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Commercial importance of marine macro algae

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ABSTRACT

India with a vast coastline of more than 8000 km supports a rich standing crop of marine algae wherever rocky or coral formations occur along the coast. The current estimate of annual standing crop of marine algae of lndia is 3, 01,646 tonnes (fresh weight).The algae contain minerals, trace elements (iodine and bromine), proteins, carbohydrates, lipids etc.The marine algae are a good source of organic constituents such as vitamins, bioactive substances and polysaccharides and also are useful as raw material for biofuel production and liquid fertilizer. Important polysaccharides obtained from algae are agar, carrageenan and algin. The Indian red algae such as *Gelidinm, Gelidiella, Pterocladia* and *Gracilaria* yield agar and agarose. Agarose is the most important medium for electrophoresis. The red algae viz. *Hypnea, Kappaphycits, Acanthophora, Laitrencia* are the sources of carrageenan. Algin is extracted from brown algae like *Sargassum, Turbinaria, Hormophysa and Cystoseira.* Mannitol is also obtainable from brown algae. This is used as a diuretic and helps in excretion of some toxins. Many of the green, brown and red algae form part of the diet taken by people of South East Asia. In India, the red alga *Gracilaria edulis* is eaten in certain coastal areas of Tamil Nadu as porridge. Some of the marine algal constituents are of antimicrobial, antifungal, antiviral, diuretic and spasmolytic values. The algae are used in the treatment of goiter and as ichthyotoxic compounds. Other medicinal properties and commercial uses of algae in industry and biotechnology are reviewed in this paper. Efforts must therefore be made by concerned agencies and entrepreneurs to make best use of the renewable marine algae which are available along our coasts.

Introduction

The importance and use of marine algae for various purposes is gaining momentum world over with bright prospects for future growth. While the traditional uses of marine algae as food, fodder and manure remain steady, they are increasingly used nowadays as raw material for extraction of the phycocolloids viz. agar, agarose, algin and carrageenan. In addition to this, they are attracting the attention as a source of biofuel (Chennubhotla *et* o/., 2011) and ethanol has been produced from fresh *Kappaphvcus alvarezii* biomass by Central Salt & Marine Chemicals Research Institute, Bhavnagar (Gujarat) (Khambaty *et al.,* 2011) and liquid fertilizer from *Sargassum wightii, IJlva* *lactuca*, *Spatoglossum asperum*, *Kappaphycus alvarezii* etc (Bukhari and Untawale, 1978; Anantharaman *et al.*, 2011; Siddhanta, 2005). Investigations carried out by various institutions like Department of Biochemistry, University of Tokyo, The Korean Institute for Industrial Technology, National Institute for Environmental Studies, Japan, Institute on the Environment at the University of Minnesota USA, Institute of Engineering and Technology, Massey University, New Zealand and Central Food Technological Research Institute, Mysore. National Institute for Pharmaceutical Education & Research, Mohali (Punjab) have reported encouraging results on the prospects and possibilities of extraction of biofuel from the cultured algae. The marine algae (Fig. 1) contain minerals, trace elements (iodine and bromine), primary metabolites like proteins, carbohydrates, lipids, laminarin and also are a good source of organic constituents such as vitamins, bioactive substances etc., The principal use of marine algae is as a source of human food and the other main use is as raw material for extraction of phycocolloids (Chennubhotla *et al.*, 2000).As the marine algae are capable of absorbing the aquaculture effluents, waste water containing nutrients and plankton is ideal for growing marine algae in the shrimp farms to get the twin benefits of treatment of aquaculture pond as well as successfully growing the marine algae of economic importance (Chennubhotla,1995). The products obtained from marine algae and their industrial and medicinal importance has been dealt with in detail by various workers (Renn, 1984; Chennubhotla *et al.*, 1987; Ramalingam *et al.*, 2003; Krishnamurthy, 2011; Anantharaman *et al.*, 2011; Kaliaperumal, 2011; Umamaheswara Rao, 2011).

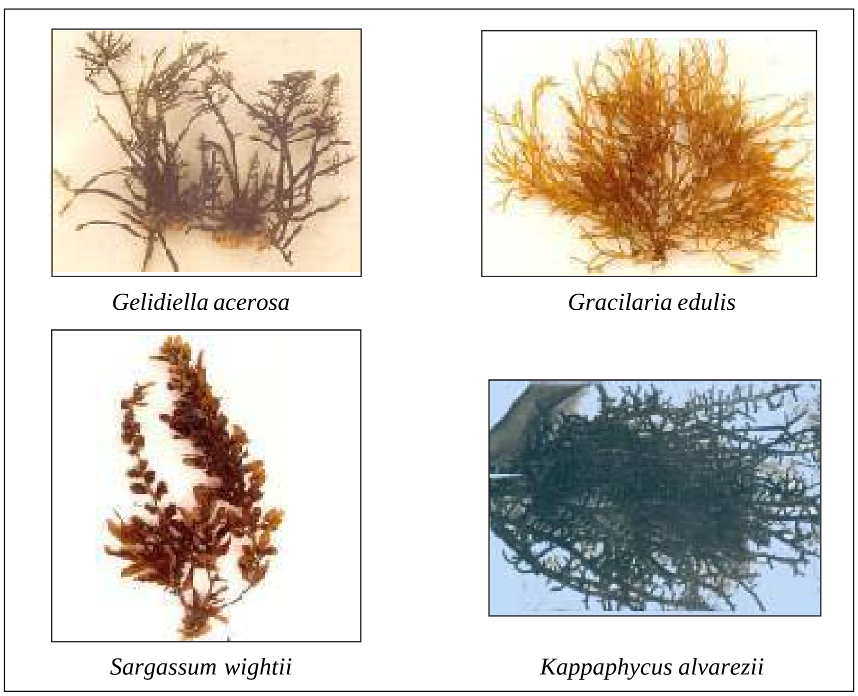


Fig. 1. *Marine algae of commercial importance*

Marine algal resources

It is difficult to obtain accurate information on the availability of marine living resources, as from time to time there are changes in the environment which reflect upon the resource under study. According to FAO year book of statistics (2006) the global production of both economically important (Richards Rajadurai, 1990; McHugh, 1991) and other marine algal species was > 15 million metric tonnes, of which 15 to 20% was estimated to be from Indian Ocean region. India has a coastline of more than 8000 km. Several Research Institutes such as Central Marine Fisheries Research Institute, Kochi, Central Salt & Marine Chemicals Research Institute, Bhavnagar, National Institute of Oceanography, Goa, Maritime State Fisheries Departments and other organisations have conducted the surveys of marine algal resources along the coastline of India in the intertidal and shallow waters and estimated the standing crop as 3,01,646 tonnes (fresh weight) of marine algae (Table-1) following the standard statistical methods (Chennubhotla, 1999; Kaliaperumal *et al*., 1987; Kaliaperumal, 2011; Qasim, 2003; Subba Rao and Vaibhav Mantri, 2006; Krishnamurthy and Subbaramaih, 2007;Umamaheswara Rao, 2011).

Rath and Adhikary (2005) assessed the total standing crop as 2,630 tonnes(wet weight) by extrapolating the estimated values to the entire Chilka lake area of 1,032.44 sq.km. According to Adhikary, the actual standing crop in the surveyed area of 78.77 sq.km. was estimated as 44,000 tonnes wet weight (unpublished). Due to the unique properties of polysaccharides and other products, marine algae are playing an important role in various emerging areas of biotechnology, as medicine, food and industry. A review covering this points is presented in this paper.

Table 1. *Estimated quantities of marine algae in India*

Maritime State	Quantity (fresh weight) in tonnes
Tamil Nadu (inshore waters up to 5meters)	22,044
Tamil Nadu (deep waters 5 to 22 meters)	75,373
Gujarat	19,445
Maharashtra	20,000
Lakshadweep Islands	19,345
Goa	2,000
Kerala	1,000
Andhra Pradesh	7,500
Orissa	44,000
Andaman-Nicobar Islands	90,939
Total	3,01,646

Marine algae in industry and biotechnology

Agar

The red algae such as *Gelidium*, *Gelidiella*, *Pterocladia* and *Gracilaria* yield agar. Major use of agar is as a culture medium for various microorganisms and is indispensable in micro biological studies. Agar is used as a thickener in food industry, in cosmetics, for clarifying beverages and in paper manufacture. Agar is often employed in pharmaceutical industry, leather industry, photographic industry, dairy industry etc. It gels at room temperature and freezing and thawing are used to purify the same.

Agarose

Agarose is a polysaccharide obtained from agar that is used for a variety of life science applications especially in gel electrophoresis. Agarose forms an inert matrix utilised in separation techniques. Many structures easily affix to agarose including various types of proteins. Agarose is obtained by purification of agar after separation of agaropectin from agar by chromatographic techniques. Agarose is mainly used in the biotechnological tools of electrophoresis, immunology, microorganism culture, chromatography, gel permeation chromatography, serum electrophoresis, gene mapping and immobilized systems technology and also used in estimation of the size of DNA molecules and in PCR product analysis e.g. in molecular genetic diagnosis or genetic finger printing. After fusion, hybridomas cells have been found to reproduce more consistently on agarose than on agar. Agarose gel electrophoresis is a method of gel electrophoresis to separate proteins by resultant charge. This method is extensively used in biochemistry and molecular biology i) to separate a mixed population of DNA and RNA fragments by length, ii) to estimate the size of DNA and RNA fragments and iii) to separate proteins by charge. Great strides in cancer research in the discovery of oncogenes and in AIDS research were made by the agarose as gel matrix.DNA finger printing is based on the separation and identification of gene fragments by agarose gel electrophoresis. Proteins are separated by their relative charges in agarose because the pores of the gel are too large to sieve proteins.

Carrageenan

Red algae viz. *Hypnea, Kappaphycus, Acanthophora, Laurencia* etc.are the sources of carrageenan. There are three important forms of carrageenan namely kappa, lambda and iota forms, each with its own gelling property. Like agar, the carrageenan is used to gel, thicken, suspend and stabilize foods and other products. This is mainly used in frozen poultry industry, coffee industry, prawn feed, tooth pastes, shampoo industry, air freshener gels and in tissue culture medium. It has been reported that carrageenans have anti-tumor and anti viral properties and also controls stomach ulcers. Carrageenan is also used as suspension agents and stabilizers in drugs, lotions and medicinal creams. Further, they have applications as anti coagulant blood products and for treatment of diarrhea, constipation and dysentery. The production of carrageenan was started in 1930's in the United States. In China, the production of carrageenan was initiated during 1970's from *Eucheuma gelatinae* and *Hypnea* as raw material. The major carrageenan producing countries are U.S.A., Denmark, France, Japan, Spain, China, Korea, Brazil and Philippines. The annual world production is about 15,000 tonnes including 600 tonnes of carrageenan produced by China (Ji Ming Hou, 1990).There is heavy demand for the unrefined carrageenan in the meat industry in United States and Philippines is the leading country exporting the crude carrageenan to Europe, Japan and U.S.A (Gopakumar, 1997). Steps must be taken to start the carrageenan production in India also on commercial scale by upgrading the existing small units in Tamil Nadu.

Algin

The algin is extracted from brown algae like *Sargassum, Turbinaria, Hormophysa, Cystoseira* etc.Its property of forming emulsions is best used in the manufacture of antibiotics and insecticides. It is extensively used in textile industry and in various pharmaceuticals, rubber adhesives, paper products, cosmetics etc. Alginates are also used in dental impression moulds (Chennubhotla *et al.*,1987).Alginic acid helps to protect against potential carcinogens and it clears the digestive system and protect the surface membranes of the stomach and intestines (Anantharaman *et al.*, 2011).

Mannitol

Mannitol is a monosaccharide present in the cell sap of brown algae such as species of *Sargassum, Turbinaria* etc. Mannitol is used in the production of tablets, for making diabetic food, chewing gum etc and used as a diuretic to excrete some toxins. It is also used as dusting powder in paint and varnish industry, leather and paper industries and in making explosives.

Food

Because of the presence of various nutritional elements like proteins, lipids, carbohydrates, vitamins and minerals, many green, brown and red algae form part of the diet taken by people of South East Asia in the form of raw salads, curry, soup or jam. The content of these elements varies depending on season and the area of production. In India, the red alga *Gracilaria edulis* is eaten in certain coastal areas of Tamil Nadu as porridge. The marine algae are low in calories and high in dietary fibers and hence they form an ideal health food for human. The ash content in marine algae is high compared to vegetables which maintain alkaline nature in the body of the individual. The marine algae are consumed largely in countries such as Japan (since fourth century), China (since sixth century) and Republic of Korea (Anantharaman *et al.,* 2011).

Medicinal value of marine algae

Plants have been the reliable source of medication for nearly 60% of the world's population. In this context, marine algae offer great scope as they possess both nutritional and medicinal values. Marine algae are rich in proteins, calcium and fiber and have an extraordinary quantity of potassium very similar to human's natural plasma level. Marine algae were considered to be of medicinal value in the Orient as early as 3000 B.C. The Chinese and Japanese used them in the treatment of goiter and other glandular diseases. The iodine rich marine algae such as *Asparagopsis taxiformis* and S*arconema* sp.can be used for controlling goiter disease caused by the enlargement of thyroid gland (Umamaheswara Rao, 1970).The British used *Porphyra* to prevent scurvy during long voyages. Dulse (*Palmaria palmata*) is reported to be a laxative and also used to reduce fever. Several red algae like *Chondrus crispus*, species of *Gracilaria, Gelidium* and *Pterocladia* have been used to treat various stomach and intestinal disorders. Extracts of *Digenea simplexa*, *Chondria armata* and species of *Hypnea* have been used by Japanese as an antihelmentic agent for centuries. Red algae like *Corallina officinalis, C.rubens and Alsidium heliminthocorton* were used in early days to control worms in the digestive tract. (Chennubhotla *et al*., 1987). *Ulva lactuca*, rich in chlorophyll, carotenoids and phenolic compounds with anti oxidant and anti bacterial properties is utilized as a natural preservative in food and pharmaceutical industry (Hanna *et al*.,2008).*Ecklonia stolonifera* was shown to have strong anti diabetic and antioxidant properties (Iwai, 2008).

In China and Japan, the lower prevalence of breast and prostate cancer has been traced to marine algal consumption in appreciable quantities. In China, species of *Laminaria* and *Sargassum* were used for cancer treatment and in Japan kelp was shown to inhibit breast cancer. Several sulphated macroalgal polysaccharides have cytotoxic properties.Fucoidans are known to have antitumor, anticancer, antimetastatic and fibrinolytic properties and are known to reduce cell proliferation. Fucoidan showed anti cancer against the stomach, colon and leukemia cancer cells. The green alga *Bryopsis* sp. produces some of Kahalalide F peptides which are found to be effective on lung, colon and prostate cancers. The species of *Corallina*, *Chondria, Palmaria, Laminaria, Macrocystis, Nereocystis, Cladophoropsis* and *Amphiroa* showed high cytotoxic effect against human cervical adenocarcinoma cell line, murine leukemic cell lines, nasopharyngeal and colorectal cancer cells. (Murugan, 2011).Many marine algae like *Caulerpa, Dictyota, Hypnea, Ulva, Gracilaria* etc. have neuroprotective properties by presence of acetylcholinesterase enzyme inhibitory activity in them which is very important to control Parkinson's disease, Alzheimer's disease, multiple sclerosis etc. (Pangestuti and Kim, 2011). Extracts from *Chondrus crispus and Gelidium cartilagineum* have been found to be active against influenza and mumps virus (Garber *et al*., 1958).Antibiotic substance isolated from *Enteromorpha* effected complete inhibition of the growth of the tubercle bacilli in the cultures. (Sreenivasa Rao and Shetlat, 1979). *Padina tetrastromatica, Gelidiella acerosa* and *Acanthophora spicifera* exhibited 100% antifertility activity (Naqvi *et al*., 1981).

Conclusion

The marine red algae *Gelidiella acerosa, Gracilaria edulis, G.verrucosa* and other species of *Gracilaria* are used for agar production and brown algae such as species of *Sargassum, Turbinaria and Cystoseira trinodis* for alginates by about 25 marine algal based industries at different localities along the maritime states of Tamil Nadu, Kerala and Karnataka. All these marine macro algae are harvested since 1966 only from the natural beds occurring along the coast from Rameswaram to Kanyakumari. Data collected by Central Marine Fisheries Research Institute for 28 years from 1978 to 2005 showed that the quantity of agarophytes exploited ranged from 248 to 1518 tonnes (dry wt.) and alginophytes from 529 to 5537 tonnes (dry wt.) depending upon the availability of these marine algae in the natural beds and the raw material requirement form the marine algal based industries. During 2010, about 800 t. of agarophytes and 3500 t. of alginophytes harvested from natural beds were utilized for the production of 80 t. of agar and 350 t. of algin. Since the above supplies of agarophytes were inadequate to meet the demand of agar industries, the required quantity of agarophytes were imported from few foreign countries. The natural resource of alginophytes from Indian coast is quite adequate and only about 50% of standing crop is exploited. The carrageenan yielding marine alga *Kappaphycus alvarezii* is cultivated on commercial scale since 2002 in Tamil Nadu and about 1500 t. (dry wt.) of material is produced per year, of which 250 t. is used for manufacture of carrageenan by the SNAP Natural & Alginate Products Pvt. Ltd., Ranipet, Tamil Nadu.The rest of the material is exported to foreign countries like Philippines and Malaysia.(Kaliaperumal,2011).The industrial methods followed for the manufacture of agar, alginates and carrageenan on commercial scale are given in Annexure-I, II and III respectively.

From the above information it is evident that the marine algae, which is a renewable marine living resource, is unique as it has all the beneficial characteristics. More studies are needed to use marine algal secondary metabolites as drugs and health care products. At present, the marine algae are being used in India for extraction of phycocolloids only and efforts must therefore be made by concerned agencies and entrepreneurs to make best use of the renewable marine algal resources which are available in appreciable quantities along our coasts.

Annexure - I

Processing technology for agar production

(Kaliaperumal, 2011)

Dried seaweed (*Gelidiella*, *Gracilaria)* Leaching in freshwater for 12-18 hrs
↓
Washing two times with freshwater in agitator tanks (3 washes - 10 minutes duration each)
↓
Softening of seaweeds with Hcl for 12 hrs (pH 2-4)
↓
Washing with freshwater (pH 7)
↓
Cooking seaweed in digester for 2-3 hrs by passing steam at 50 lb pressure
↓
Settling agar gel for 1/2 hr
↓
Filtering agar gel through filter cloth
↓
Collection of agar gel in aluminium trays
↓
Cooling agar gel in aluminimum trays
↓
Cooling agar gel at room temperature for 1-2 hrs
↓
Shredding agar gel with gel chopper
↓
Freezing agar gel for 24 hrs (till temperature comes down to 20^{o}C)
↓
Thawing agar after removal from freezing room
↓
Drying agar in sun on velon screen frames
↓
Bleaching agar in 10% chlorine water for 5-10 minutes
↓
Washing agar with freshwater for 2-3 times
↓
Drying agar in sun on velon screen frames
↓
Dried agar
↓
Packing dried agar sheets in polythene bags (1 kg packets)

Annexure - II

Processing technology for carrageenan production
(Ji Ming Hou, 1990)

Dried seaweed
(*Kappaphycus, Eucheuma, Chondrus, Hypnea)*
↓
Sun bleaching
↓
Alkali treatment
↓
Washing
↓
Hot extraction
↓
Filtration
↓
Gelling
↓
Cutting (→ A, B); Gelling → C

(A) Freeze-thaw
↓
Freezing chamber
↓
Thawing
↓
Drying chamber
or
Sun drying
↓
Strip carrageenan

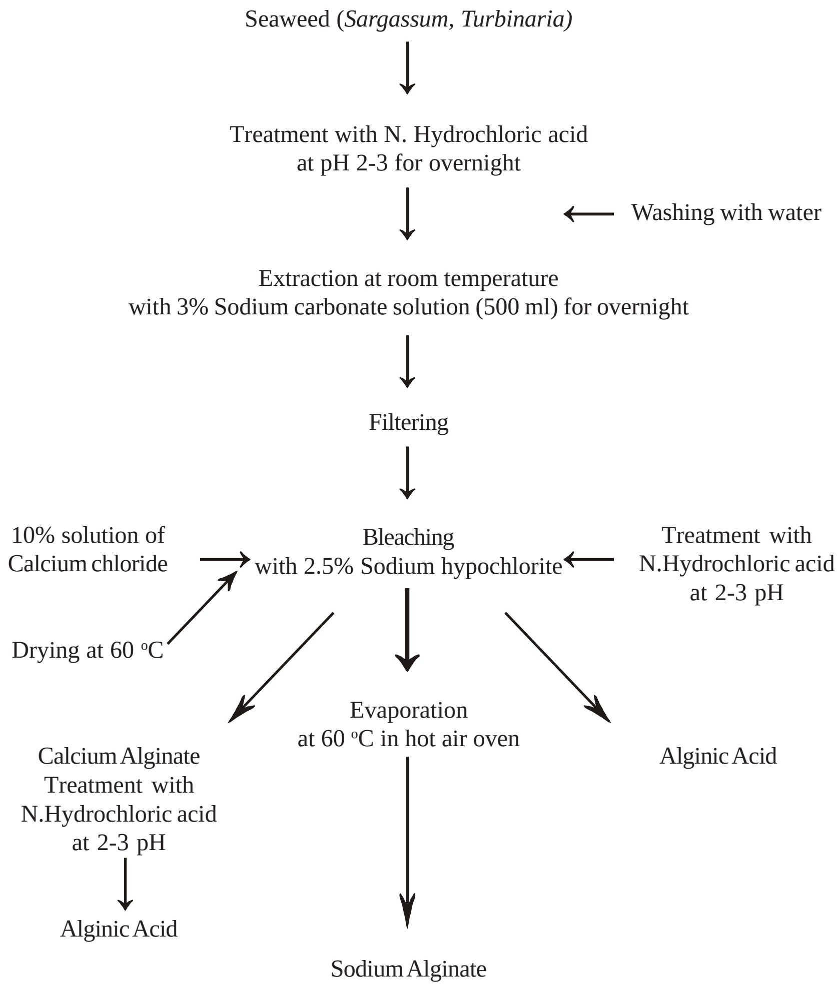
(B) Gel-press
↓
Hydraulic pres
↓
Drying chamber
↓
Milling
↓
Carrageenan powder

(C) KCl precipitation
↓
Evaporation
↓
KCl precipitation
(in 1-1.5% KCl sol.)
↓
Washing
↓
Press or freeze-thaw
↓
Chopping
↓
Milling
↓
Carrageenan powder

Annexure - III

Processing technology for alginates and alginic acid production

(Visweswara Rao & Mody, 1964)



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