Monograph on

Recent Advances on Applied Aspects of Indian Marine Algae With Reference to Global Scenario

The Central Salt & Marine Chemicals Research Institute, Bhavnagar, Gujarat, India is publishing a monograph on *"Recent Advances on Applied Aspects of Indian Marine Algae with Reference to Global Scenario"* under the editorship of A. Tewari. Two volumes in this series are already in press (printed by the National Institute of Science Communication and Information Resources (CSIR), New Delhi). Volume 1 is on natural resource, taxonomic identification, aquaculture, vulnerability to fungal disease, and aspects of fouling. Volume 2 deals with their utility as food and feed, source of phycocolloid, source of bioactive substances, and in environmental aspects. The chemistry of value addition and biotechnological aspects are also covered. Volumes 1 and 2 contain fifteen and seventeen review papers, respectively, which have been written by leading experts in the field. Each volume (7.25" x 9.5") will have about 400 printed pages on art paper and the majority of figures will be in four colors. Both the volumes will have hard case binding with gloss laminated jacket. The details (title of paper, name of authors, their addresses and abstract) for Volume 1 and 2 of the monograph are given in ANNEXUREs I & II, respectively, in this website. The first two monographs will be ready for dispatch in two months.

The price for both the volumes is Rs. 2300/- (Indian Rupee) or 500 US $. In addition to this the buyer has also to pay Rs. 150/- in Indian currency or US $ 10 for sea mail/ surface mail or US $ 20 by air mail towards the charge of packing and forwarding. The volumes will be send by registered post parcel. 10% reduction in selling price will be

given to Indian students and other students of developing and underdeveloped countries. However, in such case the students have to produce certificate from the Director of the Institute or Head of the Department of residential universities or Principle of affiliated colleges. The certificate awarding authority has to certify that the monograph is required for approved project work of the student. 5 % rebate on selling price of the monograph will also be available to all those who pay this amount on or before 30th June 2006. The cost of the monograph and postage charges have to be paid in advance by crossed demand draft drawn in favor of "The Director, Central Salt & Marine Chemicals Research Institute" payable at the State Bank of India, Diwanpara Branch, Bhavnagar, India.

ANNEXURE I

The review papers to be published in the

Recent Advances on Applied Aspects of Indian Marine Algae With Reference to Global Scenario- Volume 1

Aquaculture, Resource, Fouling, Disease and Seaweed Taxonomy

TECHNOLOGY AND BIOLOGICAL ASPECT ON THE CULTIVATION OF EDIBLE SEAWEED IN JAPAN

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The different large scale techniques and processes for aquaculture of edible species of *Monostroma, Enteromorpha, Laminaria, Undaria, Cladosiphon, Nemacystis* and *Porphyra*, in the coastal waters of Japan, are described. The harvesting and post harvest processing details are also presented. The indigenous annual production along with their estimated value, both harvested from nature as well as artificial cultivation and import of some of the seaweeds in Japan are also depicted.

CULTIVATION OF SEAWEEDS IN SOUTHEAST ASIA; WITH SPECIAL REFERENCE TO THE *EUCHEUMA* SEAPLANTS

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Commercial seaweed cultivation in Southeast Asia is currently based primarily on the eucheuma seaplants although some *Gracilaria* spp. is also cultivated. Eucheuma seaplant cultivation is an example of widespread farming that has evolved from simple methods refined mainly by farmers in the sea. This phenomenon has led to current production exceeding 150,000 dry tons /yr from at least ten countries. Farm-gate revenues on the order of 80-100 million USD remain in rural coastal areas of tropical

regions where eucheuma seaplant value chains are the main source of income to tens of thousands of people. These value chains are still building and the information base for eucheuma seaplant is expanding but it has not yet achieved useful stability. Much "knowledge" about the biology of eucheuma seaplants is practical conjecture extrapolated from studies of other genera and eucheuma seaplant value chains lack the transparency essential to efficient operation. The present paper is intended as a step toward moving beyond this state of affairs.

FIELD CULTIVATION OF *KAPPAPHYCUS ALVAREZII* IN INDIA

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Carrageenan is gel-forming colloid extracted from certain species of red algae. Due to its varied and often unique gelling nature, this phycocolloid has a wide range of applications. Recently the world demand for this colloid has been increasing steadily, but the availability of the quality raw material to the processing units has drastically declined. This is due to the over exploitation of the natural stock and lack of awareness of the seaweed cultivation, emphasizing the need for selection and cultivation of commercially important species. In order to test the possibility of cultivation of carrageenan yielding seaweed, *Kappaphycus alvarezii* (Doty) Doty was initially cultured on the Okha, West coast of India. Acclimatization and commercial cultivation of this alga was achieved on the coast of Mandapam, Southeast coast of India, during 1995-1997. Plants were cultivated by vegetative propagation of fragments in perforated

polyethylene bags (bag culture) and net bags, raft and open culture by the monoline rope methods. Raft and net bag culture methods were proved safe and suitable for large scale cultivation, as they prevented loss by grazing and drifting, produced plants free from epiphytes and allowed easy harvest. All the physicochemical factors remained favorable throughout the year for the survival and growth of the alga. *K. alvarezii* in Indian waters showed a daily growth rate between 0.4 and 11.4% with a mean of 4.0%, carrageenan yield between 32 and 54.7% and gel strength of 210-795 g. cm^{-2}.

PROSPECTS OF MARICULTURE OF *HYPNEA* SPECIES IN INDIA

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Species of *Hypnea* constitute a potential source of carrageenan the world over. The genus is pantropic in distribution occurring in subtropical and tropical seas. *H. musciformis* and *H.valentiae* are the most dominant species. Its biology, life history, chemistry of its phycocolloid, utilization and cultivation has been extensively studied in many countries. In all extensive studies in India, its biology revealed most valuable information useful for its mariculture. A technique for its field cultivation was developed at Krusadai island in the Gulf of Mannar, Tamilnadu. A yield of 6.34 kg fresh wt. from 150 meter length of rope in 25 days was obtained in *H. musuciformis*. Recently *H. musciformis* is being cultivated by long line rope method. During first year from June 2001 to May 2002, average biomass per hectare per month was 1.40 ton fresh. During June 2002 to February 2003, average biomass per hectare per month was 2.08 tons fresh

per hectare (which includes nil biomass during December 2001 and January 2002 due to cyclonic wind. *H. valentiae* was also artificially cultivated from stellate bulbils on coral stones at Krusadai island.

FIELD CULTIVATION OF G*ELIDIELLA ACEROSA* IN INDIA

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G*elidiella acerosa* (Forsskal) Fieldmann et Hamel is the principal agarophyte in India yielding bacterial and pharmaceutical grade agar. This seaweed was comercially exploited and exported till 1966. As a result of over exploitation the natural resources had been deteriorating year after year. To over come this problem development of cultivation technologies were under taken since 1969. Among the cultivation technologies developed viz; Long line method, Net method, Bottom culture method and Single Rope Floating Raft Technique (SFRT) method, Bottom culture method in the open shore environment involving coral stone as a substratum was found to be the best one. A crop yield of 4.0 tons (dry) $ha^{-1}y^{-1}$ in 2 harvests was achieved. Because of the limitation of the using the coral stone as substrate, the alternate substrate like holo or solid cement blocks could be utilized for large scale cultivation to generate rural employment and the crop yields like the ones obtained on the coral stone could also be obtained.

CULTURE OF *GRACILARIA EDULIS* AND OTHER SEAWEEDS IN INDIA

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Seaweeds are cultivated for using them as raw material for seaweed industries and as human food. In India, culture of seaweeds is going on since 1964. The works carried out on culture of commercially important red algae such as *Gracilaria edulis, G.corticata, G.crassa, Gelidiopsis variabilis, Acanthophora spicifera;* brown algae *Sargassum* spp and *Hormophysa triquetra* and green algae *Ulva lactuca, U.fasciata and Enteromorpha flexuosa* in different environments using various culture techniques are reviewed in this paper. The prospects of commercial scale cultivation of seaweeds in India are highlighted.

MASS CULTURE OF *SPIRULINA* (*ARTHOSPIRA*) FOR HUMAN NUTRITION AND AQUACULTURE INDUSTRY

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Spirulina (*Arthrospira*) is considered a wonder alga because of its high nutritive value. This is evidenced by the large body of literature that has appeared on its production and applications over the past decade. The review mainly concerns those planktonic species, which are mass produced for commercial purposes. The ecological aspects such as frequent bloom formation in shallow water bodies, the preference of highly saline inland waters, of the warm tropical zones have been dealt with. Nutritional physiology and physico-chemical conditions in laboratory batch cultures are the basic

requirement for the scale up process. The open-air cultures with very different conditions need an entirely different approach with careful monitoring of agitation of culture, depth, nutrient and CO_2 supply, control of contamination, harvest frequency, drying, packaging and quality control. Major producers of *Spirulina* in the world are gradually increasing in the eastern part with China leading the production.

The decentralized small and medium scale operations in remote areas in South America, Africa and India for local populations as a nutritive supplement are also described with the modifications in pond design, manual mode of operation and use of fertilizers, effluents from food industries and extracts of crop wastes such as husk, bran etc. for cost reduction. Some suggestions are given for locating *Spirulina* production in coastal areas to facilitate the aquaculture industry.

MICRO ALGAE CULTURE AS LIVE FEED

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The early life stages of every cultivable organism in a hatchery system depend on the feed provided. Micro algae form the basic food for all the larval stages of crustaceans, molluscs, sea cucumber and finfishes. Even though, large number of micro algae is identified, only a few are used as live feed. Identification, isolation and the maintenance of stock culture and mass culture of required micro algae as feed is the prior task in every hatchery system. Moreover, the preference of the organisms varies with species and in its different stages of life cycle. Here, we try to discuss the present status, methods and protocols adopted for the production of micro algae as live feed, for the benefit of aquaculture.

ROLE OF DIATOMS IN MARINE BIOFOULING

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Diatoms are one of the early colonisers on surfaces submerged in the photic zone of the environment. Their colonisation on man made structures, termed biofouling, has enormous implications to the marine industry. The processes involved in biofouling and the role of diatoms is presented. The article also provides an over-view of the current and potential measures for the control of diatom fouling.

ALGAL- FUNGAL INTERACTIONS IN THE MARINE ECOSYSTEM: SYMBIOSIS TO PARASITISM

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A wide array of partnership exists between algae and fungi. These range form loose commensal association between algae and fungi as in primitive lichens, obligate symbiotic association termed mycophycobioses between the systemic marine fungi and the macroalgae, parasitism where the fungi are pathogens causing disease in the host and saprobic association where fungi grow on senescent to moribund algae. Among these, the fungal parasites are relatively fewer in number than those reported as parasites in

terrestrial plants and are limited in their geographical distribution due to their range of host specificity. Fungal pathogens of fresh water phytoplankton play an important role in governing their periodicity in lakes. However, we do not know whether this holds good for the marine environment too. Fungal pathogens associated with green, brown, red algae and phytoplankton around the coast of India are described here with an emphasis on different kinds of algal-fungal relationships. The observation on seasonal occurrence of a few fungal pathogens, host specificity and changes in physiology of host algae are discussed here.

STANDING STOCK OF SEAWEEDS ON INDIAN COAST

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Indian coastline stretches about 7,500 kms including Andaman and Nicobar Islands in Bay of Bengal and Lakshadweep Islands located in Arabian Sea. The quantity of the seaweeds reported by Scientists of Central Salt and Marine Chemicals Research Institute, Bhavnagar and others have been incorporated in the present article.

SEAWEEDS LANDING IN INDIA

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Luxuriant growth of seaweeds occurs in south Tamil Nadu coast, Gujarat coast, Lakshadweep and Andaman- Nicobar Islands. The total standing crop of seaweeds from intertidal and shallow waters of all maritime states and Lakshadweep island is estimated as 91,339 tonnes (wet wt). The seaweed resources in deep water of Tamilnadu are estimated as 75,372 tonnes (wet wt) in an area of 1863 sq km from Dhanushkodi to Kanyakumari. Data collected on the commercial exploitation of seaweeds from the natural seaweed beds of Tamil Nadu during 27 years from 1978 to 2004 showed that the quantity of agar yielding seaweeds *Gelidiella acerosa, Grcilaria edulis, G.crassa, G.foliifera* and *Gracilaria* spp varied from 248 to 1518 tonnes (dry wt) and alginophytes *Sargassum* spp, *Turbinaria* spp and *Cystoseira trinodis* from 651 to 5537 tonnes (dry wt) per year. The commercial harvest of seaweeds in Gulf of Mannar and Palk Bay is recommended only during the peak growth period of the algae from July to January every year. The harvest of commercially important seaweeds in a rational way from other parts of the Indian coast, Lakshadweep and Andaman-Nicobar Islands is suggested.

ENDANGERED AND EXTINCT SEAWEEDS OF INDIAN SHORES

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The limited surveys along the coast and the archipelagoes of India revealed rich diversity of the seaweeds. Currently the seaweed wealth has been affected in many areas due to exploitation, man made pollution and natural calamities. Some useful seaweed have been exploited from their natural habitats without taking proper conservation measures. At the present rate of exploitation, *Gelidiella acerosa* may become an endangered species. Long term monitoring for the occurrence of seaweeds in two localities revealed disappearance of twenty five species near Bandra and Colaba areas of Mumbai and fifteen seaweed species at Visakhapatnam. Three species viz. *Cladophora saracenica* Boergs., *Monosporus indicus* Boergs., *Myriogramme bombayensis* Boergs., reported only from their type localities in Mumbai, were not encountered in the subsequent surveys and therefore stand as presumably extinct seaweed species. The primary causes of seaweed species endangerment or extinction on the Indian shores are either degradation or destruction of the habitats and commercial exploitation. It is necessary to identify threats to the seaweed diversity of India and to develop its conservation strategies plans.

KEY TO THE TAXONOMIC IDENTIFICATION OF GREEN AND BROWN MARINE ALGAE OF INDIA

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A key to the order, families, genara and species belonging to the classes Chlorophyceae and Phaeophyceae is given. It is emphasized that for correct identification

of a taxon, it is not sufficient to follow the key but one should also verify the name derived by consulting full description in available literature. Two new soecies are validated by providing latin descriptions – *Dichotomosiphon salina* Untawale, Jagtap and Durgalkar and *Turbinaria indica* Gopalakrishnan.

KEY TO THE IDENTIFICATION OF INDIAN RED SEAWEEDS

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Keys for 129 genera and 338 species and varieties of red seaweeds growing along the Indian shores are given in this article for identification of different red algae.

ANNEXURE II

The review papers to be published in the

Recent Advances on Applied Aspects of Indian Marine Algae With Reference to Global Scenario- Volume 2

Application and Utilization, Food and Feed, Biotechnology, Chemistry, Drugs and Bioactive Substances, Environment

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PRESERVATION AND STORAGE OF SEAWEEDS FOR INDUSTRIAL UTILIZATION

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The review paper provides the comprehensive and detailed information on the thermal and non-thermal method of drying of industrially utilized seaweeds, their preservation by chemicals, ensilage as well as by cryogenic methods. The effect of preservation on the nutritional quality of seaweeds, biochemical quality of phycocolloids and their microbial degradation are described in detail. The paper also deals in length with the storage of seaweeds and changes in them during the course of storage.

CAROTENOIDS FROM *DUNALIELLA* -A JOURNEY FROM TEST-TUBE TO CUSTOMER

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Carotenoids, which are group of tetra terpenoids, are known for their role in humans contributing to provitamin – A activity, antioxidant property and other beneficial effects as prophylactic agents in various diseases. Deficiency of vitamin-A is one of the major concern especially in developing countries. In this regards there is increasing interest for enhancement of carotenoids intake through their enrichment in food

ingredients. Biotechnology as a tool to enrich carotenoids production is receiving attention as evident from the interest generated in golden rice. Micro algae are also rich sources of a range of carotenoids. Some of the well known micro algal forms which are important sources of carotenoids are, *Dunaliella*, *Spirulina* and *Heamatococcus*. Of them *Dunaliella* is known to accumulate high quantity of carotenoids as a response to various physical stress and it is used as commercial source of β- carotene in certain parts of the world. This is a compilation of the various facets of cultivation and utilization of *Dunaliella* for carotenoids production, which has definite advantages over other production systems. The industrial application of this organism has been highlighted.

PHYCOBILIPROTEINS FROM MICROALGAE

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Microalgae including Cyanobacteria are the largest primary producers in any aquatic ecosystem. Their metabolic functions have developed during the evolutionary process for adapting to diversified & extreme environments. With the development of marine biotechnology, microalgae from unique & extreme marine environments are attracting attention as a novel biological sources for superfine chemicals to be employed in varied applications of pharmaceuticals, neutraceuticals, cosmeceuticals, etc. where phycobiliproteins have an indispensable role to play. Due to the present day health awareness amongst the human beings, the gradual increase in demand of the natural / herbal products have rightly evaluated the treasure of our planet *Earth* i.e. *Microalgae.* Its

biotechnology encompasses the search, collection of marine microalgae, discovery of their unique structure & functions with genetic manipulation / metabolic engineering (if & where desired).

This chapter is just a glimpse of the huge realm of phycobiliproteins with a brief introduction of the natural pigments revealing the unravelled structures correlating their functional properties leading to the development of the technology for C-Phycocyanin with an integrated process.

MICROALGAE – A POTENT SOURCE OF BIOTECHNOLOGICAL PRODUCTS

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Microalgae occurs worldwide occupying different niches. Their photoautotrophic nature makes them more ecofriendly and economical in making microalgal biotechnology a reality. They hold great promise in agriculture and bioremediation. Some compounds serves as clinical diagnostics, pharma and nutraceuticals. Organisms serve as good sources of enzymes and antioxidants too. They also play a pivotal role in contributing to H_2, the renewable non-polluting fuel.

BIOSENSORS WITH CYANOBACTERIA AND ALGAE

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Biosensors-analytical devices incorporating a biological component and a physicochemical transducer- are able to detect different type of chemicals. Biosensors with algae and cyanobacteria play an increasing role in the field of environmental monitoring for the detection of pollutants such us herbicides (diuron, atrazine etc.,), heavy metals (Pb, Cu, Cd, Zn etc.,) or other inhibitors (formaldehyde , methanol or 2,4,6-trinitrotoluene, antimycin A). Moreover, cyanobacteria bioreporters- whole cells biosensors using reporters gens- can be used to monitor the bioavailable iron, nitrate or phosphate. Biosensors, including bioreporters, with algae and cyanobacteria can benefit form the revolution in Nanotechnology and could contribute to the efforts for a healthy and friendly environment, more accurate monitoring of biotechnological processes and a more decent life worldwide.

SEAWEEDS: AN EFFECTIVE ALTERNATIVE SOURCE AS A BIOFERTILIZER

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Seaweeds are large plants growing in the sea, especially various marine algae like the rockweeds, kelps, sea lettuce and dulses. They are used as dried or fresh or as a liquid extract by farmers, horticulturists, orchadists and gardeners as a fertilizer. Seaweed extracts are now available as Maxicrop, SM-3, Sea-sol, Kelpak, Algistim, Cytex, biozyme etc. The effect of seaweed extract as fertilizer is not only due to nitrogen, phosphorus and potash content but also because of the presence of trace elements and metabolites similar to plant growth regulators such as cytokinin, auxins and betaines

present in it . Seaweed extract is used mainly as a foliar spray, soil drenching, root and fruit immersions and also for soaking of the seeds prior to sowing. It enhances the germination of seeds and seedling growth, increases fresh and dry mass, increases biochemical constituents, improves uptake of plant nutrients, increase the yield and importantly protects the plants from fungal diseases. Not only this but seaweed extract is also effective for ripening of fruits, increasing shelf-life of produce, improving the quality of produce and also helps in maintaining the colour of some fruits. When applied to the soil, it serves as an excellent soil conditioner.

REMOTE SENSING FOR MARINE ALGAE

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Marine algae are extremely important for their role as primary producers, in regulating global carbon cycle, building calcareous banks and cementing coral reefs. Understanding the temporal and spatial distribution of marine algae is a vital component to study and manage the algal resources. Remote sensing technology has proved to be useful in providing this information. Oceansat-1 carrying Indian Remote Sensing (IRS) – P4 Ocean Colour Monitor (OCM) has been operational since July 1999 to quantitatively retrieve phytoplankton biomass concentration in Indian waters and study its dynamics on spatial and temporal time scales for various oceanographic and biological applications. Medium and High resolution IRS LISS III, RESOURSESAT-1 has helped in mapping

macro algal habitats, differentiation between seaweeds and other macro-algae, benthic micro and macro algae, etc., along the Indian coast. This paper gives an overview of the recent advances of remote sensing technology to monitor and manage the marine algal resources.

FOOD, NUTRITIONAL AND NUTRACEUTICAL QUALITY OF MARINE MACROALGAE

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A comprehensive and detailed information on food and nutritional value of marine macroalgae is presented. This includes their utilizaition as source of protein and amino acid, polysaccharide and dietary fiber, lipid and fatty acid, macro and micro non-metallic inorganic nutrient, metal, vitamin, polyphenol, carotenoid, quality standard, taste and odor, food color, toxicity, food safety and risk assessment. It also presents their nutraceutical and antioxidant qualities.

AGAR AND VALUE ADDITION OF INDIAN AGAROPHYTES

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Agar is a phycocolloid isolated from several red marine algae. It is a very useful gelling biopolymer of plant origin, which is obtained only from certain red seaweeds,

called agarophytes. Agar is a galactan polymer with average molecular weight ca. 10^5 D. Agar's application started as a gelling agent in foods. Later on it was extensively used in microbiological applications. Recent new applications harness its gelling property and hydrophilicity in microfluidic devices besides other applications involving agar and agarose composites.

CARRAGEENANS FROM INDIAN MARINE ALGAE

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The use of seaweeds for industrial purpose is gaining importance world over with bright prospects for future growth. Red seaweeds have received immense attention because economically important polysaccharides are obtained from them. Carrageenans are used commercially as thickening, suspending, gelling, emulsifying and stabilizing agents. They are extensively used as a food additive in dairy products. In the present article, extraction, isolation, identification and characterization of carrageenan from marine red algae have been reviewed. Literature survey of carrageenan yielding seaweeds, carrageenan, its properties, uses and methods of characterization have been described.

STANDARDS AND REFERENCE MATERIALS FOR MARINE ALGAE

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The need for development of increasing number of Standard Reference Materials is well recognized. The standardisation and related activities help in exchange of goods and services, initiating cooperation in spheres of intellectual, scientific, technological, economical activities. In general, it improves the quality of life. The present work deals with the existing standards and reference materials for marine algae in the international scenario, and also emphasizes the pressing need to develop standard reference materials for various useful parameters of Indian marine algae.

SECONDARY METABOLITES OF MARINE ALGAE OF THE INDIAN COAST – DEVELOPMENTS AND PROSPECTS

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Secondary metabolites of marine algae are intriguing in keeping with their unique position in the marine ecosystem. Several terpenes (mostly sesqui- and diterpenes), steroids, ceramides, heterocyclics, aromatic compounds and polyethers, many of them new and vested with biological activity are reported from species occurring along the Indian coasts. The contributions indicate, from both chemistry and biological activity points of view that their vast exploitable potential (along the Indian coasts) remains under explored. A case is made for intensifying efforts in this direction so that the ongoing search for drugs from sea is better rewarded.

BLOOD ANTICOAGULANTS FROM MARINE ALGAE

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Commonly used antithrombic drugs include heparin (animal source) and streptokinase (microbial source). Heparin has disadvantages like cumbersome isolation procedures, in homogeneity in structure and hemorrhagic side effects, whereas streptokinase is very expensive. Marine algae contain sulfated polysaccharides, novel biologically active substances not occurring in terrestrial plants. Due to structural similarities between algal sulfated polysaccharides and heparin, algal antithrombic agents hold a strong potential as a lead molecule. The key advantage of algal blood anticoagulant over heparin would be its availability from non-animal source. Anticoagulant activity of marine algae has been widely studied for the last 65 years. Sulfated polysaccharides, proteoglycans and proteins from Rhodophyceae, Phaeophyceae and Chlorophyceae are reported to have this property. Some of the active components have been chemically well characterized and efforts have been made to explain their mechanism of action. Sulfated galactans, sulfated fucans from red and brown algae respectively and arabinan and rhamnan sulfates, proteoglycans from green algae are the active molecular species identified. It has been reported that activity is related to molecular size, type of sugar, sulfate content, position of sulfation and type of linkages in the molecule. The proposed mechanisms of action are predominantly heparin cofactor-II mediated anti-thrombin activities, direct anti-thrombin action (thrombin-fibrinogen complex) and minor anti-thrombin III mediated anti-thrombin activities.

SEAWEED POLYSACCHARIDES, THEIR BIOACTIVITY AND VALUE ADDITION – THE INDIAN PERSPECTIVE

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The prominent seaweed polysaccharides are agar, carrageenan and alginates, which are of wide commercial importance. These are obtainable only from the seaweed resource, except for alginates which can also be produced from bacteria. Agar and carrageenans are obtained from red seaweeds (Rhodophyta), while the alginates are isolated from brown seaweeds (Phaeophyta). Agar and carrageenans are galactans, having 1, 3- and 1,4-linked D- & L- and D- & D-galactose repeating units respectively. Alginates are copolymers of D-mannuronic and L-guluronic acids. Water soluble polysaccharides have been reported to be bioactive. Partially reduced sulphated alginic acid has been reported to exhibit blood antithrombic acitivity, while sulphated polymannuronoguluronates isolated from marine brown alga have been reported to exhibit anti-AIDS activity. Besides these, there are other seaweed polysaccharides which are variously sulphated containing assorted sugar units. The latter may be gelling or non-gelling, and reported to have various bioactivities including blood anticoagulant and antiviral activities. In this account an overview is given on the water soluble polysaccharides of seaweeds with an accent on the sulphated ones. Glimpses on the work that has been done in this area in our laboratory to move these compounds up the value chain have also been presented in this article.

SEAWEED HEMAGGLUTININS

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Lectins are a very heterogenous group of proteins, classified on the basis of their capability to agglutinate cells. The term 'haemagglutinin' was introduced as a common name for all substances that exhibited this biological activity. When the important discovery was made that some haemagglutinin selectively agglutinated blood cells of a particular human blood group within the A, B, O blood group system, the novel term 'lectin' was introduced. At present, three terms viz. haemagglutinin, agglutinin and lectin are used to indicate the same group of proteins.

Lectins are being used in many areas of biological research. Search for new lectins from various sources has attracted the attention of the scientists in recent years as there are increasing applications of lectins in various areas of biological research. Though considerable progress has been made in understanding the biochemical characteristics of marine macro-algae (seaweeds), much less is known about their lectins. This means that utilization of algal lectins is not well understood as compared to the lectins obtained from other sources. However, in recent times, a good number of active algal species containing lectins have been found out due to the improvement in the detection methods.

MARINE ALGAL BIOMARKERS

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Biomarkers are organic compounds of biological origin that have enough of structural features by which they can be attributed to: (i) taxa that produced them, and (ii) the resident environmental conditions in a historical perspective. Marine algae are a fundamental source of marker compounds present in the three phases of the Sea viz., water column, suspended particles and bottom sediments. Biomarkers of particular use are tetrapyrrole and carotenoid pigments, fatty acids and hydrocarbons, steroids and triterpenoids, and more recently, long chain alkenones (LCAs). Biomarkers are helpful in the investigations of primary production, as contributed by different taxa, surface nutrient availability, sea surface temperature (SST), salinity, dissolved carbon dioxide, red-ox characteristics and pollution of the environment, provenance, thermogenicity and seismicity of the seafloor (sediments) etc. In the central Indian Ocean and Bay of Bengal, thermogenic areas are characterized by large concentrations of aromatic hydrocarbons. In the Indian Ocean and Arabian Sea, SSTs estimated from LCA indices are in coherence with those based on inorganic and biological proxies. This area of research is one of the intensely pursued topics globally, and there is immediate need of applying it to the unique Indian marginal Seas.

ENVIRONMENTAL IMPACT ASSESSMENT OF *KAPPAPHYCUS* CULTIVATION IN INDIA IN CONTEXT TO GLOBAL SCENERIO

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The environmental impact of *Kappaphycus alvarezii* commercial cultivation on the coastal environment of India is presented and discussed with reference to global scenario. The controversial issues like uncontrolled growth of alga, invasion through spores and fragmentation, damage to corals, depletion of nutrients and similar other things are discussed. The environmental impact assessment study in India has shown that commercial cultivation of this alga has many positive impacts and only a few negative impacts to the environment. The negative impacts could be mitigated by planned scientific farming including regular monitoring of environment. The detailed mitigation measures for negative impacts have been presented in this paper. It has also been emphasized that the impact of *Kappaphycus* farming will differ from environment to environment therefore, the negative impact in one environment may not be necessarily be noticed in another environment. It has been concluded that the commercial cultivation of *Kappaphycus alvarezii* is not harmful to the environment under Indian conditions. Similar is the case, in the South East Asian regions. However, in some limited parts of the world it has shown harmful effects.