seaweeds or marine algae have long made up a key part of the Asian diet and are also consumed in other parts of the world, such as in Ireland and Wales. Seaweed has often been used as a food for people who are sick and has been credited with health-giving properties. Today, seaweed supplements for human use are usually considered to be sources of iodine or minerals but may offer other therapeutic benefits.

### Marine Algae as Food

Marine algae are classified as brown, red, or green algae. Examples from all of these categories are edible and are shown in Table 1. This article concentrates on brown seaweeds, in particular the commonly eaten Japanese wakame or Undaria pinnatifida.

Japanese and Korean populations are the biggest consumers in the world of seaweed products. Most of the brown seaweed intake in the daily diet is of Undaria, commonly known as wakame and mekabu and of Laminaria species commonly known as kombu. Both are used dried in condiment and soup bases or eaten fresh in salads, rolls, or stews, or with rice.

It is thought that the overall content of certain traditional Asian diets contributes to the low incidence of cancer, particularly breast cancer. It is apparent that the unique levels of seaweed intake contribute to the variance in the levels of breast cancer. There is a ninefold lower incidence of breast cancer in the Japanese population and an even lower incidence in the Korean population compared to the incidence in the West.

The relative longevity and health of Okinawan Japanese populations has been attributed in part to dietary algae in studies. These studies compared Okinawan descendants who were living in Brazil with Okinawans. The former have a higher risk of developing cardiovascular and other diseases. For a dietary intervention study, 3g of decosahexaenoic acid, 5g of seaweed (wakame) powder, and 50 mg of isoflavonoids from soybean (Glycine soja) were given daily to immigrants, at high risk for developing diseases, in Brazil for 10 weeks. This combination reduced blood pressure and cholesterol levels, suppressed the urinary markers of bone resorption, and attenuated a tendency toward diabetes.

### Possible Therapeutic Role of Sulfated Polyanions

Fucoidans are found only in brown algae. They consist of long branched chains of sugars and include a substantial amount of fucose. The type of fucoidan, its sulfation, molecular weight, and conformation of sugar residues varies with the species of seaweed. Thus, the fucoidan from Fucus vesiculosus contains 90 percent fucose, whereas the major fucoidan in Undaria contains a roughly equal balance of fucose and galactose. The fucose composition (as a percent of total sugars) of the fucoidans isolated from the Undaria and Laminaria was 57.11 percent and 80.43 percent respectively. It should be noted that while the bulk of the fucoidans in seaweeds are of high molecular weight, there is a small percentage of smaller fucoidan-type molecules that are sometimes complexed with proteins.

Fucoidans are considered to have similarities to the (much smaller) mammalian molecule heparin sulfate. As such, they compete for heparin sulfate-type receptors such as those used for viral entry into cells. Thus, fucoidans are highly effective antiviral agents. In addition, they inhibit leukocyte movement into tissues, modulate metastasis, have heparin-like anticoagulant qualities in vitro, anticomplement activity in vitro and in vivo, and antilipidemic activity in vivo. Other biologic activities related to the heparin-like nature of fucoidans include stimulating hematopoietic progenitor cell mobilization and inhibiting smooth-muscle proliferation.

Most of the effects noted above were observed when using intravenous fucoidans in animal models. However, in vivo bio-

### Contents of Algae and Algal Extracts

Brown algae consist mainly of water (90 percent) in the native state. Polysaccharides are major components and comprise alginites, cellulose, and sulfated polysaccharides such as fucoidans and laminarins. Other components include proteins, free mannitol, minerals such as iodine and arsenic (inorganic and organic), polyphenols, peptides, fatty compounds, and various pigments. Alginites, probably the most widely used of the algal extracts, are composed of block copolymers of mannuronic and guluronic acid sugars and have been adopted by the food industry as thickening agents and by the pharmaceutical industry as binders, gelling agents, and wound absorbents.
logic effects after Undaria ingestion indicate that there is uptake of active components, via the gut; for example, ingestion of water extracts of Undaria by mice with carcino- 
gen inhibitory effects on herpes viruses. Herpes viruses are important human pathogens and include Herpes simplex (HSVVI), genital herpes (HSVII), Varicella/chicken pox/shingles, cytomegalovirus, Epstein-Barr virus (EBV), herpes 6, 7 (Roseola, post-transplant infections), and herpes 8 (associated with Kaposi’s sarcoma). In Japan, where ingestion of brown seaweed in the diet averages 2–3 g per day with a high of 12 g calculated as dry weight, there is a lower rate of reactivation of HSV1, and the lowest levels of HSVII compared to other countries. In Korea, new mothers are given a diet that is rich in seaweed for the first month after birth because this diet is believed to provide many health benefits for mothers and their children.

Brown algal preparations have been used as detoxifying agents. The iodine and other elements in the seaweeds inhibit absorption of similar radioactive elements by the body. In addition, there is some chelation of contaminants such as Strontium 90 by alginates in seaweeds. More recently, it has been demonstrated that Undaria ingestion assists in eliminating dioxins in rats. Feeding on beach-cast seaweeds or seaweed-treated pasture is known to improve health and increase disease resistance in sheep and cattle. Seaweed and other natural polysaccharides also alter the bacterial spectrum of the gut, indicating a possible mechanism for these observed effects.

Antiviral Effects

Brown seaweeds, including the commonly eaten Undaria, have inhibitory effects on herpes viruses. Herpes viruses are important human pathogens and include Herpes simplex (HSVVI), genital herpes (HSVII), Varicella/chicken pox/shingles, cytomegalovirus, Epstein-Barr virus (EBV), herpes 6, 7 (Roseola, post-transplant infections), and herpes 8 (associated with Kaposi’s sarcoma). In Japan, where ingestion of brown seaweed in the diet averages 2–3 g per day with a high of 12 g calculated as dry weight, there is a lower rate of reactivation of HSV1, and the lowest levels of HSVII compared to other countries. In Korea, new mothers are given a diet that is rich in seaweed for the first month after birth because this diet is believed to provide many health benefits for mothers and their children.

Anticancer Effects

The lower incidence of breast cancer in the Japanese and Korean populations has intrigued researchers. Researchers have found that dietary brown algae and their extracts inhibit carcinogen-induced breast cancers, lung metastases, and leukemia in animal models. Similarly, tests on the seaweed extracts in bacterial systems revealed that the extracts had a profound antimutagenic quality. Most recently Funahashi et al. have shown that wakame extracts (as wakame soaked in animals’ drinking water) have a potent inhibitory effect on the progression of mouse mammary tumors. Similar extracts produced an equally profound apoptotic effect on breast cancer cells in vitro while the extracts were nontoxic to ordinary breast cells.
From the animal model experiments, when *Undaria* or other brown seaweed was included in the animals' diets, it is very clear that there is a direct anticancer effect of ingestion although the active components have not been determined. Over the years, it has variously been attributed to iodine, tryptophan, fucoidans, or vitamins.

**The Viral Connection with Breast Cancer**

There has been a recent revival in research on viral connections with breast cancer. Human homologues of mouse mammary tumor virus, papilloma viruses, and herpes viruses, chiefly EBV, are implicated. The lower rates of herpes in seaweed-eating populations may be a cofactor in the observed lower rates of breast cancer. Seaweed ingestion, which is already thought to be connected with reduced rates of breast cancer, may, perhaps, elicit these protective effects via inhibition of herpes viruses.

**Effects on Immunity and Inflammation**

Stimulation of T-cell multiplication in vitro by algal extracts may account for in vivo observations by other researchers, including increased monocytes in cattle who were fed seaweed-extract sprayed grasses. The extensive gut lymph tissue would contact seaweeds passing through the gut. Specialized T cells in gut lymphatic tissue are important in achieving a rapid response to pathogens, in particular, to viruses such as HSV I and may also modulate intestinal lipid metabolism.

Inflammatory disorders, such as psoriasis and some types of colitis, are characterized by an excessive presence of leukocytes and may be ameliorated by seaweed ingestion. Algal-derived fucoidans inhibit the passage of leukocytes into tissues by receptor blocking. These fucoidans are being investigated clinically for their potential to prevent destruction of postischemic heart muscle by invading leukocytes.

**Effects on Plasma Cholesterol and Hypertension**

Many foods are known to reduce cholesterol levels and brown algae fall into this category. *Undaria* ingestion results in lower cholesterol levels in rats. This effect on lipid processing seems to be the result of stimulation of liver enzymes. *Undaria* fucogalactan fractions were shown to reduce lipid clearance times dramatically when introduced intravenously. The fucoidan component may block the macrophage scavenger receptor that is involved in low-density lipoprotein uptake. *Undaria* contains substantial amounts of laminine and similar tetrapeptides, which have been shown to have angiotensin-converting enzyme inhibitory qualities both in vitro and in vivo. Ingesting 3.6 g per day of *Undaria* (wakame) for 4 weeks resulted in a 14 mm Hg drop in systolic blood pressure in Asian patients who had hypertension. Relying on ion exchange properties, rather than laminine, a Swedish clinical study found that ingesting potassium-loaded seaweed fibers countered hypertension successfully.

**Mineral Contents**

Mineral concentrations vary according to the growth environment and age of marine algae. Iodine or trace-element requirement is currently the most common reason for seaweed supplementation. The maximum tolerated dose of 1000 µg of iodine per day (according to the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives) can be reached with only small amounts of some kelps and should be assessed carefully by practitioners. Arsenic is considered to be toxic in the form of the inorganic salt when it consumed in excess of 2 µg per kg body weight per day. Arsenic is also an essential trace element with a recommended minimum intake of 12–50 µg per day.

In broad terms, annual growth algae such as *Undaria* contain the lowest amounts of minerals and can, therefore, be consumed in larger quantities. For example, Tasmanian *Undaria* contains 53 µg per g of iodine and 0.96 µg per g of arsenic.

**Conclusions**

Brown algae as either food or in supplement form may provide useful additional therapy for treating herpetic viral infections and some cancers. Other benefits include mild antihypertensive- and cholesterol-reducing effects. Used with caution, so as not to exceed the maximum iodine or arsenic intakes, these algae also provide valuable mineral supplementation.

**Acknowledgment**

The author wishes to acknowledge the support of Marine Resources Pty. Ltd., Tasmania, Australia and the assistance of Julia Pearson.

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*Marine Resources data, personal communication.*
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