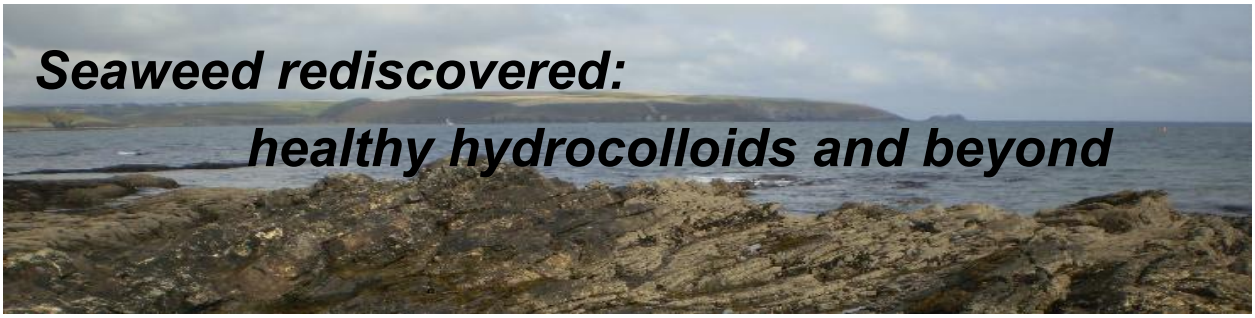

Seaweed rediscovered: healthy hydrocolloids and beyond

A quick analysis of current food and health trends in Europe will show you that key industry players are seeking novel sources of nutritional components such as fibre, carbohydrates, antioxidants, proteins, polyunsaturated fatty acids, vitamins and minerals. Seaweeds contain all of these at levels similar to or often greater than traditional sources. Weight for weight, certain seaweeds contain more fibre than prunes or bananas; more calcium than cheese and more iron than sirloin steak. They are generally high in protein (up to 47% in some red species), low in fat (<2%) and provide valuable non-animal sources of essential minerals and vitamins most notably Vitamin B12. Seaweed has been used as a traditional food source, fodder and medicine in European cultures for hundreds of years but recently the food and health industries have become aware of the huge potential of using seaweed in innovative ways and seaweed has, in a sense, been rediscovered.

Eighty five to ninety percent of the global seaweed industry is used directly for human consumption. This equates to approximately €4 billion [(1)], and of this, €2.3 billion is from nori alone [(1)]. Demand far outstrips natural supplies and the majority of seaweed is aquacultured in countries like Japan, China, North & South Korea where the demand is highest (Tab. 1). About 20 species of seaweed are commonly harvested or grown for the food industry although more than 500 different species are known to be consumed worldwide.

In France, 10 species are classified safe for use in the food industry [(2)] and Europe tends to take its lead from these guidelines. Those species listed are the brown seaweeds *Ascophyllum nodosum* (egg wrack, knotted wrack), *Fucus vesiculosus* (bladder wrack), *F. serratus* (serrated wrack, saw wrack), *Himanthalia elongate* (sea spaghetti) and *Undaria pinnatifida* (wakame); the red seaweeds *Porphyra umbilicalis* (nori, laver, sleabach), *Palmaria palmata* (dulse, dillisk), *Gracilaria verrucosa* and *Chondrus crispus* (Irish moss, carragheen); and species of the green seaweed *Ulva* (sea lettuce).

The kelps are not on this list, although widely consumed in Asia, there are unresolved issues in Europe concerning the levels of iodine in these seaweeds.

There is a wealth of historical and anecdotal evidence for the nutritional and health benefits of eating and using seaweed - a quick search on the internet will throw up numerous websites to confirm this. Research and industry alike have been well aware of this fact for sometime, in the 1980's seaweeds and microalgae were the source of approximately 35% of newly discovered chemicals [(3).] Now, it appears that seaweed has again become a key focus area for the discovery, validation and development of new pharmaceutical and health ingredients.

The typical modern diet is high in refined and processed products and lacks the necessary levels of dietary fibre, minerals and vitamins that are necessary to keep our bodies healthy. Many of the illnesses and diseases that plague our society, the so called "*diseases of affluence or excess"* like heart disease, high blood pressure, stroke (cerebrovascular disease or CVD), impaired immune function, obesity, diabetes and even cancer can be linked to poor diet.

Incorporation of seaweed into a balanced diet could help and we only have to look to Asian cultures where seaweed does feature strongly in the diet to see this. The Japanese diet characteristically contains 10-15% seaweed and as a nation these people appear to suffer significantly less than western cultures from

diseases such as breast and prostate cancer, thyroid disease, heart disease and even dementia.

Europe is rapidly opening its eyes when it comes to the potential role of seaweed in health and nutrition and a scientific basis in support of the many claims is rapidly amassing (Tab. 2).

Table 1. Comparison of global seaweed harvest and cultivation for top edible species (metric tonnes per year dry weight [4]

Top edible seaweeds	Cultivated	Harvested
Laminaria (kombu)	673 064	58 413
Porphyra (nori)	130 614	8
Undaria (wakame)	101 708	20 006
Chondrus (Irish Moss)	1	12 213
Hizikia	6 300	1200
Ulva (sea lettuce)	2438	1500
Monostroma (green nori)	1250	-
Totals	**915 000**	**93 000**

Healthy hearts

Cardiovascular disease - Coronary heart disease (CHD) and cerebrovascular disease (CVD) - is the single largest cause of mortality in the world [5] claiming more lives each year than the other four leading causes of death. In Europe alone the economical costs associated with this amount to €169 billion per year [6].

There is no doubt that poor diet/lifestyle plays an important role here, and health authorities worldwide are promoting the same key messages -

"cut down on saturated fats, cholesterol, sugar and salt" because diets high in these components can lead to increased risk of heart failure and stroke - through elevated blood pressure, high cholesterol levels, increased thrombotic activity, atherosclerosis (hardening of blood vessels) and disease.

"eat more whole grains, fresh fruit, vegetables and oily fish" because these foodstuffs are high in the key dietary components that have been demonstrated to lower the risk of CHD/CVD - *i.e.* soluble fibre, vitamins, minerals, phytochemicals and polyunsaturated fatty acids (PUFAs).

Seaweeds contain fibre, sulphated polysaccharides, minerals, PUFAs and sterols all of which have been shown to reduce the risk of cardiovascular disease.

Lowering cholesterol

The dietary fibre content of seaweed can be as high as 75% of the total dry weight [7] and essentially comprises the structural polysaccharides *i.e.* alginate and fucoidan (brown seaweeds), carrageenan, agar and porphyran (red seaweeds) and ulvan (green seaweeds).

These fibres are primarily soluble [7] and form viscous gels as they pass through the gastrointestinal tract [8]. This can restrict the absorption of bile acids by the body as the bile binds to the gel and is excreted. In turn, this forces the liver to scavenge cholesterol from the blood to synthesize and replace the bile, thus lowering cholesterol levels in the blood [7,8]. Such activity has been recorded for a range of polysaccharides including alginate [3,8], laminaran [3,], ulvan [3,9] porphyran [3] and carrageenan [3,] and the general mechanism is exploited for commercial purpose. Polymann TM (Korea Bio Polymer Co. Ltd), is one such product, based on a purified form of polymannuronic acid from the kelp *Undaria* .

Seaweeds, in particular the browns, also contain sterols which have been shown to restrict the solubility of cholesterol in bile micelles and therefore lower the absorption of cholesterol in the bloodstream [10]. Seaweed derived sterols do not appear to have the

same potency as those derived from plants, however, Fucosterol that is found in species of *Fucus,* appears worthy of further investigation [11,12].

Antithrombotic & anticoagulant activity

Although the mechanisms involved are different, the sulphated polysaccharides of seaweed have been shown to induce antithrombotic and anticoagulant activity that rivals heparin [3,12,13] and preparations from the brown seaweeds *Acophyllum nodosum* and *Fucus vesiculosus* are commercially available as patented anticoagulants [3].

In brown seaweeds, the fucoidans (fucans) can comprise 5-20% of the total dry weight. These polysaccharides are a complex and heterogeneous group but are essentially made up of repeating L-fucose units with a vast array of sulphated groups and side branches (see Berteau & Mulloy [13] for an excellent review). The degree of, and arrangement of, sulphate groups appears to be key to the biological activity of these polysaccharides [3,13]. Porphyran can comprise <45% of the total dry weight of some red seaweeds. Structurally it is similar to agarose but differs in the inclusion of an L-galactose-6-sulphate residue.

Spiralled wrack - *Fucus spiralis*

Reducing blood pressure

High blood pressure can result from an imbalance in sodium and potassium in the body and deficiency in other minerals, such as magnesium and calcium, can also lead to vasoconstriction. Seaweeds typically contain high concentrations of potassium, magnesium and calcium and have been shown to have a positive effect on regulating mineral balances and blood pressure [10]. The soluble fibre component also promotes increased nutrient absorption and bioavailability in the small intestine [8].

Antihypertensive activity has also been reported in rats and rabbits through ingestion of seaweed fibre [3] and laminine, a brown seaweed protein [12]

General heart health

Seaweeds are generally low in fat (<2%) but much of this can comprise PUFAs - polyunsaturated fatty acids [12,14] including the essential omega (n)-3s LNA, EPA and DHA (*resp.* α-linoleic, Eicosapentaenoic and Docosahexaenoic acids) and omega-(n)-6 LA (linoleic acid). n-3 and n-6 fatty acids have opposing physiological functions that require a balance for normal growth and development in humans [14]. A ratio of 5:1 (omega n-6:n-3) is recommended but most European diets are overly high in n-6 and low in n-3 [15]. Brown and red seaweeds provide a good balance with ratios that are comparable with cold fish sources [14].

Omega-3 fatty acids are not thought to have a direct effect on blood cholesterol levels but they show an ability to reduce blood triacylglycerol (storage fats) levels and hence help to maintain general heart health. Long chain *n*-3 fatty acids have been shown to reduce the risk of having a fatal heart attack [11]. Although precise mechanisms are not clearly understood, protection against blood clot formation (thrombosis), protection against heart arrhythmias and a beneficial impact on blood pressure are likely [11].

Table 2. Scientific support for the nutritional and health claims of seaweed derived components, symbols indicate where direct evidence is available, numbers in brackets refer to listed

references..

NUTRITIONAL GROUP	BIOACTIVE	HEART & CVD	GUT HEALTH	CANCER	IMMUNE SYSTEM	BONES & JOINTS
CARBOHYDRATES	FIBRE	♥ (7,8)	✔ (3,8,17)	✚ (8)		
	LAMINARAN	♥(3)	✔ (17,18)	✚ (29,30)		
	FUCOIDAN	♥ (3,12,13)	✔ (21)	✚ (29)	🌡 (3, 13, 35,36)	
	ALGINIC ACID	♥ (3)	✔ (18,19,22)	✚ (26)	🌡	
	CARRAGEENAN	♥ (3)	✔	✚ (25)	🌡 (33)	
	PORPHYRAN	♥ (3)		✚		
	ULVAN	♥ (9)				
PROTEINS	ESSENTIAL AMINO ACIDS	♥ (12)				•●
	CAROTENOIDS	♥	✔ (21)	✚ (27,28)	🌡	
LIPIDS	OMEGA 3 & 6	♥ (11,14)	✔	✚ (3)	🌡 (3)	
	STEROLS	♥ (10, 12)		✚		
ANTIOXIDANTS	POLYPHENOLS			✚		
	VITAMINS	♥		✚	🌡	●
MINERALS	CALCIUM	♥ (10)				●
	IRON	♥ (10)				
	MAGNESIUM	♥ (10)				●
	POTASSIUM					●
	ZINC				🌡	●
	SELENIUM				🌡	
	IODINE					

Healthy digestion

Dietary fibre is key to healthy digestion, it is required to clear the digestive tract, protect surface membranes in the stomach and intestine against ulcers and carcinogens, and promotes a healthy gut flora. The recommended daily intake of fibre or Guideline Daily Amount is 24g [(16)] approximately 12.5% of which could be provided by an 8g (dry weight) portion of selected seaweeds [(10)].

Seaweeds high in dietary fibre have also been shown to have positive effects on reducing hyperglycemia and hyperinsulinemia and thus are useful in relation to controlling diabetes and obesity [(8).]

Lowering digestive tract disease

Some seaweed fibre is fermented in the lower intestine but in general, soluble and insoluble seaweed fibre tends to pass through the gut without being digested [(8,17)], this results in decreased bowel transit time and increased faecal bulking and water retention. A lowering in bowel transit time can reduce the risk of colo-rectal cancer, ulcers and inflammatory bowel diseases, and the incorporation of seaweed fibre into the diet has been shown to actively reduce the above [(3, 8,).]

Research has shown that the non-starchy polysaccharides of seaweeds in general can have a prebiotic effect *i.e.* they selectively stimulate and activate useful gut flora microorganisms [(8,17).] Prebiotic ingredients, or those that boost the growth of beneficial

probiotic bacteria in the gut, are worth about €90 million in the European marketplace [18]. As little as a 2.5% (wt/vol) addition of alginate oligosaccharides can significantly increase the levels of bifidobacteria and lactobacilli in rats and humans [18].

Fighting obesity

A range of seaweed based preparations are commercially available to help with weight control. One might be sceptical when reading advertisements such as "*Lose Weight With a High-Fibre Seaweed Supplement That Supports Your Liver, Slows Digestion, and Makes You Feel Full"* but in fact, the bulking effect of seaweed fibre is known to prolong postprandial feelings of satiety and reduce the absorption of metabolites in the intestine [8,19]. For these reasons, researchers at Newcastle University have even experimented with adding alginate fibre to burgers in an attempt to make "healthier" junk food [20].

The brown algal pigment, Fucoxanthin and its metabolite fucoxanthinol have been shown to induce the expression of UCP1 a protein that suppresses fat accumulation, particularly around internal organs in rats and mice, resulting in an increase of <10% fat oxidation [21]

Diabetes

An estimated 19 million people in the EU and 20 million in USA suffer from diabetes [22]. The presence of soluble alginate fibre in the diet is known to regulate the absorption of metabolically available nutrients, thus reducing glycaemic load and the resultant insulin response [8,23]

Laver, Nori - *Porphyra* sp. on mussels

Fighting cancer

The anti-cancer properties of seaweeds have been well documented since ancient times, the Chinese and Egyptians used brown seaweed to treat breast cancer. Seaweeds contain large amounts of antioxidants and polyphenols which constitute their own protective antioxidative defence systems and many studies have demonstrated *in vitro* antioxidant activity in a range of them [3].

Seaweed derived oligo and polysaccharides have been demonstrated to induce apoptosis (programmed cell death) in cancer cell lines [24] and some, including carrageenan [25] and alginate [26] can inhibit the growth of tumours in rodents through immunomodulating activity.

The Takara Bio Inc., Japan produces a range of seaweed based products that are active against leukaemia, stomach and colon cancer. The active ingredient is U-Fucoidan™, a guluronic rich polysaccharide extracted from kelps. Modiflan™ (www.modiflan.com) boasts similar properties and is a polysaccharide based extract from the kelp *Laminaria japonica.* The active components are fucoidan, laminaran and alginate.

Fucoxanthin (photosynthetic pigment) extracted from the *kelp Undaria* can, significantly reduce the viability of human prostate cancer cells [27] and colon cancer cells [28].

Japanese women typically suffer from very low levels of estrogen related cancers (breast and cervical) and it is thought that this is due, in part, to the high levels of brown seaweed that they ingest. Incorporating the brown seaweeds *Laminaria* and *Fucus vesiculosus*

into the diet has been shown to prolong the length of the menstrual cycle in women and to exert anti-estrogenic effects that may be responsible for the reduced risk of estrogen related cancers[29,30].

Seaweeds are also a good source of the trace element selenium which is currently attracting a lot of attention regarding its potential anti-cancer properties [31]

Boosting the immune system

Seaweeds appear to have endless potential when it come to protective *"anti-"* activity. With demonstrated efficacy against a wide range of ailments from bee stings, hayfever, *Herpes simplex,* intestinal parasites, HIV (human immunodeficiency virus), snake bites and malaria, it seems likely, that given time, a scientific basis could be found for even the most bizarre of anecdotal claims.

Anti-inflammatory

Polysaccharides, in particular the sulphated ones like fucoidan are well known for their anti-inflammatory activity. Modiflan™ which contains fucoidan, is marketed as an anti-inflammatory. The fucoidan component promotes the growth of fibroblasts, in turn repairing inflamed cells (www.modiflan.com).

Normal metabolism of PUFAs in seaweeds can lead to the production of eicosanoids which are important for range of physiological functions, including anti-inflammatory activity [3]. An ecosanoid like compound isolated from the brown *seaweed Caulocystis cephalornithos* has shown anti-inflammatory activity akin to salicylic acid [3] and Caulerpeyne, isolated from the green seaweed *Caulerpa* has been shown to be effective against bees stings [3].

In Japanese women, high intake of seaweed has been shown to reduce the prevalence of allergic rhinitis – hay fever [32].

Egg wrack - *Acophyllum nodosum*

Antimicrobial protection

The range of seaweed derived compounds that show antimicrobial activity is diverse and well documented [3, 13, 33]. Seaweeds naturally employ antimicrobial systems for wound defence and prevention of disease [34]. Most compounds employed are halogenated substances, terpenoids or phenolics [3] but also sulphated polysaccharides.

The red seaweeds in particular are rich in carbohydrates with antiviral activity. In a study of 40 different species of red seaweed, carbohydrate extracts from 37 showed significant suppression of retroviral growth [33].

Commercial antiviral preparations are readily available however, Carraguard™ (containing 3% carrageenan) is probably the best known and this is still under clinical trial. It has demonstrated antiviral activity against sexually transmitted viruses including HIV – Human Immunodeficiency Virus and will conclude trial in December 2007.

Sulphated polysaccharides from brown seaweeds, namely fucoidan, are also active against a range of gram positive and gram negative bacteria [35, 36] and viruses [3, 13]. Viracle™ (Marine BioMedical Research Pty. Ltd., Australia) is a product containing an extract from the kelp *Undaria* that shows

confirmed inhibitory activity against HSV – Herpes Simplex Virus and potential activity against HIV.

Seaweeds also have antifungal properties. Proteins isolated from the red alga *Hypnea musiformis* were shown to be active against human pathogenic yeasts [37] but in general, the antifungal properties of seaweeds are utilised more in the horticultural industry for disease and pest control [38].

Seaweeds naturally produce chemical deterrents in response to grazing activities of invertebrates and fish [34]. Some of these compounds have been responsible for human deaths [3] but a few amino acid derivatives are utilised as vermifuges [3, 12].

Mixed seaweeds including Sea spaghetti *Himanthalia elongata* and Sea lettuce *Ulva lactuca*

Healthy bones, joints & skin

Seaweeds are naturally high in minerals that are essential for healthy bones and joints. They are also high in vitamins and anti-oxidants - important components of cosmetic preparations [39].

Calcium can comprise up to 7% of dry weight [9] and is also found in association with with polysaccharides, such as alginate and carrageenans. The calcareous red seaweeds such as *Lithothamnion* spp. can contain as high 35% calcium. An Irish Product Aquamin™ is a multi-mineral preparation from *Lithothamnion* spp. It has been shown to be high in bioavailable calcium, more so than the standard calcium carbonate that is used in supplements, and is effective against mobilisation of bone calcium through parathyroid hormonal activity (www.marigot.ie). Similar activity has been observed with a mix of oystershell and the brown seaweed *Cystophyllum fusiforme* [40].

Three genera of seaweeds are routinely used in cosmetics -*Laminaria, Fucus* and *Chondrus* - for their ability to nourish and rehydrate the skin [41]. Topical application of fucoidan has been shown to have anti-aging activity by increasing the moisture and elasticity of the cells [42, 43]. Fucoidan is known to stimulate the production of HGF – Heparin Growth Factor which promotes growth in a range of cells and tissues and this is exploited commercially by the Takara-Bio Company in Japan (www.takara-bio.com.jp).

The intention of this article was to provide a very general overview of the health and nutrition properties of seaweeds and it is very clear that they have much to offer. What is also very clear, is that seaweed derived polysaccharides show great potential over and above their traditional use as hydrocolloids. It is an area of research that deserves future attention and one that CyberColloids has a keen interest in.

Sarah Hotchkiss ***sarah@cybercolloids.net***

CyberColloids, Strand Farm, Currabinny, Carrigaline, Co. Cork, Ireland

References

1. The Food and Agriculture Organisation website (www.fao.org) accessed July 2007
2. Burtin, P. (2003). Nutritional Value of Seaweeds. EJEAFChe. 2(4). ISSN 1579-4377.
3. Smit, A.J. (2004). Medicinal and pharmaceutical uses of seaweed natural products: A review. Journal of applied phycology 16: 245-262.
4. www.surialink.com accessed July 2007
5. World Health Organisation Fact Sheet: the top ten causes of death. Fact sheet No. 310. February 2007.
6. www.foodnavigator.com accessed July 2007
7. Jimenez-Escrig, A. and Sanchez-Muniz, F.J. (2000). Dietary fibre from seaweeds: chemical structure, physicochemical properties and effects on cholesterol
8. Warrand, J. (2006). Healthy polysaccharides. Food technology and Biotechnology. 44(3): 355-370.
9. Pengzhan Y, Quanbin Z, Ning L, Zuhong X, Yanmei W, Zhi'en L. (2003). Polysaccharides from Ulva pertusa and preliminary studies on their antihyperlipidemia activity. Journal of Applied Phycology. 15:21-27.
10. MacArtain, P, Gill, C., Brooks, M., Campbell, R. & Rowland, I. The nutritional and bioactive components of European edible seaweeds. Nutrition Reviews 2007, *in press.*
11. Ikeda I, Tanaka K, Sugano M, Vahouny V, Gallo L. (1988). Inhibition of cholesterol absorption in rats by plant sterols. Journal of Lipid Research:, 29:1573
12. Ito, K. and Hori, K. (1989). Seaweed: chemical composition and potential food uses. Food reviews international. 5(1): 101-144.
13. Berteau, O.& Mulloy, B. (2003). Review. Sulphated fucans, fresh perspectives: structures, functions and biological properties of sulphated fucans and an overview of enzymes active towards this class of polysaccharide. Glycobiology 13(6): 29-40.
14. Dawczynski, C., Schubert, R. & Jaheris, G. (2006). Amino acids, fatty acids and dietary fibre in edible seaweed products. Food Chemistry 2006, doi 10.1016.
15. British Nutrition Foundation Fact Sheet. Fatty Acids and Health. www.nutrition.org.uk Accessed July 2007.
16. Best Practice Guideline on the Presentation of Guideline Daily Amounts. London, UK. Institute of Grocery Distribution. 2006.
17. Devill, C., Damas, J., Forget, P., Dandrifosse, G. & Peulen, O. (2004). Laminarin the dietary fibre concept. Journal of the science of Food and Agriculture. 84: 1030-1038.
18. Wang, Y., Han, F., Hu., B., Li., J. & Yu, W. (2006). In vivo prebiotic properties of alginate oligosaccharides prepared through enzymatic hydrolysis of alginate. Nutrition Research 26: 597-603.
19. Brownlee, et. al. (2005). Alginate as a source of dietary fibre. Critical Reviews in Food Science and Nutrition 45: 497-510
20. Burgers' seaweed health boost. www.bbc.new.co.uk Monday, 26 September 2005.
21. Bernstein, M. (2006). Pigment in Brown seaweed: Fucoxanthin, poten5tial anti-obesity agent. www.newstarget.com. Accessed July 2006.
22. Daniells, S. (2007). Fibre, magnesium may slash the diabetes risk. www.nutraingredients.com Accessed July 2007.
23. Vaugelade, P., Hoebler, V.P., Guillon, f., Lahaye,, M., Duce, P.H. & Darcy-Vrillon, B. (2000). Non-starch polysaccharides extracted from seaweed can modulate intestinal absorption of glucose and insulin in the pig. Reproduction nutrition development. 40(1): 33-47.
24. Kwon, M-J. and Nam, T-J. (2007). A polysaccharide of the marine alga *Caposiphon fulvescens* induces apoptosis in AGS gastric cancer cells via an IGF-IR mediated PI3K/Akt pathway. Cell Biology international 31: 768-775.
25. Yuan, H., Song, J., Li, X, Li, N. and Dai. J. (2006). Immunomodulation and antitumour

activity of k-carrageenan oligosaccharides. Cancer Letters, 243(2): 228-234.

26. Alves de Sousa, A.P., Rocha Torres, M., Pessoa, C., Odorico de Moraes, M., Rocha Filho, F.D., Negreiros-Nunes Alves, A.P. & Veres Costa-Lotufo, L (2007). In vivo growth inhibition of sarcoma 180 tumours by alginates from brown seaweeds *Sargassum vulgare*. Carbohydrate polymers 69(1): 7-13.

27. Kotake-Nara, E., Sugawara, T. & Nagao, A. (2005). Antiproliferative effect of neoxanthin and fucoxanthin on cultured cells. Fisheries Science 71: 459-461.

28. Hosokawa, M., Kudo, M., Maeda, H., Kohno, H., Tanaka, T. & Miyashita, K. (2004). Fucoxanthin induces apoptosis and enhances the antiproliferative effect of the PPAR γ ligand, troglitazone, on colon cancer cells. Botanica et Biophysica Acta 1675: 113-119.

29. Skibola, C.F. (2004). The effect *of Fucus vesiculosus,* and edible brown seaweed, upon menstrual cycle length and hormonal status in three pre-menopausal women: a case report. BMC Complementary Medicine and Alternative Medicine. 4 (10): 1-8

30. Teas, J. (1996). The dietary intake of *Laminaria* a brown seaweed, and breast cancer prevention. Anticancer Research 16(3A): 1213-1218.

31. Black, A. (2006). The mineral selenium proves itself as a powerful anticancer medicine. www.newstarget.com. 4 January 2006.

32. Miyake, Y., Sasaki, S., Ohya, Y., Miyamoto, S., Matsunanga, I., Yoshida, T., Hirota, Y., Oda, H. (2006). Dietary intake of seaweed and minerals and prevalence of allergic rhinitis in Japanese pregnant females: baseline data from the Osaka Maternal and Child Health Study. Ann. Epidemiol. 16(8): 614-621.

33. Neushal, M. (1990). Antiviral carbohydrates from marine red algae. Hydrobiologia. 204/205:99-104.

34. Seaweed Ecology and Physiology. Lobban, C.S. & Harrison, P.J. (eds).Cambridge University Press 1994.

35. Zapopozhets TS, Besednova NN, Loenko IN. Antibacterial and immunomodulating activity of fucoidan. Antibiot Khimioter 1995 Feb;40(2):9-13.

36. Shibata H, Iimuro M, Uchiya N, Kawamori T, Nagaoka M, Ueyama S, Hashimoto S, Yokokura T, Sugimura T, Wakabayashi K. Preventive effects of Cladosiphon fucoidan against Helicobacter pylori infection in Mongolian gerbils. Helicobacter. 2003 Feb;8(1):59-65.

37. Aguilar-Cordeiro, R.A., Moreira-Fgones, V.M., Urano-Carvalho, A.F. & Macia-Melo, V.M. (2006). Effects of proteins from the red seaweed Hypnea musciformis (Wulfen)Lamx. on the growth of human pathogen yeasts. Brazilian Archives of Biology and Technology 49(6): 915-921.

38. Young, C. Seaweed can help combat fungal diseases in potatoes. Organic Production (www.batphone.com.au) Accessed July 2007

39. Luop, M.P. (2001). Antioxidants and Vitamins in Cosmetics. Clinics in Dermatology 19:467-473.

40. Fujita, T. (2005). Active absorbable algal calcium (AAACa) changes calcium paradigm. Clinical Calcium 15: 87-93.

41. De Roeck-Holtzhauer, Y. 1991. Uses of seaweeds in cosmetics. pp. 83-94. *In* Guiry & Blunden, 1991

42. Fujimura, T. Tsukahara, K., Moriwaki, S., Kitahara, T., Sano, T. & Takema, Y. (2002). Treatment of human skin with an extract of *Fucus vesiculosus* changes its thickness and mechanical properties. J. Cosmetic Science 53(1): 1-9.

43. Fujimura, T., Shibuya, Y., Moriwaki, S., Tsukahara, K., Kitahara, T., Sano, T., Nishizawa, Y. & Takema, Y. (2000). Fucoidan is the active component of *Fucus vesiculosus* that promotes contraction of fibroblast-populated collagen cells. Biol/ Pharm. Bull 23(10): 1180-1184.