

Seaweed: Nature's Secret for a Long and Healthy Life?

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Abstract

The health benefits of consuming seaweed were recognised over three thousand years ago, particularly in Asia, where marine algae are still prized for their nutritional content. The vast majority of marine algae are edible, with only a few tropical species being poisonous. Some species, however, are specially selected for their appealing flavour, texture or culinary versatility; these include dulse (Palmaria palmata), nori (Porphyra tenera), sea lettuce (Ulva lactuca) kombu (Laminaria japonica), wakame (Undaria pinnatifida), arame (Eisenia bicyclis), hijiki (Hizikia fusiforme) and agar-agar (Sphaerococcus euchema). Sea vegetables are low in fat, low in calories and rich in essential minerals, vitamins and protein. The mineral content of seaweeds is very significant and is likely to explain many of their beneficial effects on health. Seaweeds provide all of the 56 minerals and trace minerals required for the body's physiological functions. Indeed, they contain 10 to 20 times the minerals of land plants and an abundance of vitamins and other elements necessary for metabolism. The modern diet is severely depleted of minerals due to a general decline in soil and crop mineral content, and to refining and processing which strips food of minerals and other vital nutrients. Thus, addition of seaweed into the diet is very important to ensure adequate intake of minerals, which are in a highly assimilable form because they are integrated into living plant tissue. Sea vegetables are especially useful for vegetarians and those abstaining from dairy foods because of their high levels of calcium, iron and iodine. In addition to minerals, seaweeds contain vitamins A, B, C, and E, and Porphyra species are reported to contain vitamin D. Moreover, some seaweeds contain what appears to be vitamin B12, which is normally found only in animal products. Seaweeds contain 50 to 60% polysaccharides, notably cell wall structural polysaccharides that are extracted by the hydrocolloid industry. Despite this large quantity of carbohydrate, sea vegetables add few calories to the diet; this is because much of their starch consists of a substance called algin. Alginates are not easily digested by the body, acting like soft fibre, soothing and adding bulk to the digestive tract. Scientific studies have shown that alginates inhibit absorption of toxic metals and radioactive isotopes such as strontium-90 in the digestive tract. All sea vegetables contain significant amounts of protein, sometimes as much as 48%. Lipids represent only 1-5 % of algal dry matter and show an interesting polyunsaturated fatty acid composition, particularly regarding omega 3 and omega 6 acids which are concentrated in the galactolipid fractions. Sea vegetables have traditionally been used in Asia to treat cancer, heart disease and thyroid problems. Other medicinal uses are currently being investigated. Scientific research aimed at explaining the positive effects of seaweeds on health is in progress and some key findings related to breast cancer, heart disease, thyroid problems, immune function, inflammation, and anti-bacterial and anti-viral activity are reviewed. Finally, practical information on how to prepare and cook nori, arame, dulse, kombu, wakame, hijiki and agar-agar is given, as well as some recipes.

History of Use

Most westernised societies ingest seaweed extracts in the form of alginates, agars and carrageenans every day in their foods or pharmaceuticals¹. Eating whole seaweeds or sea vegetables, however, is considered rather an unusual thing to do and few people in this country are aware of their remarkable nutritional and health benefits. This has not always been the case. Regulations for the gathering of *Palmaria palmata* (dulse, dillisk), a red seaweed, are mentioned in the Icelandic sagas of the 10th century², and the Celts and the Vikings chewed dulse on their travels. In Ireland, people started collecting sea vegetables in 1200 AD, and dulse and wild nori, known locally as laver (Latin for water plant), have been popular in Ireland, Wales and Scotland for centuries³. Bladderwrack, carrageen, badderlocks, sea lettuce, sloke and tangle are other species still remembered as delicacies in various parts of the British Isles.

In other parts of the world, coastal peoples have prized seaweed as a source of valuable nutrients for millennia. It is believed that seaweed has been consumed in China since 2700 BC. In 600 BC, Sze Teu wrote, "Some algae are a delicacy fit for the most honoured guests, even for the King himself"⁴. Six types of seaweed were used in cooking in Japan in 800 AD and now some 21 species are included in the Japanese diet. The ancient Hawaiians grew kelp gardens. They used 60 to 70 species of marine algae for food, medicine, ceremonies and leis (flower garlands)⁵. In Tonga, people have eaten a brown seaweed called "Limu Moui" for over 3000 years, and believe it is responsible for their remarkable longevity and good health. When Captain Cook visited Tonga in 1777, he was given Limu Moui to restore his strength and energy⁶. In Europe, Mediterranean seaweeds were used as fodder and as herbal medicines in Greek and Roman times. Greeks used seaweeds as animal food as early as 100 BC and started collecting them for human consumption in 46 BC. From pre-Christian times in the Mediterranean, some red algae were used as sources of dyeing agents and as a medicine to treat parasitic worms⁷.

Nowadays there is a thriving seaweed industry whose products are used as food, fodder, fertilisers and cosmetics and for a wide range of industrial purposes⁸. It is thus clear that sea vegetables have long been important to humans for food and other uses and are not just a modern health fad.

What are sea vegetables?

Sea vegetables or seaweeds are marine algae: saltwater-dwelling, simple organisms that have very few tissue types compared with land plants. There are green, brown and red species, which have a frond (leaf), stipe (stem) and holdfast (root). The holdfast does not extract nutrients and acts only as an anchor; nutrients are absorbed through the entire surface of the plant⁹.

The vast majority of marine algae are edible, with only a few tropical species being poisonous^{10,11,12}. Some species, however, are specially selected for their appealing flavour, texture or culinary versatility. The food species most commonly available in shops in the UK are dulse (*Palmaria palmata*), nori (*Porphyra tenera*), sea lettuce (*Ulva lactuca*) kombu (*Laminaria japonica*), wakame (*Undaria pinnatifida*), arame (*Eisenia bicyclis*), hijiki (*Hizikia fusiforme*) and agar agar (*Sphaerococcus euchema*). The Food Standards Agency has reported that hijiki contains significant levels of inorganic arsenic and recommends that it is not consumed on a regular basis¹³; this does not apply to the others.

Health benefits of sea vegetables

Sea vegetables have very interesting nutritional properties. They are virtually fat-free, low in calories and rich in essential minerals, vitamins and protein (Table 1).

Table 1: Nutritional analysis of sea vegetables compared to other foods

g/100g	Fibre NSP	Water	Protein	Fat	Carbo- hydrate	Minerals*	Energy	
							kcal	kJ
Nori	4.7	5.1	35.6	0.6	46.3	1.03	349	1,483
Arame	1.1	11.5	12	0.2	68.1	6.36	313	1,328
Dulse	1.2	13.8	7.9	0.1	59.8	9.20	272	1,155
Kombu	3.0	18.2	7.3	0.3	61.6	7.27	274	1,165
Wakame	3.6	16.3	17.3	0.7	39.0	9.17	232	983
Hijiki	17	6.2	10	0.1	56.8	6.50	260	1,104
Agar-Agar	0	20.6	1.9	0.4	73.7	3.40	306	1,300
Spinach raw	2.1	89.7	2.8	0.8	1.6	0.91	25	103
Broccoli Raw	2.6	88.2	4.4	0.9	1.8	0.54	33	138
Carrots Young raw	2.4	88.8	0.7	0.5	6.0	0.34	30	125
Whole milk	0	87.6	3.3	3.9	4.5	0.42	66	274
Oranges	1.7	86.1	1.1	0.1	8.5	0.23	37	158
Dried skimmed Milk	0	3.0	36.1	0.6	52.9	4.50	348	1482
Beef average trimmed raw	0	71.9	22.5	4.3	0	0.64	129	542

* Sum of concentration of Ca, K, Na, Mg, P, Fe, I in g/100g

per 100g	Calcium mg	Iron Mg	Iodine Mg	Potassium mg	Vit A IU	Vit B1 mg	Vit B2 mg	Vit C Mg
Nori	470	23	1	3,505	11,000	0.25	1.24	20
Arame	1,170	12	300	3,860	50	0.02	0.20	0
Dulse	296	150	150	8,060	188	0.63	0.50	30
Kombu	800	15	300	5,800	430	0.08	0.32	11
Wakame	1,300	13	25	6,800	140	0.11	0.14	15
Hijiki	1,400	29	40	14,700	150	0.01	0.2	0
Agar-Agar	400	5	0	-	0	0	0	0
Spinach, Raw	170	2.1	0.002	500		0.07	0.09	26
Broccoli, Raw	56	1.7	0.002	370		0.1	0.06	87
Carrots, Young Raw	34	0.4	0.002	240	12036	0.04	0.02	4
Oranges	47	0.1	0.002	150	247	0.11	0.04	54
Whole milk	118	0.03	0.031	155	490	0.03	0.23	2
Dried skimmed milk	1280	0.27	0.15	1590	122	0.38	1.63	13
Beef average Lean raw	5	2.7	0.01	350	0	0.1	0.21	0

Sources: U.S.D.A.; Japan Nutritionist Association food tables; public analyst data supplied courtesy of Clearspring Ltd; McCance and Widdowson’s Composition of Foods (6th edition).

Please note that nutritional assays vary according to maturity of plant at time of harvest, storage techniques etc.

Minerals

The mineral content of sea vegetables is highly significant and is probably responsible for many of their health benefits. The major minerals are instrumental in most of the life-sustaining activities in the body; for example, magnesium is crucial in calcium absorption, iodine in thyroid function, iron in blood oxygen exchange, and chromium in blood sugar regulation. Seaweeds provide all of the 56 minerals and trace minerals required for the body’s physiological functions. Indeed, they contain 10 to 20 times the minerals of land plants (Table 1) and an abundance of vitamins and other elements necessary for metabolism. Gram per gram, they are higher in minerals than any other class of food. The minerals are available in chelated, colloidal forms that make them especially bioavailable^{14,15}.

The ability of marine algae to chelate metals and form ionic colloids is due to the properties of the cell wall constituents, such as alginate and fucoidan. Chemically, alginates consist of a linear chain of (1–4)-linked residues of β -D-mannuronic acid and α -L-guluronic acid in different proportions and sequential arrangements. The most common arrangement is that of a block copolymer, in which long homopolymeric sequences of guluronic acid residues (G–G blocks) and similar sequences of mannuronic acid residues (M–M blocks) are intercalated between sequences of mixed composition (M–G blocks)¹⁶. The alginic acid offers anionic carboxylate and sulphate sites at neutral pH. The fresh water forms contain galacturonic acid and its polymer pectin which also has anionic sites to which metals can bind by electrostatic attractions^{17, 18}. The amino and carboxyl groups, and nitrogen and oxygen of the peptide bonds are also available for coordination bonding with metal ions such as lead (II), copper (II) or chromium (IV). Such bond formation could be accompanied by displacement of protons and is dependent in part on the extent of protonation which is determined by the pH.

The various groups involved in metal binding have been discerned using modification/blocking of the groups. Carboxyl groups were suggested to be involved in binding Cu^{2+} and Al^{3+} in algal species, as blocking of carboxyl groups by esterification led to a decrease in metal binding¹⁹. As with land plants, the origin of the seaweeds is important because certain areas of the oceans are polluted, particularly with toxic metals. Since no body of water can now be considered to be pristine, it is helpful to know that wherever seaweeds grow, they do not simply absorb and concentrate toxins. Rather, they detoxify and transform a certain amount of toxic metals, converting them to harmless salts, which the body excretes through the intestines²⁰.

The minerals in sea vegetables are more important to humans and animals today than ever. Statistics published at the Rio Earth Summit in 1992²¹ indicate that the mineral content of the world’s farm and range soils has decreased dramatically over the last 100 years:

Continent	% depletion
North America	85
South America	76
Asia	76
Africa	74
Australia	55

Table 2: Percentage of mineral depletion from soil during the past 100 years²¹

There are many reasons for this, mostly related to the intensification of agriculture. Factors such as crop removal, heavy tillage of the soil, soil erosion, livestock manure not being returned to the soil, increased nutrient demand by high yielding crops, and over-fertilisation of some nutrients causing deficiencies in others, have all led to a reduction in soil mineral content. Some studies have compared the nutrient content of organically-grown food with

that produced using chemicals, and results indicate that organic food can contain substantially higher levels of minerals - as much as 90% more – than intensively produced food^{22, 23}. This adds further weight to the suggestion that modern farming methods have led to a reduction in the quality of the soil and of the food which grows in it.

Analysis of the 1st and 5th editions of McCance and Widdowson’s book "*The Composition of Foods*" suggests that many foods have declined in mineral content over the last half century (Table 3)²⁴. It is important to recognise that accurate comparison of these data is difficult due to variation in analytical techniques, crop varieties, weather and so on; nevertheless, the differences observed are probably large enough to be significant.

Table 3: Decline in mineral content of vegetables and fruit between 1940 and 1991²⁴.

Mineral	Vegetables	Fruit
Sodium	49%	29%
Potassium	16%	19%
Magnesium	24%	16%
Calcium	46%	16%
Iron	27%	24%
Copper	76%	20%
Zinc	59%	

On top of this general decline in soil and crop mineral content, food is further stripped of minerals and other vital nutrients by refining and processing. The dramatic increase over the last 100 years in the intake of refined foods, such as baked white flour products and white sugar, has further reduced the availability of essential minerals in the diet. Dr Linus Pauling, winner of two Nobel Prizes, stated: “*You can trace every sickness, every disease and every ailment to a mineral deficiency.*” Other workers have also proposed that many poor health and behavioural conditions are related to a deficiency of essential minerals or an excess of toxic ones. In one study, clients requesting a hair mineral analysis were required to complete a questionnaire including lifestyle, health status and diet. Most prevalent health conditions in order of frequency were depression, allergies, low back pain, arthritis, cardiovascular disease and poor digestion. Most deficient minerals were chromium, magnesium, zinc and calcium. Aluminium was the most frequent toxic mineral. It was suggested that such mineral abnormalities were caused by an over consumption of nutrient-poor, highly processed foods such as white flour, sugar and harmful fats²⁵.

Research on Attention-Deficit Hyperactivity Disorder (ADHD) in children has proposed a link with abnormalities in essential fatty acid metabolism which, in turn, may be related to mineral deficiency, particularly zinc²⁶. Sometimes, specific diseases can be clearly linked to a deficiency of a particular mineral, for example, Keshan disease in China. Keshan is a form of heart disease suffered by people living in a broad swathe across China, running from the south-west up to the north-east which is an area of known selenium deficiency²⁷.

Given their crucial role in the correct functioning of the body, it is vital to ensure adequate dietary intake of minerals. Sea vegetables are of particular value in this regard due to the fact that they contain such a high amount of a broad range of minerals. Their minerals are in a highly assimilable form because they are integrated into living plant tissue. Sea vegetables are especially useful for vegetarians and those abstaining from dairy foods because of their high levels of calcium, iron and iodine (Table 1).

Vitamins

Seaweeds contain vitamins A, B, C, and E²⁸ (Table 1). *Porphyra* species are especially rich in vitamin D²⁹. The brown seaweeds contain higher levels of vitamin E than green and red seaweeds. Among the brown algae, the highest levels are observed in the Fucaceae, *Ascophyllum* and *Fucus* sp., which contain between 200 and 600 mg of tocopherols per kg of dry matter. Brown algae contain alpha, beta and gamma tocopherol while the green and red algae only contain the alpha tocopherol²⁸.

Many seaweeds contain what appears to be vitamin B12, which is normally found only in animal products. For example, the edible purple laver, *Porphyra yezoensis*, was found to contain 51.49+/-1.51 µg of vitamin B12 compounds per 100 g dry weight³⁰. The source of the B12 in seaweed is uncertain - it has been proposed that it may be made by bacteria living on the surface or in the water. Some researchers believe that the B12 found in seaweed is an analogue which the human body is unable to utilize³¹. Others have published work indicating that feeding seaweed (nori) to vitamin B12-deficient rats significantly improved their vitamin B12 status, suggesting that it is bioavailable³². Given the conflicting information available about the biological activity of vitamin B12 derived from seaweed, it would be prudent to include other sources of B12 in the diet.

Algin and other polysaccharides

Seaweeds contain 50-60% polysaccharides, notably cell wall structural polysaccharides that are extracted by the hydrocolloid industry: alginate from brown seaweeds, carrageenans and agar from red seaweeds. Other minor polysaccharides are found in the cell wall: fucoidans (from brown seaweeds), xylans (from certain red and green seaweeds), ulvans in green seaweeds. Seaweeds also contain storage polysaccharides, notably laminarin (β -1,3-glucan) in brown seaweeds and floridean starch (amylopectin- like glucan) in red seaweeds²⁸. Despite this large quantity of carbohydrate, sea vegetables add few calories to the diet; this is because much of their starch consists of a substance called algin. Algin is a soft sticky gel that protects the cell walls of the algae, giving them flexibility to withstand the constant movement of the sea and to retain moisture when the tide leaves them stranded above the water line.

Alginates are not easily digested by our bodies, acting like soft fibre, soothing and adding bulk to our digestive tract. Algin is abundant in kombu, wakame, arame and hijiki. Scientific studies have shown that alginates inhibit absorption of toxic metals and radioactive isotopes such as strontium-90 in the digestive tract^{33,34}. As already discussed, the indigestible viscous seaweed polysaccharides such as alginates, carrageenans and funorans, are capable of forming ionic colloids, and have shown positive effects on serum lipid levels in rats. The capacity of seaweed polysaccharides to lower serum cholesterol levels seems to be due to their ability to disperse in water, retain cholesterol and related physiologically-active compounds and inhibit lipid absorption in the gastrointestinal tract¹⁵.

Protein and fats

All sea vegetables contain significant amounts of protein, sometimes as much as 48% (Table 1). Lipids represent only 1-5 % of algal dry matter and show an interesting polyunsaturated fatty acid composition, particularly regarding omega 3 and omega 6 acids, which are concentrated in the galactolipid fractions²⁸. For example, stearidonic acid and hexadecatetraenoic acid are included in edible marine algae such as *Undaria* spp. and *Ulva* spp. at relatively high levels (up to 40%) of total fatty acids³⁵. These galactolipids include sulphoquinovosyldiacylglyceride (SQDG) found in commonly eaten brown algae such as *Undaria* spp. and *Laminaria* spp.³⁶. Interestingly, algal SQDG is a potent telomerase inhibitor, suggesting potential as an anticancer agent³⁷. The green algae show interesting

levels of alpha linolenic acid (ω 3 C18:3)²⁸. The oxygenated derivatives of fatty acids (including eicosanoids) are known as oxylipins. The occurrence of eicosanoids is well-documented in marine red algae³⁸. Eicosanoids have many key roles in the body, including regulation of cell differentiation, immune responses, and homeostasis.

Sea vegetables to treat disease

Sea vegetables have traditionally been used in Asia to treat cancer, heart disease and thyroid problems. Other medicinal uses are currently being investigated. Scientific research aimed at explaining the positive effects of seaweeds on health is in progress and some key findings are summarised below.

Breast cancer

The aetiology of breast cancer is complex and a range of genetic, environmental and lifestyle risk factors have been identified. There is at least a 10-fold variation in breast cancer incidence rates worldwide³⁹. Although genetic factors can play a role in mammary carcinogenesis, and susceptibility genes such as *BRCA1* and *BRCA2* have been identified, environmental factors are thought to be more important. Studies of migrants provided the first solid evidence that environmental, rather than genetic, determinants were responsible for most of the observed international and inter-ethnic differences in breast cancer incidence. Comparisons of breast cancer in (low-risk) Asian populations migrating to the (high-risk) USA and their offspring revealed major increases in risk between successive generations⁴⁰.

There is overwhelming evidence that oestrogen levels are a critical determinant of breast cancer risk^{41,42}. Oestrogen participates directly in the cancer process and also tends to indicate the presence of other female hormones that play a role in breast cancer risk^{43,44}. The high rates of breast cancer in developed countries have been attributed to a higher prevalence of the known risk factors for the disease, many of which – early age at menarche, nulliparity, late age at first birth, late age at any birth, low parity, and late menopause – relate to the hormonal (largely oestrogen) milieu to which the breast is exposed from menarche to the cessation of ovulation at menopause. The evidence on exposure to endogenous and exogenous oestrogen indicates that the lifetime length of exposure to endogenous oestrogen has been increasing, which is consistent with upward trends in incidence of breast cancer, particularly in developed countries. The association between socio-economic status and risk of breast cancer is well established, with women in higher socio-economic groupings being at higher risk⁴⁵.

Can these differences in oestrogen exposure between populations, and hence breast cancer risk, be explained at least in part by variation in diet and, if so, via what mechanisms?

Results of studies on the effect of diet on the occurrence of breast cancer have been equivocal⁴⁶. It has long been suggested that there is a correlation between the incidence of breast cancer and the intake of fat in populations, with some compelling evidence that the correlation is relevant only to animal fat rather than plant fat⁴⁷, but not all studies have produced consistent results. There is now, however, a significant body of evidence suggesting that increased levels of oestrogen and related hormones are the result of consumption of typical Western diets, high in animal fat and protein and low in dietary fibre^{48,49,50,51,52,53,54}.

These findings have been reinforced by the results of “The China Study” – a major nutritional and epidemiological survey of rural China by a team from China's Academy of Preventive Medicine, Cornell University and Oxford University⁵⁵. This study found a strong association between a high-animal protein, high-fat diet and increased reproductive hormones, increased blood cholesterol and early age of menarche. Overall, Chinese oestrogen levels were only half

those of British women. Furthermore, the later age of menarche and earlier onset of menopause observed in China compared with the USA and the UK, means that rural Chinese women experience only 35-40% of the lifetime oestrogen exposure of British and American women. This corresponds to Chinese breast cancer rates that are only one-fifth of those of Western women.

The idea that breast cancer is strongly linked to oestrogen exposure is significant because it suggests that the risk of breast cancer can be significantly reduced if foods that control oestrogen levels are consumed. The fact that the typical Western diet appears to increase lifetime oestrogen exposure may explain the greater rates of breast cancer in developed countries compared with developing countries, as well as the positive correlation between breast cancer and higher socio-economic status – the more affluent people become, the more animal protein and fat they consume⁵⁵.

Excessive alcohol intake also seems to increase risk, with a recent re-analysis of 53 studies indicating that about 4% of breast cancers in developed countries might be attributable to its consumption⁵⁶. Circulating insulin levels and hyperinsulinaemia with insulin resistance increase the risk of breast cancer independent of adiposity^{57,58}. Plasma insulin regulates bioavailable insulin-like growth factor-1 concentrations and affects plasma oestrogen⁵⁹. To what extent diet and physical activity may influence these pathways and provide opportunities for breast cancer prevention remains to be explored. Other factors that have been considered in studies of the role of nutrition in cancer aetiology include food additives⁶⁰, naturally occurring carcinogens⁶¹ and trace element deficiencies⁶².

The role of protective dietary factors which may act as anti-carcinogens has also been investigated. A wide range of plant chemicals have been shown to have a protective effect against cancer, including flavonoids, carotenoids, isoflavones, micronutrients, pre-biotics and 1,3 1,6- beta D glucans⁶³. Phytoestrogens have been well studied because of their anti-oestrogenic effect, and some studies have shown a reduced risk for breast cancer associated with soy intake⁶⁴. Indeed, genistein, one of the predominant soy isoflavones, has been shown to compete with 17beta-oestradiol for oestrogen receptor binding because of its structural similarity, resulting in agonistic or antagonistic activity. It causes inhibition of cell growth in breast and prostate cancers *in vivo* and *in vitro*⁶⁵. It has also been reported to induce apoptosis⁶⁵, to prevent metastasis by inhibition of matrix metallo-proteinases⁶⁶ and to encourage re-differentiation of cancer cells⁶⁷. Phytoestrogens also have oestrogenic effects, however, and may increase breast tissue proliferation⁶⁸.

The dietary intake of seaweed has also been implicated as a potential protective agent in the aetiology of breast cancer⁶⁹. Traditional Chinese medicine includes the brown alga *Laminaria* sp. in the treatment of cancer. According to the Ebers Papyrus, the ancient Egyptians used seaweed to treat breast cancer and it has also been recommended in ancient Ayurvedic texts⁷⁰. In Japan and Korea large amounts of sea vegetables are consumed; Koreans averaged 6.6 g per day in 1995⁷¹. The traditional diet of these countries is plant-based and is low in saturated fat, high in fibre and contains fish and soy products. Breast cancer is typically six to ten times less prevalent in post-menopausal Japanese women than in Western women^{72,73}. Clearly, something about this diet helps to protect against cancer and other degenerative diseases, and seaweed may be an important factor.

Proposed mechanisms of action of seaweed in reducing the risk of breast cancer include:

1. *Reduction of plasma cholesterol.* As already discussed, seaweed has been shown to reduce plasma cholesterol levels due to the physical and biochemical properties of its polysaccharides¹⁵; seaweed also contains beta-sitosterols which are known to reduce

cholesterol⁶⁹. Cholesterol is the precursor for the peripheral conversion of sex hormones, thus an alteration in fat metabolism also affects hormone levels. Exposure of breast tissue to hormones, particularly oestrogen, has been shown to be an important factor in the aetiology of breast cancer^{41,42,45}.

2. *Binding of biliary steroids.* Published research suggests that diet influences levels of oestrogens, and an important mechanism is metabolism of oestrogens in the intestine^{48-54,74}. The intestinal microflora play a key role in the enterohepatic circulation of oestrogens by deconjugating bound oestrogens that appear in the bile, thereby permitting the free hormones to be reabsorbed. By suppressing the microflora with antibiotic therapy, faecal oestrogens increase and urinary oestrogens decrease, changes indicating diminished intestinal reabsorption. A low fat-high fibre diet is associated with similar findings and it appears that the microflora play a key role in the metabolism of female sex hormones. Faecal flora in populations consuming a Japanese diet compared with a Western diet were examined and significant differences in the numbers and kinds of aerobic organisms were observed as a result of dietary manipulations⁷⁵. Non-digestible components of edible seaweeds were found to modify the metabolic activity of intestinal microflora in rats, leading to a reduction of its fermentative capacity⁷⁶. It is also possible that the importance of seaweed to faecal flora may be the reported antibiotic activity of extracts of brown, green and red marine algae⁷⁷.
3. *Anti-oxygenic activity.* Extracts of lipids and phospholipids from a range of marine algae have been shown to have significant antioxidant activity and act as free radical scavengers⁷⁸. Seaweeds also contain vitamins A, C and E which have important antioxidant effects. Epidemiological studies provide convincing evidence that a diet rich in antioxidant-containing foods, mostly fruits and vegetables, is associated with a lower incidence of most cancers⁵⁵. For example, a high intake of green tea, which contains abundant antioxidants, has been shown to reduce the risk of breast cancer in Asian women⁷⁹. Thus, the antioxidant activity of seaweed could be a protective factor in the occurrence of breast cancer.
4. *Binding of toxic materials.* The ability of seaweed to bind metals and radioactive pollutants in the gut has already been mentioned^{33,34}. This occurs by ion exchange reactions between acidic polysaccharides and the metal ion in question, resulting in the formation of insoluble salts which are unabsorbable and are thus excreted. Some metals, particularly the heavy and transition metals, are known to be involved in carcinogenesis⁸⁰. Thus the ability of seaweed to chelate these metals and prevent their absorption in the gut could protect against cancer.
5. *Induction of apoptosis.* About 4 percent of the total dry weight of many types of brown seaweed consists of a polysaccharide known as **fucoïdan**. Fucoïdan is a sulphated polysaccharide that possesses a complex structure. Its chief components include a sulphuric esterified L-fucose, and the trace components of galactose, xylose, and glucuronic acid. Fucoïdan was found to inhibit proliferation and induce apoptosis in human lymphoma HS-Sultan cell lines through caspase and ERK pathways⁸¹. Fucoïdan also induced apoptosis of human T-cell leukaemia virus (HTLV) type 1-infected T-cell lines and primary adult T-cell leukaemia cells. This was mediated through down-regulation of cellular inhibitor, of apoptosis protein-2 and survivin, and G1 phase accumulation through the down-regulation of cyclin D2, c-myc, and hyperphosphorylated form of the retinoblastoma tumour suppressor protein. Further analysis showed that fucoïdan inactivated NF-kappaB and activator protein-1 and inhibited NF-kappaB-

inducible chemokine, C-C chemokine ligand 5 production, and homotypic cell-cell adhesion of HTLV-1-infected T-cell lines⁸².

6. *Inhibition of cell adhesion.* Evidence is mounting that changes in the ability of cancer cells to adhere to extracellular matrices (ECM) play a decisive role in metastasis. The effect of different sulphated polysaccharides on the adhesion of MCF7 and MDA-MB231 adenocarcinoma breast cells to different substrata was investigated: a reconstituted basement membrane (Matrigel) and various adhesion-mediating proteins (fibronectin, laminin, type IV collagen). Most of them inhibited cell adhesion and the most active component was a galactose rich polysaccharide, carrageenan iota. Taken together, the results suggest that this inhibitory activity depends on the charge density related to sulphate groups, the molecular weight and also the carbohydrate structure. These products probably destabilize the interaction between the glucosaminoglycan portion of proteoglycans and the ECM proteins and then block the ability of these adhesive proteins to bind to cells⁸³.
7. *Addition of important trace minerals to the diet.* Minerals such as selenium and zinc are reported to be important for cancer prevention and treatment. Development of dimethylbenz(a)anthracene (DMBA)-induced breast cancer was highly reduced in rats fed selenium-enriched garlic⁸⁴. In another study, selenium was also shown to inhibit the incidence of breast cancer in rats by inhibition of DMBA-DNA binding in breast tissue⁸⁵. Some of the mechanisms suggested for this anti-cancer activity include changes in prostaglandin synthesis and selenium's antioxidant and glutathione peroxidase properties. Zinc is vital for the metabolism of Vitamin A and has important roles in many of the body's systems, including its immune functions, maintaining the integrity of sense organs, reproduction, mental function and wound healing. Mei and colleagues studied the influence of zinc and selenium-zinc upon the immune function (T-cells, granulocytes and NK cells) of cancer patients. The results showed that immune response was strengthened, suggesting that zinc or selenium-zinc may be instrumental in restoring failing immunocompetence of cancer patient⁸⁶. The effect of dietary zinc deficiency on the carcinogenic potential of cadmium in rats was investigated⁸⁷. Zinc-deficient diets markedly increased the number of tumours generated by cadmium exposure while significantly reducing the number of pre-neoplastic lesions. Zinc deficiency appears to cause a generalized increase in the chronic toxic effects of cadmium. Significant differences in serum zinc levels in prostatic cancer patients compared with patients with benign prostatic conditions have been observed, as well as differences in serum zinc in prostate cancer patients before and after therapy. Therefore, zinc concentration in serum may be a valuable index for the differential diagnosis and therapy of prostatic carcinoma⁸⁸. As discussed earlier, seaweeds contain relatively high concentrations of a wide range of minerals in a bioavailable form, which is important as many agricultural soils are severely depleted of minerals. Many of the seaweeds, notably *Porphyra* spp., contain physiologically significant levels of selenium⁸⁹, and levels of zinc of 1mg per 100g in seaweed have been reported⁹⁰. Thus, the ability of seaweeds to supply the body with essential trace minerals may help to protect against cancer.

It can therefore be seen that there are multiple ways in which seaweeds can protect the body against cancer.

Heart disease and stroke

A number of factors contributes to the overall risk of hypertension and heart disease⁹¹. Although high levels of LDL (low density lipoprotein) cholesterol are implicated, it is far from being the most important factor. There are at least 5 other factors:

- 1) In the average Western adult LDL levels are generally too high; but in most people the LDL cholesterol is also insufficiently protected by anti-oxidants and therefore too prone to oxidation. In this state it forms Cholesterol Oxidation Products (COPs) which damage the lining of the arteries, setting up sites of inflammation and exacerbating chronic inflammation of the arteries, known as Endothelial Dysfunction or ED;
- 2) Levels of HDL (high density lipoprotein) cholesterol (the protective form) are too low;
- 3) Levels of the toxic amino acid homocysteine, which can also drive ED, are too high;
- 4) The inflamed artery walls produce molecules which attract immune cells into the arterial tissue. In turn, smooth muscle cells in the inner layer of the arteries begin to proliferate, leading to a narrowing of the artery. This reduces blood flow to the heart and can cause chest pain – angina pectoris;
- 5) Blood platelets are too sticky and therefore clump together – which makes it easier for blockages to take place.

Possible explanations for the cardio-protective effects of seaweed are as follows:

- 1) *Reduction of plasma cholesterol.* Ingestion of carrageenans and other seaweeds has been observed to lower serum lipid and cholesterol levels^{15,69,92}, which may reduce the risk of cardiovascular disease, although as described above this is only one of several risk factors. Undoubtedly, part of the activity is similar to that seen for other soluble fibre-containing foods such as oats. That is, cholesterol binds to the soluble fibres in the bowel, where they are excreted (rather than being bound to bile salts and processed)⁹³. Early work in this area included injecting laminarins (algal beta-glucans) in hypercholesterolaemic patients with apparent success⁹⁴. In an animal study, positive synergistic effects on serum lipids were observed when *Undaria* sp. and fish oils were combined as part of an experimental diet⁹⁵.
- 2) *Antioxidant activity.* As discussed in the section on breast cancer, extracts of lipids and phospholipids from a range of marine algae have been shown to have significant antioxidant activity and act as free radical scavengers⁷⁸. Seaweeds also contain the antioxidant vitamins A, C and E. Seaweeds are reported to contain a wide range of flavonoids which are different from those in fruit and vegetables⁹⁶; these have powerful anti-oxidant and anti-inflammatory activity. These components are likely to exert a cardioprotective role.
- 3) *Omega 3 fatty acids.* Omega 3 fatty acids are known to reduce mortality among patients who have already suffered a heart attack. Omega 3 is incorporated into the membranes of heart muscle cells and makes the heart less likely to develop a fatal arrhythmia *after* a heart attack has happened⁹¹. There are also substantial benefits conferred by the improvements in triglyceride (blood fat) levels, blood pressure and inflammatory tendencies which can be achieved at intakes of around 2 g per day and above. Marine algae contain a high proportion of omega-3-type fatty acids concentrated in the galactolipid fractions³⁵. Whilst these are present at much lower concentrations than believed to be necessary to reduce inflammation, they may contribute to cardiovascular health.
- 4) *Mineral content.* Mineral nutrients, such as calcium, potassium and magnesium, lower blood pressure, and calcium also has beneficial effects on serum lipids^{97,98}. Calcium and magnesium as divalent cations can form insoluble soaps with fatty acids in the intestine and thus prevent the absorption of part of the dietary fat. Decreased absorption of

saturated fat leads to reduction in serum cholesterol level via decreased production of VLDL and increased intake of LDL in the liver. Dietary calcium may also bind bile acids, which increases the conversion of cholesterol to bile acids in the liver. Furthermore, calcium appears to enhance the cholesterol-lowering effect of plant sterols⁹⁷. Thus, the high mineral content of seaweeds is likely to contribute to cardiac health.

- 5) *Anti-blood clotting and complement activation.* Fucoidans are of great interest as replacements for heparin (an anti-coagulant drug) due to their potential anti-thrombotic qualities^{99,100}. They also have the advantage of coming from an algal source rather than from porcine gut or lung mucosae.

In summary, both epidemiological studies and randomised controlled trials have shown that cardiovascular health is dependent on a diet containing multiple protective factors, i.e., an appropriate combination of macronutrients, micronutrients and fibre⁹⁸. Seaweeds contain many agents that are known to be beneficial to the heart, indeed, the inhibition of development of cerebrovascular diseases in stroke-prone spontaneously hypertensive rats was observed with an *Undaria pinnatifida*-rich diet^{101,102}.

Thyroid problems

The World Health Organisation has estimated that two billion people have insufficient iodine in their diets, and countless population studies have shown that they have thyroid-related problems¹⁰³. In addition to unsightly goitres, they experience increased infant mortality, infertility, impaired growth, and frequent or endemic hypothyroidism. Most harmful are the widespread milder forms of developmental retardation that cause poor performance in school and in the workplace. These factors are reflected in impaired social and economic development. In fact iodine deficiency is the leading cause of preventable mental deficiency in the world today. In contrast, inhabitants of the United States, Canada, Japan, and certain other countries eat more iodine than is really necessary. The Food and Nutrition Board of the National Research Council of the USA has recommended a daily intake of 150 to 300 micrograms of iodine per day. In the United States the daily dietary iodine intake is probably between 200 and 700 micrograms per day, because extra iodine has been added to bread, milk, salt, and other foods¹⁰⁴.

In countries where seaweed is eaten, the consumption of iodine may be much higher. One study found that the inhabitants of the Japanese island of Hokkaido who consume large quantities of kombu take in more than 200 mg of iodine per day, a thousand times the recommended daily requirement¹⁰⁴. Although there is a 10 percent incidence of thyroid enlargement or goitre on Hokkaido, the inhabitants do not appear to have an increased risk for other thyroid problems¹⁰⁵.

Thus, provided that seaweed is not consumed in excess quantity, its iodine content may be very valuable in addressing the global problem of iodine deficiency and its associated health problems.

Immune function

Recent studies on ingestion of *Undaria pinnatifida* (wakame) in a rat model illustrated an increase in interleukin-12 (IL-12), and interferon-gamma (IFN-gamma), both mediators of increased natural killer (NK) cell activity¹⁰⁶. Algal extracts are known to stimulate immune cells^{107,108}. Seaweed contains beta 1,3-glucans²⁸, for example, laminarin, which are known to prime the immune system and boost its function¹⁰⁹. Decreased allergic responses in mice were observed following the injection of alginic acid oligosaccharide, which suppressed IgE production by inducing IL-12 production¹¹⁰.

Inflammation modulation

Seemingly paradoxically, sulphated polysaccharide extracts can act as both inflammation inhibitors and promoters. Carrageenan (from red marine algae) is commonly used as an inflammation initiator in animal models¹¹¹, yet fucoidans from brown marine algae are usually anti-inflammatory and potent selectin-blocking agents. Some carrageenan fractions are also anti-inflammatory¹¹². Fucoidans have been used experimentally to reduce post-ischaemic leukocyte influx into damaged organs¹¹³. Ingesting nori or kombu exerts different histological effects on gut lining. Nori-fed rats had a higher incidence of submucosal oedema than the kombu-fed rats, which may have been related to the higher sodium/potassium ratio in the nori diet¹¹⁴.

Anti-viral and antibiotic activity

All marine algae seem to possess antiviral sulphated polysaccharides. Carrageenans, fucoidans and sulphated rhamnogalactans have substantial antiviral activity against enveloped viruses, such as herpes and HIV. These compounds block the entrance of viruses into cells, although other algal fractions have virucidal and enzyme inhibitory activities, or can inhibit syncytium formation^{115,116,117,118,119,120}. Recently, algal consumption has been proposed as one unifying characteristic of countries with anomalously low rates of HIV¹²¹. Pilot studies with *Undaria pinnatifida* preparations indicate that it can inhibit the reactivation of herpes infections¹²². Carrageenan preparations are in trial to establish their efficacy as vaginal microbiocides¹²³.

The antibacterial activities of marine algae are partly due to their iodine and polyphenolic contents. Funoran, however, a sulphated polysaccharide from *Gloiopeltis furcata*, was highly effective at inhibiting the adherence of dental plaque¹²⁴. More recently, *in vitro* and animal studies demonstrated the efficacy of a fucoidan extract from *Cladosiphon* (known as Okinawan Mozuku) against the ulcer-causing bacterium *Helicobacter pylori*. Human trials were then carried out on gastric ulcer and non-ulcer dyspepsia, indicating benefits in a clinical setting¹²⁵.

Other health benefits

Seaweed feeds the shafts and the ducts of the scalp to help improve the health of the hair. It has been said that the thick, black, lustrous hair of the Japanese is partly due to their regular diet of mineral-rich brown sea vegetables such as arame. Hair health depends on a range of macro and micronutrients, particularly protein, Vitamins A, B, C, D and E, essential fatty acids (particularly omega 6 oils) and minerals such as zinc¹²⁶, all of which are present in seaweeds²⁸.

Numerous other health benefits have been claimed for seaweed include strengthening the nervous system, regulating the hormones, enriching the bloodstream, assisting in metabolism, and promoting youthful skin colour and mental agility¹²⁷. Whilst it is possible to speculate on the reasons for these effects based on the nutrient composition of marine algae, significantly more scientific research is required to elucidate the mechanisms of action.

Cooking with sea vegetables

Sea vegetables are available in many health food shops and are usually sold in a dried form, which makes them ideal for long-term storage. Some sea vegetables, such as dulse, wakame, nori and sea lettuce can be tender enough to eat raw or after a brief soaking; some such as

aramé need light cooking by boiling or steaming, whilst others such as kombu and hijiki require longer cooking by sautéing or simmering. All sea vegetables expand after soaking, so care must be taken not to use too much. Ideally, one should use about 1 tablespoon of dried sea vegetables per person per meal every day.

Nori is the most popular of all sea vegetables as it is versatile and easy to prepare. It has a sweet and salty taste, which is sometimes too strong for beginners. Nori contains more protein than other sea vegetables, averaging a remarkable 40% by weight. It contains about 1.5 times more vitamin C than oranges and as much vitamin A as carrots. The mineral content of nori is about 10% by weight, which is lower than that of other sea vegetables, but is still very high for a vegetable food. Nori is sold either as flakes or as sheets, which are folded ten to a pack. The flakes do not require soaking or cooking and can be sprinkled directly onto grains, or incorporated into purées, batters, sauces, dressings and dips to give an appealing herb-like flavour. Nori sheets are best lightly toasted before use. This is done by rotating the sheet, shiny side up, over a low flame for a few seconds until its colour changes to a lighter green. Pre-toasted nori sheets are also available in the shops. Once toasted, nori can simply be torn into smaller pieces or cut with scissors into attractive shapes. These pieces can be added as a garnish to cereal dishes, soups and salads or mixed with nuts and seeds to make a tasty snack. Toasted sheets of nori can also be used to make sushi rolls and rice balls.

Arame is a good introductory sea vegetable as it has a sweet flavour and delicate texture. When harvested, arame is tough, so to make it easy to use, the fronds are shredded into fine thread-like strips and boiled in their own juices for several hours to soften. During this process, the colour changes to a deep black. It is then thoroughly air-dried before being packed for sale. Because arame has been pre-cooked, it is one of the easiest sea vegetables to use. It just needs soaking in cold water for several minutes, during which time it will expand to approximately double its volume. It can then be added to soups, stir-fries, salads, stews, pasta, grain and vegetable dishes. Alternatively, it can be cooked for 10 to 15 minutes and flavoured with soya sauce and/or other seasonings such as lemon rind, apple juice concentrate and ginger.

Dulse is purple in colour and has a soft texture and mildly spicy flavour. It has the highest iron content of all the sea vegetables and, gram for gram, contains between 10 and 50 times more iron than spinach and between 3 and 10 times more iron than liver. Dulse is very easy to prepare and can be cut with scissors, quickly rinsed in water and added to salads, soups and all vegetable dishes. It combines very well with oats in wholegrain porridge and, lightly cooked, tastes delicious with onions. If dried dulse is fried in oil for a few seconds it becomes crispy and can be served as a snack.

Kombu is sold as thick dark green strips which require soaking and then cooking for 30 to 40 minutes before eating. It is valuable as a flavour enhancer and as a softening agent as well as being eaten as a vegetable in its own right. Its properties as a flavour enhancer stem from the fact that it contains glutamic acid, a natural version of the synthetic additive monosodium glutamate (MSG). Unbound glutamate is found in many foods in addition to kelp, including parmesan cheese, peas, tomatoes, grapes and plums, but usually in small enough quantities for the body to deal with, thus it has no detrimental effects. In contrast, larger quantities of synthetic MSG are added to foodstuffs to enhance flavour. Recent research has shown that such quantities of MSG have adverse effects on nerve cell development, both alone and in combination with other food additives, and the adverse effects of the different additives are synergistic¹²⁸.

Kombu also increases the digestibility of legumes²⁰. Despite numerous anecdotal reports of this effect, there are no publications in the scientific literature explaining the mechanism. Legumes are notorious inducers of flatulence due to the presence of substantial amounts of flatus-producing oligosaccharides of the raffinose family of sugars¹²⁹. Owing to the absence in humans of the enzyme α -galactosidase capable of hydrolyzing the α -6 galactosidic linkage, these oligosaccharides accumulate in the large intestine and undergo fermentation by anaerobic bacteria. Marine algae are known to contain a range of carbohydrase enzymes and the hydrolysis of α -1,6-linked glucosaccharides has been demonstrated in marine algal extracts¹³⁰. This is interesting as this type of activity has been reported in only a limited number of biological samples. It is therefore possible that carbohydrase enzymes from kombu at least partially degrade the flatus-inducing oligosaccharides in legumes, thus improving digestibility, although they would be inactivated on boiling; further studies would need to be conducted to test this hypothesis. Alternatively, it is possible that glutamic acid may act in some way to soften the fibres of legumes but there are no reports in the literature demonstrating this. Even if a scientific explanation is not available, it is well known from experience that a strip of kombu soaked and cooked with beans will not only tenderise them, but will also improve their flavour and increase the overall digestibility of the dish.

Kombu is extremely rich in minerals, sometimes containing up to 35% by weight. It is particularly high in iodine and the Chinese have used kombu for the treatment of goitre for centuries. Kombu also has high levels of alginic acid which acts as an intestinal cleanser. Kombu may be cooked alone or in stews and soups for about 30 to 40 minutes until it becomes tender. A nutritious stock is produced by soaking and cooking kombu, which can be used for soups and other dishes. Dried kombu may also be fried as described for dulse and served as a crispy snack. Alternatively, a mineral-rich table condiment can be prepared by putting a strip of dry kombu on a baking tray in the oven, cooking until brittle and then grinding to a fine powder.

Wakame is another sea vegetable with a mild flavour and its soft, leafy structure gives it a wide range of culinary uses. Wakame is related to kombu and is a native of the Far East, although a similar plant *Alaria* sp., commonly known as badderlocks, murlins or wing kelp, grows freely in Atlantic waters. Wakame has a mineral content of up to 30% by weight and contains high levels of the B vitamins and vitamin C. Wakame is also rich in calcium, having a similar level to that of cow's milk. Wakame's mild flavour allows it to combine well with land vegetables. After soaking for 2 to 3 minutes in cold water, it can be cut into small pieces with scissors and added to salads or soups. It is delicious when sautéed with onions and served with boiled or steamed greens and salad. Wakame also goes well with fish, particularly when added to a foil wrapped fish before baking. Like kombu, it can be cooked with beans to tenderise them and enhance the flavour of the dish. If dried wakame is lightly baked in an oven, it can be crushed into a powder and used as a mineral-rich table condiment for grain and cereal dishes.

Hijiki is one of the strongest tasting sea vegetables and is thus more suitable for the experienced user. In Japanese, 'hijiki' means 'bearer of wealth and beauty' and it has traditionally been recognised for its beneficial effects in balancing blood sugar levels, encouraging good facial colour and adding lustre to hair. Like kombu, it has an abundance of minerals and is particularly noted for its calcium content which, gram for gram, is higher than that of cow's milk. It looks similar to arame but has rather different properties. Hijiki will expand by up to four times its original volume after soaking, so care must be taken not to use too much. For those unaccustomed to the taste, it is best to soak hijiki for 10 to 15 minutes and discard the water. Then add fresh water and bring to the boil for 1 minute.

Discard this water, cover with fresh water again and simmer for 30 minutes, seasoning with soya sauce and apple juice concentrate towards the end. It is ready when tender and the liquid has evaporated. It combines well with sautéed sweet root vegetables such as carrots and onions.

Agar-agar is an ideal vegetarian alternative to gelatine for making jellies and aspics. It is most commonly available as flakes, bars or powders. Agar-agar combines well with fruit juice or other liquids and requires simmering in the liquid for about 10 minutes until dissolved. To check the gel, put a small spoonful of the liquid containing dissolved agar-agar on a cold plate to set. More agar-agar or more liquid can be added if required. It is necessary to allow at least an hour for setting at room temperature.

It is thus clear that sea vegetables have great culinary versatility and that there are numerous ways to cook them. A small selection of recipes is given below.

Recipes

Dulse salad

Ingredients: a variety of mixed salad leaves, cucumber (cut into half rounds), radishes (cut in quarters), dulse, olives, fresh basil

Dressing: 1 tbsp white miso, 1 tbsp olive oil, 1 tbsp apple juice concentrate, water

- Mix all the salad ingredients in a serving bowl
- Soak the dulse for 1-2 minutes, cut with scissors and add to the salad
- Blend all the dressing ingredients and serve with the salad

Creamy courgette and leek soup

Ingredients: 2 leeks (sliced in half lengthwise, washed and cut in small pieces), 2 courgettes (sliced), 1-2 strips of wakame (rinsed and cut into pieces), a pinch of fine sea salt, white miso, olive oil, dried basil

- Heat a cooking pot, add a small amount of oil, the leeks and a pinch of salt. Sauté uncovered for 5-6 minutes
- Add the rinsed wakame, courgettes, dry basil and 2 cups of water. Cover and cook on a medium flame for 15-20 minutes
- Blend to a smooth consistency, adjusting liquid if necessary. Add some white miso to taste. Serve hot with croutons.

Arame with onions and pecans

Ingredients: 3 onions (finely sliced in half-moons), 1 cup arame (rinsed and soaked in cold water for 15 minutes), lemon rind (finely grated), olive oil, pinch of fine sea salt, soya sauce, apple juice concentrate. *Garnish:* pecans (lightly toasted and chopped)

- Sauté the onions with some olive oil and a pinch of sea salt for 15 minutes uncovered until they are translucent and have a rich aroma
- Drain the arame and add to the onions, together with ½ cup water. Cover and simmer gently until all the water has been absorbed (approx 20 minutes)
- Season to taste with some soya sauce, apple juice concentrate and lemon rind. Garnish with pecans and serve.

Lentil pâté

Ingredients: 1 cup brown lentils (washed), 1 strip kombu, 2 bay leaves, 4 cups water, 1 onion, 2 carrots, 1 stalk celery (all diced small). *Seasonings:* Barley miso, mustard, tahini

- Bring lentils, kombu, bay leaves and water to a boil, add vegetables and cook over a medium flame for 45 minutes. Check that lentils are well-cooked and soft.
- Dilute 1½ tsp miso with a small amount of water and add to the lentils, along with the mustard and tahini to taste.
- Cook over a low heat for 5 minutes more, then discard the bay leaves and blend to a smooth consistency. Serve with finely chopped spring onions or chives.

Much more will be learned in future years as the study of these fascinating algae from the sea continues. Like the Tongans, the regular use of sea vegetables may well be the secret of a long and healthy life for everyone.

About the Authors

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