



# KUXULKAB'

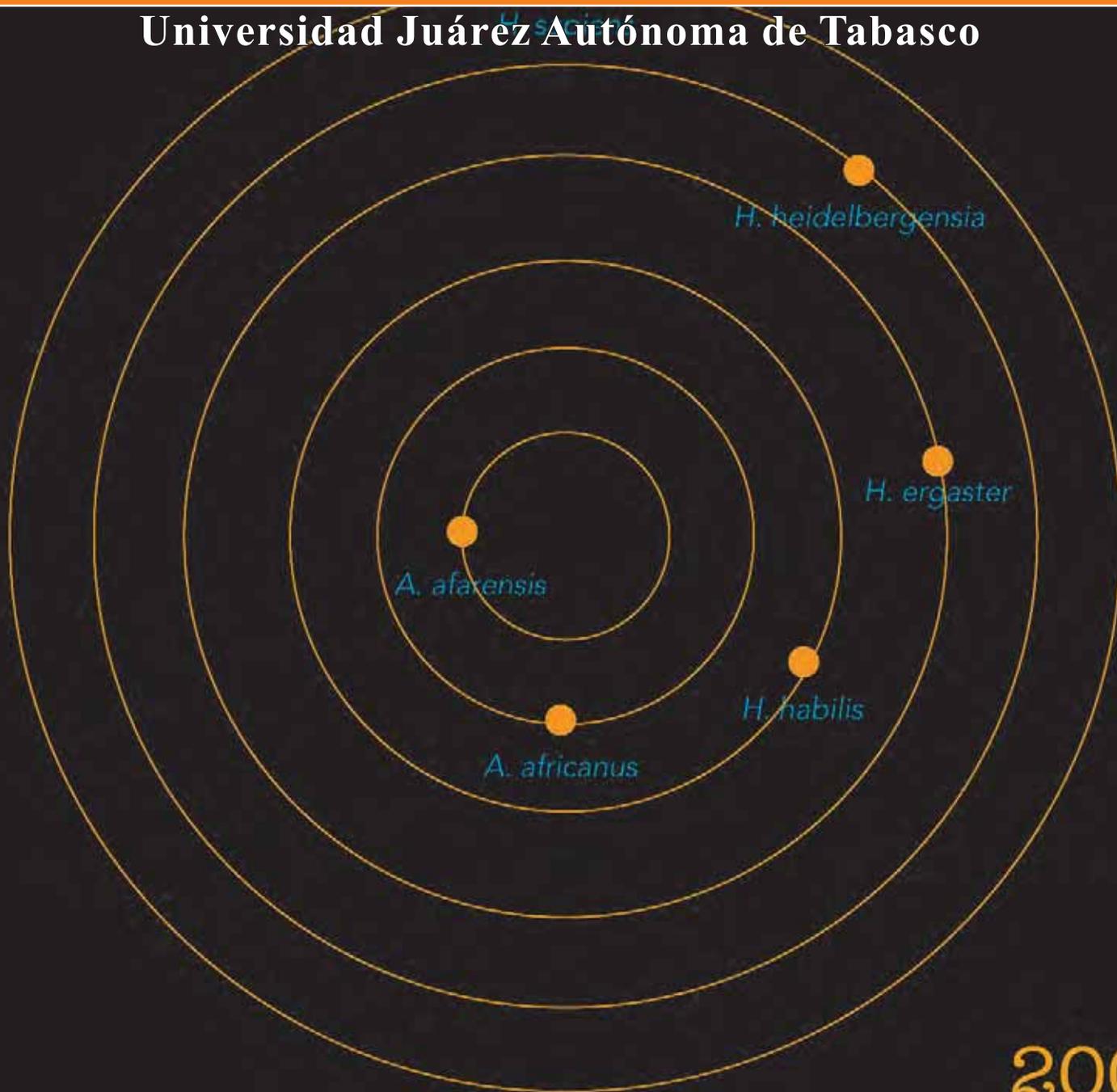
REVISTA DE  
DIVULGACIÓN

División Académica de Ciencias Biológicas

ISSN 1665-0514

• Volumen XVI • Número 29 • Julio - Diciembre 2009 •

Universidad Juárez Autónoma de Tabasco



200

aniversario

Charles Robert Darwin

## REVISTA DE DIVULGACIÓN

División Académica de Ciencias Biológicas  
Universidad Juárez Autónoma de Tabasco

*Kuxulkab' Voz chontal - tierra viva, naturaleza*

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Publicación citada en:

- El índice bibliográfico PERIÓDICA., índice de Revistas Latinoamericanas en Ciencias.  
Disponible en <http://www.dgbiblio.unam.mx>  
<http://www.publicaciones.ujat.mx/publicaciones/kuxulkab>

KUXULKAB' Revista de Divulgación de la División Académica de Ciencias Biológicas, publicación semestral de junio 2001. Número de Certificado de Reserva otorgado por Derechos: 04-2003-031911280100-102. Número de Certificado de Licitud de Título: (11843). Número de Certificado de Licitud de Contenido: (8443). Domicilio de la publicación: Km. 0.5 Carretera Villahermosa-Cárdenas, entronque a Bosques de Saloya. Villahermosa, Tabasco. C.P. 86039 Tel. y fax (93) 54 43 08. Imprenta: Morari Formas Continuas, S.A. de C.V. Heróico Colegio Militar No. 116. Col. Atasta C. P. 86100 Villahermosa, Tabasco. Distribuidor: División Académica de Ciencias Biológicas Km. 0.5 Carretera Villahermosa-Cárdenas, entronque a Bosques de Saloya. Villahermosa, Tabasco.

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## Estimados lectores de Kuxulkab´.

**A**l cierre de este año muchas actividades a nivel mundial se realizaron conmemorando los 200 años del nacimiento de Charles Darwin, creador de la teoría de la evolución. Darwin realizó un recorrido en el “HMS Beagle” por cinco años visitando medio mundo, registrando sus observaciones lo que culminó en su famoso libro que en la primera edición tenía el nombre de: “El origen de las especies por medio de la selección natural o la preservación de las razas favorecidas en la lucha por la vida” que se modificó a sólo: “El Origen de las Especies por medio de la Selección Natural”, que cumplió 150 años de haberse publicado (24 de noviembre de 1859) con su teoría del mecanismo de cómo las especies van tomando forma.

El objetivo de nuestra revista es compartir de forma sencilla y agradable además de temas de interés algunas de las investigaciones que realizamos en la escuela como una contribución a la divulgación de las ciencias ambientales, se seleccionan temas que de forma sencilla muestren información de la situación de los recursos naturales de nuestra región además de temas relacionados a la atención de problemas ambientales. En este número publicamos una colección de diez artículos y dos notas con temas relacionados al uso y manejo de los recursos naturales, tanto de especies emblemáticas para la conservación particularmente importantes como amenazadas de la región. También se presentan estrategias metodológicas para el manejo de la información y los residuos en el estado. Se presentan resultados de cursos de licenciatura y posgrado así como de proyectos de investigación que se están realizando en la escuela.

Les invitamos a enviarnos sus manuscritos y les recordamos en especial a los alumnos de licenciatura que esta revista forma parte de las oportunidades que tienen para ingresar en la vida académica de la investigación y la misma se enriquece con las aportaciones de todos los miembros de la comunidad de la División Académica de Ciencias Biológicas, haciendo una especial invitación a que se incorporen a la divulgación de temas que consideren serán de interés a sus compañeros y se unan a aquellos que han terminado o se encuentran realizando sus proyectos de tesis y cuyos resultados de sus investigaciones comparten con nosotros. Como siempre agradecemos a los colaboradores de otras instituciones interesadas en la divulgación que comparten con nosotros temas de interés general así como los resultados de sus proyectos. Con un sincero reconocimiento a los colegas que desinteresadamente colaboran en el arbitraje que nos permite mantener la calidad de los trabajos.

**Lilia Ma. Gama Campillo**  
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# Seaweed: for Food, Medicine and Industry

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## Introduction

Seaweeds are marine macro-algae found growing throughout the world oceans and seas and none is found to be poisonous. Most of them are green (about 1200 species), brown (about 1750 species) or red (about 6000 species), and most are attached by holdfasts, which have just an anchorage function, although a particularly efficient one (Guiry, 2009). Why seaweed? People do not have a very good impression of seaweeds. They think that seaweeds are just some stinking, slimy nuisance that are washed up on clean sandy beaches. Most people do not realize how important seaweeds are, both ecologically and commercially. In fact, seaweeds are crucial primary producers in oceanic food webs. They are rich both in minerals and essential trace elements, also valuable sources of food, micronutrients, and raw materials for the pharmaceutical industry (Chapman, 1970)

Seaweed are considered as the food supplement for 21<sup>st</sup> century because they contain proteins, lipids, polysaccharides, minerals, vitamins, and enzymes. In general, seaweeds are rich in vitamins A, E, C, and Niacin with similar contents in green algae (Chlorophyta), brown algae (Phaeophyta), and red algae (Rhodophyta). The concentration of vitamins B12, B1, panthothenic acid, and folic, and folic acids are generally higher in greens and reds than in browns (Madlener, 1977).

The brown algae possess organic iodine in greater amounts, in green algae, this micronutrient is found generally in low quantity. For example, one tablespoon of cooked hijiki (*Hizikia fusiforme*) a brown algae is approximately equivalent in calcium

to one glass of whole milk. On the other hand, tea made from *Fucus vesiculosus* (bladderwrack) is called slimming tea because the high iodine content in the plants, will act as a stimulator of the thyroids that regulates the metabolism, and there is no better way to provide the body with a full complement of trace elements than consuming these kind of sea vegetables. Marine algae are similar to oats in protein and carbohydrate values. The red and green algae appear higher in crude protein far tested about 2 to 4 percent. For example, the blue green algae Nostoc species have around 20 percent protein content, which is similar for the green algae *Enteromorpha linza* (20 %), and the brown algae *Analipus japonicas* with 22 % of protein values of red algae Porphyra are higher than rice or soybeans and very close to horsemeat meal (Madlener, 1977).

All algae contain high content of carbohydrates (sugars and starches) in polysaccharide biochemical structure which is a natural nontoxic colloidal substance that has been used as mucilaginous material referred to as gel. However, this structure can not be broken by the digestive enzymes in several organisms and therefore their use for human consumption is nutritionally limited (Madlener, 1977). Fat content in sea vegetables ranges from 1 percent in *Laminarias* to 8 percent in *Pelvetia canaliculata*. In some experiments where algae species were exposed at low tide tend to be high in fat and oil contents. It is speculated that these high content are necessary for alga like *Ascophyllum* to with stand long periods of drying out between tides.

## Seaweed for Food

### Green seaweeds

The green seaweeds *Monostroma*, *Enteromorpha*, *Ulva*, *Caulerpa*, and *Codium* are commonly known as source of food. In Japan, dried fronds of edible *Monostroma* are used in preparation of “nori-jam” and soup. Edible *Monostroma* and *Enteromorpha* are called “Aonori” in Japanese (Ohno, 1997); in some Pacific regions, *Enteromorpha* is being known as “ele ele” (Hawaii), “lulua”, “lumi boso” (Fiji), and “Nalumlum malekesa” (Vanuatu). This alga is being eaten by humans as edible raw, dried, or cooked (Novaczek, 2001) *Codium geppiorum* being a favorite dish with fish cooked in milk by many Pacific islanders. *Caulerpa* is known as “sea grapes”, “green caviar” or “green sea feather”. It is commonly sold in markets and is important to the economy of many Pacific regions. *Caulerpa lentilifera* is being consumed as a salad in the Philippines and some parts in Indonesia (Trono and Toma, 1997), *C. sertularioides*, *C. peltata* and *C. bikinensis* are being consumed with coconut milk (Payri *et al.*, 2000).

### Brown seaweeds

*Laminaria* “kombu”, *Undaria* “wakame” is edible and an important resource in Japan. They are consumed raw, boiled or dried material with sweetened green beans, jelly, crushed ice, and coconut milk in Southern Vietnam (Tsutsui *et al.*, 2005). *Cladosiphon okamuranus* as salad in Japan (Toma, 1997). *Sargassum* is known as horsetail and it is eaten as soup or dressed with soybean sauce, or after being processed in Korea (Madlener, 1977), and in Hawaii (Novaczek, 2001). In the Pacific region, *Rosenvingea* or slippery cushion, *Turbinaria* or spiny leaf are eaten as soup or omelet *Colpomenia* or papery sea bubble as chop soup, stew or salad. *Hydroclatharus* or sea colander, *Dictyota* or brown, *Padina* or sea fan ribbon weeds as a food dressing, soup or stew (Novaczek, 2001).

### Red seaweeds

*Acanthophora* or spiny sea plant, *Asparagopsis* or supreme, *Calophyllis* or large wire weed, *Hypnea* or maidenhair, *Halymenia* or red sea lettuce, *Laurencia* or flower limu, *Scinaia* or tender golden weed are eaten fresh, cooked, or to make pudding, raw or as a spicy, dried and rehydrated, or used to make jellies, chopped or salted as a spice, salads or cooked with

coconut milk In the Pacific region (Novaczek, 2001).

*Gracilaria* or sea moss is being used as homemade agar, garnish for sashimi, used for commercial agar, or fresh as a salad (Madlener, 1977; Novaczek, 2001). *Gelidiella* or little wire weed, is being eaten after being simmered as a Jelly in Japan, Vietnam (Madlener, 1977; Novaczek, 2001; Tanaka & Nakamura, 2004). *Rhodymenia palmata* or dulce is the most common of edible seaweeds in Europe and North America. The following seaweed is also used by them as food: *Alaria fistula*, *Chordaria flagelliformis* and *Porphyra umbilicalis*, *Porphyra* or purple lever is being consumed fresh or dried in Japan, China, Korea, Vietnam, North America and Europe (Madlener, 1977; Tanaka & Nakamura, 2004; Tsutsui *et al.*, 2005). *Euचेuma* and *Kappaphycus* or thron grass; elkorn (*Euचेuma*); brown licorine algae, tambalang (*Kappaphycus*) are being eaten with coconut milk and sugar in Indonesia (Jogja, Bali) (Personal communication) and Vietnam (Tsutsui *et al.*, 2005).

## Seaweeds for Medicine

As we know, algae are rich in minerals, vitamins, trace elements, and bioactive substances. Because of these properties, there are many applications for seaweeds such as in medicine, and we explain only few of them. For example, *Digenea* (Rhodophyta) produces an effective vermifuge (kainic acid). *Laminaria* and *Sargassum* species has been used in China for the treatment of cancer. Anti-viral compounds from *Undaria* have been found to inhibit the Herpes simplex virus, which are now sold in capsule form. *Undaria* extract is being used to treat breast cancer and HIV. Another red alga *Ptilota* sp. produces a protein (a lectin) that preferentially agglutinates human B-types erythrocytes in vitro. Some calcareous species of Coralline have been used in bone-replacement therapy (Stein & Borden, 1984; Khan & Satam, 2003).

Seaweed extract from red algae *Asparagopsis taxiformes* and *Sarconema* sp are used to control a cure goiter heparin, in cardiovascular surgery (Stein & Borden, 1984). *Codium fragile* has been reputed to have efficacy as vermifuge for *Ascaris lumbricoides* with similar results as the sister species, *C. dichotomum*, and *Grateloupia divaricata* that has

been tested in primary school kids in Hokkaido with a positive results (Tokida, 1954).

On the other hand, marine brown algae, in particular members of Fucales, generally are assumed to function as antibacterial agents (Sieburth & Conover, 1965; Harlin, 1995; Hay, 1996), also as inducible screen against UV radiation (Hay, 1996; Pavia, et al., 1997; Pavia & Brock, 2000). Another brown alga, *Zonaria diesingiana* has been applied to screen potential anticancer drugs (Fusetani, 1987).

The most astonishing quality of seaweed is its ability to purge the body of pollutants. Watanabe, a Japanese scientist, discovered in 1998 that certain algae might overcome the toxic effect of nicotine. From Canada, Slorvna of Mc Gills University discovered that seaweeds protect us from X-ray and even reduce radioactive heavy-metal pollution (Nadu, 2002). Other property is not only preventing absorption, but also helps to eliminate toxins, including strontium and other radioactive elements that were already stored in the body (Nadu, 2002). Recently, *Lobophora variegata* was discovered as a source of bioactive compounds as antimicrobial defenses (Kubaneck *et al.*, 2003).

## Seaweeds for Industry

### Alginate

Alginates are derived from large brown seaweeds generally growing in colder-water areas worldwide, being the major producers United States, France, Norway, Great Britain and Japan (Huisman, 2000). Harvest takes place in processing countries with the alginate producers arranging their own harvesting and gathering. The main commercial sources of phaeophytes are *Ascophyllum*, *Laminaria*, and *Mycrocystis*. Other minor sources include *Sargassum*, *Durvillea*, *Eklonia*, *Lessonia*, and *Turbinaria*. As the alginates can absorb many times their own weight of water, they have a wide range of viscosity. This can readily form non toxic gels. They have countless uses in the manufactures of pharmaceutical, cosmetic creams, paper and cardboard, and processed foods (Chapman, 1970).

Alginate represents the most important seaweed colloid in term of volume. Richard-Rajadurai (1990) described production averages from 22,000 to

25,000 tons per year, and predicts an increase in demand of up to 50,000 tons by 1995. The seaweed aquaculture production (92% of the world seaweed supply) doubled between 1996 and 2004, and it is estimated at 11.3 million wet tons, with 99.7% of the biomass being cultivated in Asia The seaweed aquaculture production is valued at US\$5.7 billion (with 99.7% of the value being provided by Asian countries) (FAO 2004; 2006a, b). Alginates find their uses in varied industries, but the most important consumers are textiles (50%) and food (30%). As with other phycocolloids various grades of alginate are available for specific applications and associated prices, e.g. Sodium alginate, pharmaceutical grade (US\$ 13-15.5 per kg), food grade (US\$ 6.5-11.0 per kg). In Japan and Korea, high demands for *Laminaria* as kombu have resulted in high prices and needed the import of supplies for alginate extraction (Critchley, 1997).

### Agar

The principal seaweed sources of agar are *Gracilaria* (53%) and *Gelidium* (44%) with minor amounts (3%) from other agarophytes such as *Gelidiella* and *Pterocladia* (McHugh, 1991). *Gelidium* is the traditionally preferred source of the best quality agar and commands higher prices. *Gracilaria* tends to give good yields of agar with poor gel strength. However, the discovery that alkali treatment improves the gel strength of agar from *Gracilaria* and industrialization of the process has increased the demand for this genus (Critchley, 1997). Successful cultivation has led to increased availability of *Gracilaria* as a source of agar and its use now exceeds that of *Gelidium*. Agar can be used as a gel in foodstuffs, but its specific properties are particularly suited to its use in bacteriology to solidify media. The supply of agar is limited by the relative scarcity of suitable algae, with high prices. Agarose, a component of agar, is used in pharmaceutical and other industries for the separation and purification of a number of products (Huisman, 2000).

The world market value agar has been assessed at US\$ 200 million. The major producing countries are Japan, Spain, Chile, Mexico, China and the Republic of Korea. Recently, exploited sources of seaweeds containing agar are found in the Asia-Pacific region including Indonesia, Philippines, and Southern Africa (Critchley, 1997). A great deal a raw material goes to Japan, which is also a major

exporter of final product (Richard-Rajadurai, 1990). James (1990) indicates that the production values of 6,600 – 7,000 tons per year have been achieved consistently in the recent year. McHugh (1991) estimates 48,340 tons of raw materials that were processed. Richard-Rajadurai (1990) gives a value of 7,000–10,000 tons of agar produced worldwide of which half originates from Japan and South Korea. James (1990) states that due to recent high values of Japanese currency production and the export of agar has declined, while in Chile and China the production has increased to fill the gap of market demand.

### **Carrageenan**

Carrageenans are also gel-forming or viscous compounds derived from red algae, in this case belonging to the genus *Eucheuma*, and two genera recently segregated from it, *Betaphycus* and *Kappaphycus* and are mainly tropical in distribution (Huisman, 2000). The two species originally cultivated in the Philippines were named *Eucheuma cottonii* and *Eucheuma spinosum*. Industry shortened these, so they are often referred to as “cottonii” and “spinosum”. However, botanists have renamed both species, so that *Eucheuma cottonii* is now *Kappaphycus alvarezii*, while *Eucheuma spinosum* is now *Eucheuma denticulatum* (McHugh, 2003).

There are three main types of carrageenan; *lambda*, *kappa*, and *iota* each having their own gel characteristics. Previously, the use of carrageenan was restricted because of the availability of natural resources of *Chondrus crispus* (common name: Irish moss) from Canada, Ireland, Portugal, Spain and France and *Gigartina/Iridaea* from South America, and Southern Europe (Trono, 1997). *Chondrus* contains a mixture of two types (*lambda* and *kappa*) that could not be separated during commercial extraction. Limited quantities of wild *Chondrus* are still used; attempts to cultivate *Chondrus* in tanks have been biologically successful, but uneconomic as a raw material for carrageenan (McHugh, 2003).

These sources now only contribute 20% of the total processed material. Supplies for this pycocolloid are dominated by *Eucheuma* which are cultivated in Indonesia, the Philippines and recently

very successfully in Tanzania (Trono, 1997). In this sense, the culture of seaweeds is expected to increase the carrageenan production; however, the success of their culture has led to an oversupply of *E. spinosum* on the world market. McHugh (1991) gives the following values for the sources of carrageenan, harvested tonnages are given with values of percentages of total in brackets: *Eucheuma* 66,000 (79%), *Chondrus* 6,370 (7.7%), *Gigartina* 4,300 (5.2%), others (*Hypnea*, *Iridaea* and *Furcellaria*) 5,900 (7.2%).

In the world market, Philippines accounts for nearly 80 % of total *Eucheuma cottonii* production of 1'300,000 tones, roughly 35 % which is traded in dried form. It supplies 14 % of the world's total raw seaweed production and holds first ranks as producer's semi-refined carrageenan, contributing close to 60 % (Richards-Radjadurai, 1990; McHugh, 1991; Trono, 1997; FAO, 2002). Recently, seaweed figure prominently debates about the energy and biofuel production. They have been discussed as a potential source against global warming where seaweed and algae are very efficient carbon sinks which means that they absorb more carbon than their rate emission.

### **Other Uses of Seaweed**

#### **Integrated aquaculture**

These are just a few examples of the small- and large-scale uses that are evolving in the integrated aquaculture of seaweeds with other species. Integrated aquaculture is developing solutions to solve sustainable environmental problems, including the management of coastal areas and the disposal of effluents from large-scale aquaculture activities. This concept of polyculture, or integrated aquaculture to use the more recent terminology, has been utilized in many situations where the effluent from the aquaculture of one species, potentially threatening environmental damage, can be used by another species to its advantage, with a reduction in pollution. For example, semi-enclosed or land-based systems have been suggested, but the higher capital investment has been a deterrent (McHugh, 2003) been a deterrent (McHugh, 2003).

In Israel, an integrated system has been tried. Here the effluent from Japanese abalone culture

tanks are drained into fish tanks that used as pellet feeding. The fish effluent in turn is drained into a seaweed cultivation tank (species of *Ulva*). The seaweed produced was used to feed the abalone. The abalone and fish grew well, a surplus of seaweed was produced and the ammonia nitrogen in the seaweed effluent was reduced to 10 percent of the total amount fed to the system. In Hawaii, where *Gracilaria* species are eaten as fresh salad vegetables, shrimp farm effluent has been used to fertilize *Gracilaria* in floating cage culture. In Brazil, cage aquaculture of shrimp in the open sea has been studied in an attempt to reduce the environmental impact of the shrimp industry. It was found that culturing seaweed inside the shrimp cages can improve the economic result for both shrimp and seaweed. In Chile, when *Gracilaria* seaweed cultivation was integrated with salmon farms the seaweed grew well and removed a large amount of the ammonium excreted by fish. In France, trials were run with *Gracilaria* growing in closed and semi-enclosed systems, in the effluents from oyster farms; 90 percent efficiency was recorded in removal of ammonia coupled with useful growth of the seaweed. *Porphyra* species are the source of the human food, nori, and so their use in integrated aquaculture is an attractive economic alternative, particularly because they are very efficient in taking up nutrients. Trials are being run on the east coast of Canada and United States of America to combine *Porphyra* with salmon farming (McHugh, 2003).

### Waste water treatment

A further extension of this ability of some seaweed to take up heavy metals is to has been used to remove heavy metals in cleaning up wastewater. While there have been many small-scale trials, it is difficult to find reports of real implementation on a large scale. Milled, dried species of the brown seaweeds *Ecklonia*, *Macrocystis* and *Laminaria* were able to adsorb copper, zinc and cadmium ions from solution. In another laboratory-scale trial, *Ecklonia maxima*, *Lessonia flavicans* and *Durvillaea potatorum* adsorbed copper, nickel, lead, zinc and cadmium ions, though to varying extents depending on the seaweed type and metal ion concentration. After the extraction of alginate from brown seaweeds, there is an insoluble waste product, mostly cellulose, and the adsorbing properties of this have been tested and

found to equal some of the brown seaweeds. Using such a waste material is obviously more attractive than using the dried seaweed itself. Another waste product, from the production of Kelpak, the liquid fertilizer previously mentioned, has also been tested and found that adsorbs copper, cadmium and zinc just as effectively as the seaweed from which it is derived. So there is the potential to use either seaweed or residues remaining from seaweed extraction. It is a matter of whether this is the most economical way to do so, depending on their availability and cost at the source of the wastewater (McHugh, 2003).

### Conclusion

The use of seaweeds in the development of pharmaceuticals, nutraceuticals, botanicals, cosmetics, and as a source of pigments, bioactive compounds, and antiviral agents, is in full expansion. Ecologically and commercially seaweed are important as a potential source as food supplement for 21<sup>st</sup> century because it contains proteins, lipids, polysaccharides, minerals, vitamins, and enzymes. They are being used for food medicine, industry, and other uses such as integrated aquaculture with fishes or mollusk culture and also have been tried to remove the heavy metal in cleaning wastewater.

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ISSN - 1665 - 0514