed and full-fat dairy to floral flavors. Food Navigator-USA website. http://www.foodnavigator-usa.com/Markets/What-are-the-top-10-specialty-food-trends-for-2016. Published December 4, 2015. Accessed December 20, 2015.

Quiz

1. According to the 2013 study by Aravindan and colleagues, which polyphenolic compounds are predominant in edible seaweeds?
A. Catechin
B. Stilbene
C. Lignans
D. Resveretrol

2. The four classes of edible sea vegetables include brown, red, green algae, and which other form?
A. Purple algae
B. Microalgae
C. Kelp
D. Orange algae

3. Which seaweed is not edible brown seaweed?
A. Nori
B. Wakame
C. Kombu
D. Hijiki

4. What is fucoidan?
A. The primary color compound in sea vegetables
B. The name for fiber in edible seaweed
C. A sulfated polysaccharide that contributes health benefits
D. A culinary use for wakame

5. What is fucoxanthin?
A. The antioxidant carotenoid in brown seaweed
B. Another name for chlorophyll
C. The antioxidant caroteinoid in spirulina
D. The indigestible fiber in edible seaweeds

6. Chlorella is not indicated for individuals taking which of the following medications?
A. Warfarin (Coumadin)
B. Antibiotics
C. Multivitamins
D. Opioids

7. What gives edible sea vegetables that strong 'umami' flavor?
A. Low levels of cytsteine
B. Glutamic acid
C. Essential amino acid histidine
D. Iodine content

8. Which culinary use may be most palatable for clients who don't care for the taste of seaweed?
A. Arame chips
B. Nori wrapped around sushi
C. Wakame salad
D. Dulse flakes as a condiment

9. Which element in sea vegetables may be a health concern at high levels?
A. Arsenic
B. Zinc
C. Cyanide
D. Botulism

10. In light of the research surrounding edible sea vegetables, health professionals should do which of the following?
A. Recommend sea vegetable supplements for those who express interest.
B. Encourage clients to forage their own sea vegetables in marine areas because all seaweeds and kelps are edible.
C. Discuss the health benefits of incorporating edible sea vegetables in their diet.
D. Tell clients to avoid most sea vegetables due to potential contamination.