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Nutritional Value of Edible Seaweeds

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This article presents information on the nutritional aspects of seaweeds in terms of fiber, mineral content, fats and lipids, vitamin contents, and components that have a confirmed and investigated nutritional effect. The nutrient levels of seaweeds are also shown in comparison to currently applicable reference nutrient intakes or guideline daily amounts of nutrients and are contrasted with terrestrial foodstuffs with respect to selected nutrients. For the purpose of comparison, a sample serving size of 8 g dry weight of seaweed is used to illustrate the potential contribution of seaweeds to the diet.

Key words: seaweed, nutrition, reference nutrient intake

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INTRODUCTION

Bioactive compounds are molecules from synthetic or natural sources that have been biologically assayed for activities in a number of key therapeutic areas.[1] The activity of these bioactive compounds has been linked to good health for many years, and it appears that bioactive food components can alter the genetic expression of a host of cellular events, thereby influencing health outcomes[2] or providing beneficial antioxidant or enzyme-inhibitory activities.[3] As a result, these compounds are becoming familiar components of the mainstream vocabulary. This increased awareness is partially supported by the commercial focus on health and wellness as well as public health drives promoted by governmental organizations. The present article quantifies the nutritional impact of seaweeds as a source of essential nutrients as well as their key bioactive molecules and activities; it also describes the individual benefits ascribed to the main types of edible seaweeds.

Commercial health claims can sometimes be misleading, but structures are emerging to assist in clarifying the messages transmitted to consumers.[4] For example, in the United Kingdom there is growing public consciousness regarding the health impact of consuming vegetables and fruit, as promoted in the 'five-a-day' public health campaigns, which encourage fresh fruit or vegetable consumption. Reference nutrient intakes have been established by the UK government in terms of the daily amounts necessary to supply essential nutrients. These values have been expanded on by non-governmental organizations and documented as guideline daily amounts, which include recommended fiber intakes. The present review refers to both sets of data and compares them with the established nutrient components of seaweeds.

SEAWEEDS AS FOODS

There are a number of reviews available on the many pharmaceutical and medicinal bioactive compounds present in seaweeds.[5,6] This review focuses on the nutritional aspects of seaweeds as foods and their associated health benefits. Although previous reviews have focused on the nutritional aspects of seaweeds,[7–9] no assessments were made of the levels of nutrients compared to dietary intake and per-portion amounts.

Seaweeds are classified taxonomically as algae and they represent a food group that is not normally ingested in unprocessed form to any great extent in Western societies. Seaweeds are macroalgae and can be separated into the following four different classification groups: brown algae (phaeophyta), red algae (rhodophyta), green algae (chlorophyta), and blue-green algae (cyanophyta). This review focuses on brown, green, and red algae. In order to avoid confusion arising from the use of general terms such as 'kelp', the seaweeds' Latin names are used, although common names are also referenced.

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Table 1. Latin and common European names of seaweeds

Latin name	Most common name*
Ascophyllum nodosum	Egg wrack
Laminaria digitata	Kombu/Konbu
Laminaria saccharina	Royal or Sweet Kombu
Himanthalia elongata	Sea spaghetti
Undaria pinnatifida	Wakame
Porphyra umbilicalis (or other species)	Nori
Palmaria palmata	Dulse or Dillisk
Chondrus crispus	Irish moss or Carrigeen
Ulva lactuca	Sea lettuce
Enteromorpha (Ulva) intenstinalis	Sea grass

*Data from Morrissey et al. (2001).[10]

The use of seaweed in Asian food is well known. In Western societies, it is mainly associated with localized coastal use or historical anecdotes, but seaweeds are attracting increasing attention as a valuable food source. Typical nutritional analyses of seaweeds have identified high levels of carbohydrates as well as minerals, vitamins, and trace elements such as iodine.[10] There are two main types of polysaccharides in seaweeds—structural and storage. Structural polysaccharides are analogous to terrestrial plants and are mainly celluloses, hemicelluloses, and xylans. Storage polysaccharides, such as carrageenans and alginates, are more specific to seaweed species and represent the most commercially exploited components in seaweeds. These storage polysaccharides exhibit textural and stabilizing properties; thus, they are extracted by the hydrocolloid industry and are used in food applications.[11]

DATA ASSESSMENT

Assessing the nutritional value of seaweeds stems from analyzing their nutrient composition. Since seaweeds are normally consumed and tested as a dried foodstuff, this can make comparison with land-based foodstuffs difficult. Thus, the present analysis consists of two forms: 1) a comparison of 100 g wet-weight seaweeds with 100 g of common foods, and 2) the nutrient levels found in an 8 g dry-weight portion size. Eight grams of seaweed is a typical daily portion size consumed in Asian cuisine. This per-portion analysis was performed in comparison with UK standard reference nutrient intakes (RNI)[12] and guideline daily amounts[17] to illustrate the potential contribution of seaweeds to a balanced diet. The composition of seaweeds is known to vary according to the season and to the sampling techniques used;[7,13] thus, the average values of components as reported in the available literature were used. The common names of edible seaweeds and their Latin names are presented in Table 1.

FIBER CONTENT

Direct comparisons show that seaweeds have similar or slightly elevated levels of total fiber compared to terrestrial foodstuffs (Table 2). The main components of

Table 2. Fiber composition of seaweeds compared to whole foods

Food type	Total fiber	Soluble fiber	Insoluble fiber	Carbohydrates
Seaweed (g/100g wet weight)*				
Ascophyllum nodosum	8.8	7.5	1.3	13.1
Laminaria digitata	6.2	5.4	0.8	9.9
Himanthalia elongata	9.8	7.7	2.1	15.0
Undaria pinnatifida	3.4	2.9	0.5	4.6
Porphyra umbilicalis	3.8	3.0	1.0	5.4
Palmaria palmata	5.4	3.0	2.3	10.6
Ulva sp.	3.8	2.1	1.7	4.1
Enteromorpha sp.	4.9	2.9	2.1	7.8
Whole food (g/100 g weight)†				
Brown rice	3.8			81.3
Prunes	2.4			19.7
Porridge	0.8			9.0
Lentils green/brown	8.9			48.8
Cabbage	2.9			4.1
Carrots	2.6			7.9
Apples	2.0			11.8
Bananas	3.1			23.2

*Values for seaweeds from the Institut de Phytonutrition (2004).[15]
†Values for whole foods from McCance et al. (1993).[16]

Table 3. Seaweed fiber and carbohydrate contents by 8 g portion compared with guideline daily amounts (GDA) of fiber

Seaweed	Total fiber*	Soluble fiber*	Insoluble fiber*	Carbohydrates*	Fiber as % GDA†
Ascophyllum nodosum	2.8	2.4	0.4	4.2	11.6
Laminaria digitata	3.0	2.6	0.4	4.8	12.5
Himanthalia elongata	2.6	2.1	0.6	4.0	10.8
Undaria pinnatifida	2.8	2.4	0.4	3.9	11.6
Porphyra umbilicalis	2.7	2.1	0.7	3.8	11.25
Palmaria palmata	2.7	1.5	1.2	5.3	11.25
Ulva spp.	3.0	1.7	1.3	3.3	12.5
Enteromorpha spp.	3.0	1.8	1.3	4.8	12.5

*Values from the Institut de Phytonutrition (2004).[15]
†Guideline daily amounts from the Institute of Grocery Distribution (2006).[17]

this group are alginates, carrageenans, and agar, depending on the type of seaweed. These fibers are not digested to any great extent in the gut. Some show some fermentative capacity in the lower intestine, but the nature of soluble seaweed fibers is such that their passage through the gastrointestinal tract occurs largely without digestion. In addition, the fibers can increase feelings of satiety and aid digestive transit through their bulking capacity.[14] *Porphyra umbilicalis*, which is normally processed into 'Nori' sheets, contains slightly more fiber than bananas in direct weight comparison (3.8 g versus 3.1 g per 100 g, respectively) (Table 2), although the amounts consumed in the diet would be lower.[15] In comparing *Laminaria digitata* (Kombu) with brown rice, the seaweed shows a higher level of total fiber (6.2% versus 3.8%, respectively).[16] This seaweed also has a balance of soluble (5.38%) and insoluble (0.78%) fibers[15] and does not contain much of the starchy carbohydrate that is present in brown rice, possibly leading to a negligible glycemic load.

The guideline daily amount of dietary fiber is 24 g per day.[17] Based on this amount, seaweeds can provide up to 12.5% of a person's daily fiber needs in an 8 g serving (Table 3). This is a relatively large amount on a

Table 4. Mineral composition of seaweeds compared to whole foods

Food Type	Calcium	Potassium	Magnesium	Sodium	Copper	Iron	Iodine	Zinc
Seaweed (mg/100 g wet weight)*								
Ascophyllum nodosum	575.0	765.0	225.0	1173.8	0.8	14.9	18.2	NA
Laminaria digitata	364.7	2013.2	403.5	624.6	0.3	45.6	70.0	1.6
Himanthalia elongata	30.0	1351.4	90.1	600.6	0.1	5.0	10.7	1.7
Undaria pinnatifida	112.3	62.4	78.7	448.7	0.2	3.9	3.9	0.3
Porphyra umbilicalis	34.2	302.2	108.3	119.7	0.1	5.2	1.3	0.7
Palmaria palmata	148.8	1169.6	97.6	255.2	0.4	12.8	10.2	0.3
Chondrus crispus	373.8	827.5	573.8	1572.5	0.1	6.6	6.1	NA
Ulva spp.	325.0	245.0	465.0	340.0	0.3	15.3	1.6	0.9
Enteromorpha spp.	104.0	351.1	455.1	52.0	0.1	22.2	97.9	1.2
Whole food (mg/100 g weight)†								
Brown rice	110.0	1160.0	520.0	28.0	1.3	12.9	NA	16.2
Whole milk	115.0	140.0	11.0	55.0	Tr	0.1	15.0	0.4
Cheddar cheese	720.0	77.0	25.0	670.0	0.0	0.3	39.0	2.3
Sirloin steak	9.0	260.0	16.0	49.0	0.1	1.6	6.0	3.1
Lentils green and brown	71.0	940.0	110.0	12.0	1.0	11.1	NA	3.9
Spinach	170.0	500.0	54.0	140.0	0.0	2.1	2.0	0.7
Bananas	6.0	400.0	34.0	1.0	0.1	0.3	8.0	0.2
Brazil nut	170.0	660.0	410.0	3.0	1.8	2.5	20.0	4.2
Peanuts	60.0	670.0	210.0	2.0	1.0	2.5	20.0	3.5

*Values for seaweeds from the Institut de Phytonutrition (2004).[15]
†Values for whole foods from McCance et al. (1993).[16]
Abbreviations: NA, no data available; Tr, trace.

Table 5. Mineral contents of seaweeds as compared with reference nutrient intake (RNI) values

Seaweed	Calcium*		Potassium*		Magnesium*		Sodium*		Copper*		Iron*		Iodine*	
	mg/8 g	% RNI	mg/8 g	% RNI	mg/8 g	% RNI	mg/8 g	% RNI	mg/8 g	% RNI	mg/8 g	% RNI	mg/8 g	% RNI
Ascophyllum nodosum	184	26.4	244.8	7	72	24	375.6	23.4	0.3	22	4.7	54	5.8	4100
Laminaria digitata	176.8	25.5	976	27.8	195.6	65.2	302.8	18.9	0.14	12	22.1	254	34	24250
Himanthalia elongata	8	1.1	360	10.4	24	8	160	10	0.03	2.5	1.3	15.1	2.8	2030
Undaria pinnatifida	93.6	13.3	52	1.5	65.6	21.8	374	23.3	0.16	14	3.26	37	3.2	2300
Porphyra umbilicalis	24	3.4	212	6	76	25.3	84	5.25	0.07	6	3.7	42	0.94	670
Palmaria palmata	74.4	10.6	584.8	16.7	48.8	16.2	127.6	8	0.2	16	6.4	74	5.1	3650
Chondrus crispus	119.6	17	264.8	7.5	183.6	61.2	503.2	31.4	0.03	2.5	2.1	24	1.9	1400
Ulva spp.	260	37.1	196	5.6	372	124	272	17	0.25	21	12.2	140	1.3	920
Enteromorpha spp.	64	9.1	216	6.1	280	93	32	2	0.06	5	13.7	157	60.3	43030

*Values from the Committee on Medical Aspects of Food and Nutrition Policy (1991)[12] and the Institut de Phytonutrition (2004).[15]

weight-for-weight basis when compared to other vegetables; it also indicates that seaweed may be a valuable fiber source as a food component. When combined with its texturizing properties, the use of seaweed as a functional nutrient seems worthy of exploration.

The nutritional role of alginates from brown seaweeds has been reviewed and shown alginates to be potentially beneficial in gut health, contributing to water binding, fecal bulking, and decreasing transit time.[18] The main beneficial action of alginates in the digestive system is linked to the increase in fecal bulk associated with the water-holding and -binding capacity of the polysaccharide.[19] This helps decrease colon transit times, which is a positive factor in preventing colon cancer. The alginate polysaccharide also binds metal ions very well, which affects the bioabsorption of heavy metals through the system[20] and has been linked to the reduction of mineral availability due to the binding nature of the polysaccharide.[21] The soluble yet non-metabolized fiber content of alginates makes them useful in nutritionally balanced food applications, helping to reduce colonic transit times.

MINERAL CONTENT

Seaweeds are high in minerals due to their marine habitat, and the diversity of the minerals they absorb is wide. Important minerals, such as calcium, accumulate in seaweeds at much higher levels than in terrestrial foodstuffs. This is illustrated in an 8 g portion of *Ulva lactuca* (sea lettuce), which provides 260 mg of calcium, equaling approximately 37% of the RNI of calcium for an adult male.[12,22] In comparison, the same portion of cheddar cheese provides just 5% of the RNI (Table 4).[16] Sodium and potassium are also present at relatively high levels, although Na:K ratios are usually below 1:5.[23]

Minerals such as iron and copper are present in seaweeds at higher levels than in many well-known terrestrial sources of minerals, such as meats and spinach. For example, there is more iron in an 8 g serving of dry *Palmaria palmata* (Dulse/Dillisk) than in 100 g of raw sirloin steak (6.4 mg versus 1.6 mg, respectively).[15,16] A study on the bioavailability of iron from *Porphyra* spp. found that iron absorption and iron retention levels were lower in seaweed-fed animals than a control and it was suggested that this was due to the polyphenolic compounds or peptides from partially digested protein in the diet.[24] Copper is present at a high level in seaweeds. The reference nutrient intake of copper is 1.2 mg per day[25] and an 8 g portion of *Undaria pinnatifida* (Wakame) contains 14% of the RNI for this mineral (Table 5). Brown seaweeds bioaccumulate many elements and are a good source of magnesium, copper, iron, and iodine as well as other rarer elements. An 8 g

Table 6. Polyunsaturated fatty acid (PUFA) contents of seaweed

Seaweed	Type of fatty acid (% of total fatty acid content)*					
	Saturated	Monounsaturated	PUFAs	ω6 PUFAs	ω3 PUFAs	ω6:ω3 Ratio
Himanthalia elongata	39.06	22.75	38.16	15.08	18.7	0.81
Laminaria ochroleuca	33.82	19.23	46.94	20.99	25.08	0.83
Undaria pinnatifida	20.39	10.5	69.11	22.1	44.7	0.49
Palmaria spp.	60.48	10.67	28.86	2.14	25.52	0.13
Porphyra spp.	64.95	18.91	16.1	7.97	7.2	1.21

*Values from from Sanchez-Machado et al. (2004).[30]

daily intake of 'Kombu', as used in Asian cooking, contains 65% of the RNI for magnesium.[15]

Iodine is an important nutrient in metabolic regulation and growth patterns and is abundant in most seaweeds.[26] Seaweeds have been described as an ideal food-safe natural source of the mineral.[27] Consumption of very large amounts could induce some undesirable effects[28] but, overall, the effects of iodine consumption would be beneficial.

Trace elements, such as zinc, are present in seaweeds and some of these, such as arsenic, have negative health effects. In the case of arsenic, further analysis of speciation indicates that the type of arsenic is important in assessing toxicity; since many types of arsenic are not metabolized, these do not pose a risk to health.[29] For the vast majority of seaweeds, the levels of heavy metals are below food safety limits naturally.

FATTY ACID CONTENT

Seaweeds contain up to 2% of dry weight of lipids and much of this lipid content is made up of polyunsaturated fatty acids (PUFA).[13,30] Table 6 illustrates that PUFAs account for almost half of this lipid content, with much of it occurring in the form of omega-3 and omega-6 lipids. The omega-3 to omega-6 ratio is closely matched, a factor that has been found to be important in a balanced diet.[31] Both omega-3 and omega-6 fatty acids are essential, i.e., humans must consume them in the diet. Omega-3 and omega-6 compete for the same metabolic enzymes; thus, the omega-6:omega-3 ratio will significantly influence the ratio of the ensuing eicosanoids. This means omega-3 and omega-6 should be consumed in a balanced proportion, with the ideal ratio of omega-6: omega-3 ranging from 3:1 to 5:1.[32]

Seaweeds contain many essential fatty acids, which may add to their efficacy as a dietary supplement or as part of a balanced diet.[33] Seaweeds are also normally tested after drying, but the effects of other types of food processing, such as canning, have been found to have a detrimental post-processing effect on fatty acid levels.[30,34]

VITAMIN CONTENT

The habitat of seaweeds varies from species to species but many of them spend large amounts of time exposed to direct sunlight in an aqueous environment. As a result, seaweeds contain many forms of antioxidants, including vitamins and protective pigments. Seaweeds contain both water- and fat-soluble vitamins (Table 7). These include vitamins A, B, C, and E. Vitamin E, an important antioxidant, is present in an 8 g portion of *Undaria pinnatifida* (Wakame) at a level higher than in peanuts (1.16 mg versus 0.8 mg, respectively).[15,16] Water-soluble vitamins such as vitamin C are present in large amounts in *Ulva lactuca* (sea lettuce), *Undaria pinnatifida* (Wakame), and *Gracilaria* spp. at 10 mg per

Table 7. Vitamin composition of seaweeds

Seaweed	Vitamin (mg per 8 g dry portion)*								
	B1	B2	B3	B6	B8	B9	C	E	B12†
Ascophyllum nodosum	0.216	0.058	0.000	0.001	0.001	3.648	0.654	0.029	0.131
Laminaria digitata	0.011	0.011	4.896	0.513	0.513	0.000	2.842	0.275	0.495
Undaria pinnatifida	0.403	0.936	7.198	0.259	0.015	0.528	14.779	1.392	0.345
Porphyra umbilicalis	0.077	0.274	0.761	0.119	NA	1.003	12.885	0.114	0.769
Palmaria palmata	0.024	0.080	0.800	0.002	0.002	0.021	5.520	1.296	1.840
Ulva spp.	0.060	0.030	8.000	NA	NA	0.012	10.000	NA	6.300

*Values from the Institut de Phytonutrition (2004).[15]
†Values expressed in μg/100 g wet weight.
Abbreviation: NA, no data available.

100 g wet weight, 14 mg per 100 g wet weight,[15] and 25 mg per 100 g wet weight, respectively.[35] In a per-portion comparison, 8 g of *Porphyra umbilicalis* (Nori) provides 9 mg of vitamin C, or 15% of the RNI.[12,15] This adds to the evidence that seaweeds can contribute to nutritional intake in a balanced diet (Table 8).

Seaweeds are also one of the few vegetable sources of vitamin B12. *Ulva lactuca* can provide this vitamin in excess of the recommended dietary allowances for Ireland of 1.4 μg/day with 5 μg in 8g of dry foodstuff.[22] This may provide an alternate source of vitamin B12 for vegetarians or vegans. The red seaweed of the *Gracilaria* spp. was also recently found to have 5.4 mg of beta carotene per 100 g dry weight, which is a relatively high level compared to other vegetables.[35]

Table 8. Comparison of vitamin content in seaweeds with reference nutrient intake (RNI) values

Seaweed (μg per 8g dry portion)*	A*		B1*		B2*		B3*		B6*		B9*		B12*		C*	
	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI	μg/8 g	% RNI
Ascophyllum nodosum	3	0.4	69	6.9	19	1.1	NA	NA	0.23	0.3	1167	390	0.04188	3	209.2	0.34
Laminaria digitata	782	111	5	0.5	5	0.3	2373	14	249	31	249	83	0.24	17	1378	2.3
Undaria pinnatifida	988	141	336	33	780	48	6000	37	216	27	440	146	0.288	20.5	1232	2
Porphyra umbilicalis	544	77	54	5.4	192	12	534	3.3	83	10.5	704	234	0.5392	38.5	9040	15
Palmaria palmata	638	91	12	1.2	40	2.5	400	2.5	1	0.1	10	3.3	0.92	65	2760	4.6
Ulva spp.	256	36.5	48	4.8	24	1.5	6400	40	NA	NA	10	3.3	5.04	360	8000	13.3
Total daily RNI (μg)	700		1000		1600		16000		1400		300		1.4		40000	

*Values from the Committee on Medical Aspects of Food and Nutrition Policy (1991)[12] and the Institut de Phytonutrition (2004).[15]
Abbreviation: NA, no data available.

PROTEIN CONTENT

Some seaweeds, such as *Porphyra* spp. (Nori) are relatively high in proteins. The protein content can be as high as 47% of the dry weight,[36] but these levels vary according to the season and the species. For most species, aspartic and glutamic acids constitute a large part of the amino acid make-up of these proteins. Aspartic and glutamic acids exhibit interesting properties in flavor development, and glutamic acid is a main component in the taste sensation of 'Umami'. *Laminaria japonica* (Kombu), which is closely related to *Laminaria digitata*, is the original source of the flavor enhancer monosodium glutamate, which was discovered through its use in Asian cooking.[37] These levels are highest in brown seaweeds, with red seaweeds having lower amounts of these two amino acids. Essential amino acids such as histidine, leucine, isoleucine, and valine are present in many seaweeds, such as *Palmaria palmata* (Dillisk/Dulse) and *Ulva* spp. (sea lettuce). The levels of isoleucine and threonine in *Palmaria palmata* are similar to the levels found in legumes, and histidine is found in *Ulva pertusa* at levels similar to those found in egg proteins.[36]

The bioavailability of seaweed proteins can sometimes be inhibited by the entrapped nature of the proteins in the cellular matrix. Increasing the bioavailability by using physical processes or fermentation to break down the fibers and liberate more protein has been studied, particularly for *Palmaria palmata* (Dillisk/Dulse),[38] as has the use of digestive enzymes.[39,40] The level of digestibility of these proteins seems to be related to the amount of soluble fiber in the algae, preventing bioavailability of the proteins.

Other proteins within red seaweeds such as *Chondrus crispus*, absorb solar radiation and are generally known as mycosporine-like amino acids. There is growing evidence that these proteins are potent and stable absorbers of ultraviolet light, a characteristic that may

Table 9. Other bioactive components of seaweeds

Seaweed	Bioactive components (g/100g)*						
	Alginic acid	Fucoidan	Laminarin	Mannitol	Porphyran	Floridoside	Pentoses
Ascophyllum nodosum	28	11.6	4.5	7.5	–	–	–
Laminaria digitata	32.2	5.5	14.4	13.3	–	–	–
Porphyra umbilicalis	–	–	–	–	47.8	41.8	NA
Palmaria palmata	–	–	–	–	NA	25	46

*Values from the Institut de Phytonutrition (2004).[15]
Abbreviation: NA, no data available.

lend them to use in other areas.[41] Red seaweeds contain a group of proteins called biliproteins, some of which are extracted for their valuable use as fluorescent markers. Phycoethrin is a major light-harvesting pigment in red algae and is regularly used as a fluorescent probe in scientific experiments. The other members of this group of proteins known as phycobiliproteins are phycocyanins and allphycocyanins. These proteins are assembled into a structure in the cell that absorbs light where chlorophyll absorbs poorly, i.e., the light wavelength from 450 nm to 650 nm.[42] This allows some red seaweeds to survive in relatively deep water, depending on opacity and other conditions.

Seaweed proteins are also very low in cysteine. Although a few seaweeds accumulate this amino acid, most contain very low levels. Sulfur, however, may be held in the form of glutathione.[43] Seaweeds may be able to regulate glutathione synthesis with their high polyphenol levels, which have recently been linked to increased expression of glutamylcysteine.[44] Overall, seaweeds have been reviewed favorably as sources of nutrients and proteins for nutritional purposes.[45]

OTHER MAJOR COMPONENTS

Seaweeds contain many more components than simply fibers, vitamins, and minerals. The brown seaweeds get their characteristic color from the pigment fucoxanthin and they contain chlorophylls for photosynthesis. The more abundant components present in seaweeds include other classes of species-specific polysaccharides, such as laminarin in *Laminaria* species, ulvan in species *Ulvales* and floridean starches in red seaweeds. Alginates comprise up to 32% of the dry weight of brown seaweeds in Irish waters, and fucoidans are present at levels up to 15% of dry weight. *Laminaria saccharina* also contains substantial amounts (up to 14%) of mannitol, which has a sweet taste and gives this species the name ‘Sweet Kombu’ (Table 9).[10]

The family of red *Porphyra* seaweeds contain the polysaccharide ’porphyran’ at levels up to 48% by dry weight, and this polysaccharide has been studied for food applications.[46] The occurrence of a starch-based polysaccharide known as floridean starch or floridoside at up to 42% of dry weight in *Porphyra* spp. additionally lends this seaweed to use in food. *Palmaria palmata* contains up to 45% of the pentose-related polysaccharide xylan. The prevalence of xylose and related sugars in this polysaccharide, which is a dietary fiber, may also lend this seaweed to beneficial use in food.[15] Many other seaweed-specific bioactive molecules are present and will be described in a further publication.

CONCLUSIONS

Edible seaweeds have been shown to be high in essential vitamins and minerals, at levels that would augment a balanced diet if consumed regularly. Specifically, trace elements and minerals are abundant in seaweeds compared to terrestrial foodstuffs, and their non-animal nature lends them to use in many food products. The strong tastes associated with seaweeds are allied with the many beneficial micronutrients they contain. Cooking or washing processes may remove many of these tastes, and the culinary use of seaweeds in Asia can be studied for examples of this. Aspects of the nutrient content of seaweeds may be augmented by the research available on bioactive components, which have been studied for many years. A combination of these two properties may revitalize the use of seaweed in the newly health-conscious consumer environments of Western countries.

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