SEAWEED : PROMISING PLANT OF THE MILLENNIUM

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Seaweeds, one of the important marine living resources could be termed as the futuristically promising plants. These plants have been a source of food, feed and medicine in the orient as well as in the west, since ancient times. Although, seaweeds in India are used for industrial production of agar and alginate and as a fertilizer, it is yet to be utilized on a large scale for various purposes, which is not being done, due to lack of its awareness among the Indian populace.

In order to harness the rich potential of seaweeds in India, the present limited use needs to be diversified into other contemporary areas of application. Being a plant of unique structure and biochemical composition, seaweed could be exploited for its multi-functional properties in the form of food, energy, medicine and consmetics. In addition to the comprehensive view on its uses, the article also calls for the need to implement biotechnological tools for sustainable management of seaweed resources. All in all, an attempt has been made to highlight the prospects of seaweed in India in the modern context.

IN THE VAST ocean realm, several forms of life, starting from unicellular to multi-cellular flourish, multiply and disintegrate. It is believed that the first living cell that appeared on the planet Earth emerged from the ocean. In all its form, the life has developed from the growth of mono-cellular algae. About 90% of the species of marine plants are algae and about 50% of the global photosynthesis is algal derived'. Thus, every second molecule of oxygen we inhale comes from algae and algae reuse every second molecule of carbon dioxide we exhale[2].

The tapping of solar energy by land plants have been considerably reduced due to the change in land use pattern, agriculture, degraded forests and pollution. The oceans provide unlimited space for capturing solar energy by marine plants through photosynthesis. Marine plants comprise of algae, sea grasses, mangroves and sand dune vegetation. The algae are of different shapes and sizes. The microscopic algae are known as phytoplankton and macroscopic ones as seaweeds.

Most people come in contact with seaweeds that are washed ashore by the in coming tides. Seaweeds grow in the intertidal as well as in the subtidal area up to a certain depth where 0.1% photosynthetic light is available. They are one of the ecologically and economically important living resources of the world oceans. Being the oldest family of plants on earth, they have admirable qualities of being flexible, tenacious and prolific. They are continuously bathed in nutrient rich seawater; therefore, they absorb high level of nutrients and thus form important source of food, feed, fertilizer and chemicals (Table 1).

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Seaweed as a Dietary Supplement/ Source of Nutrition

Most people unknowingly utilize seaweed products daily in the form of processed food items like processed dairy, meat and fruit products and domestic commodities like paint, toothpaste, solid air fresheners, cosmetics, etc. Seaweeds are excellent source of vitamins A, B1, B12, C, D & E, riboflavin, niacin, pantothanic acid and folic acid[3,4] as well as minerals such as Ca, P, Na, K (Table 2). Their amino acid content is well balanced and contains all or most of the essential amino acids needed for life and health. They have more than 54 trace elements required for human body's physiological functions in quantities greatly exceeding vegetables and other land plants[5]. These

TABLE 1. Some of the common uses of seaweed species.

Sr. No.	Species	Food	Feed	Industrial uses	Medicine	Fertiliser
1.	*Ulva fasciata*	+	+	-	+	-
2.	*Enteromorpha compressa*	+	+	-	+	-
3.	*Monostroma oxyspermum*	+	+	-	-	-
4.	*Cladophora fascicularis*	+	+	-	-	-
5.	*Chaetomorpha media*	+	+	-	-	+
6.	*Codium fragile*	+	+	-	+	-
7.	*Caulerpa sertularioides*	+	+	-	-	-
8.	*Dictyota dichotoma*	+	+	+	-	-
9.	*Spatoglossum asperum*	-	-	+	-	+
10.	*Hydroclathrus clathratus*	-	-	+	-	+
11.	*Stoechospermum marginatum*	-	-	+	-	+
12.	*Colpomenia sinuosa*	-	-	+	-	+
13.	*Dictyopteris australis*	-	-	+	-	+
14.	*Padina tetrastromatica*	-	-	+	-	+
15.	*Sargassum cinereum*	-	-	+	+	+
16.	*Sargassum ilicifolium*	-	+	+	+	+
17.	*Laminaria digita*	-	-	+	+	
18.	*Macrocystis pyrifera*	-	-	+	+	+
19.	*Porphyra vietnamensis*	+	+	-	-	-
20.	*Amphiroa fragilissima*	+	-	-	-	-
21.	*Jania adhaerens*	-	-	-	+	-
22.	*Gracillaria corticata*	+	+	+	-	-
23.	*Hypnea musciformis*	+	+	+	-	-
24.	*Centroceros clavulatum*	+	-	+	-	-
25.	*Laurencia papillosa*	+	+	+	-	+
26.	*Chondrus crispus*	+	-	+	-	-
27.	*Eucheuma uncinatum*	+	+	+	-	-
28.	*Gelidiella acerosa*	-	-	+	-	-

Source : Compiled from published reports.

TABLE 2. Nutritive values of some Seaweed species (in %).

Seaweed Species	Protein	Lipid	Carbohydrates	Ash
Ulva	26.1	2.1	42.0	7.8
Enteromorpha	19.5	0.3	64.9	15.2
Monostroma	20.0	1.2	63.9	14.9
Laminaria	16.1	2.4	39.3	19.6
Alaria	17.1	3.6	39.8	14.9
Sargassum	19.0	2.9	33.0	16.2
Padina	18.81	1.7	31.6	10.3
Porphyra	28.4	4.5	45.1	6.9
Rhodymenia	21.5	1.7	44.6	5.3
Gracilaria	24.37	1.8	61.75	11.3

Source : Compiled from Published Reports.

essential elements are in chelated, colloidal, optimally balanced form hence they are bio-available.

The importance of seaweeds for human consumption is well known since 300 BC in China and Japan. These two countries are the major seaweed cultivators, producers and consumers in the world. In the Indian Ocean region countries like Malaysia, Indonesia, Singapore, Thailand, Korea etc., seaweeds are used in salad, jelly, soup etc. In India, however, seaweed consumption is negligible except in the preparation of porridge from *Gracilaria* sp. and *Acanthophora* sp. in coastal states of Kerala and Tamil Nadu.

Source of Lucrative Colloids and its uses

The three major commercial phycocolloids extracted from seaweeds are agaragar and carrageenan derived from red seaweeds such as *Gelidiella, Gracilaria, Chondrus, Hypnea* etc. and alginate from brown seaweeds like *Ascophyllum, Laminaria, Turbinaria, Sargassum* etc. These products are difficult to synthesize chemically because of the formidable chemical barriers and hence for these commercially important products we have to depend on seaweed resources. The total seaweed production of the world in the year 2000 was 7.9 million metric tones. Out of which, 6.8 million metric tones come from cultivated area of 200 x 10^3 hectares[6]. Indian Ocean region contributes about 870,000 metric tones.

The total harvest from Indian coast is about 100,000 metric tones (wet weight) (Table 3). Out of which, small-scale industrial units utilize 35 to 40% of the seaweed raw material for extraction of phycocolloids. From the remaining quantity, very little is facing closure due to non-availability of quality seaweed raw material. Since the demand for phycocolloids in the Indian market is much high'er than what is produced, the Indian market has to import these

TABLE 3. Seaweed resources along the Indian coast.

Sr.No.	Area	Annual Yield in Tonnes (fresh wt.)	Author(s)
1.	GUJARAT		
	(a) Gulf of Kuchchh	100,000	Chauhan & Krishnamurthy (1968)
	(b) Hanumandandi to	19,000	Bhandari & Trivedi (1975)
	Vumani (Okha)	650	
	(c) Adatra Reef	60	Sreenivasa Rao et. al (1964)
	(d) Saurashtra Coast	282-608	Chauhan & Mairh (1978)
2.	MAHARASHTRA		
	(a) Konkan Coast	315	Chauhan (1977)
	(b) Entire Coast	20,000	Untawale et. al. (1979)
3.	GOA	2,000	Dhargalkar (1981)
4.	KARNATAKA		Untawale & Agadi (1981)
	(a) Entire Coast	negligible	
5.	KERALA	negligible	Nair et. al. (1982)
6.	TAMILNADU		
	(a) Cape Comorin to Colachel	5	Koshy & John (1948)
	(b) Calimere to Cape Comorin	66,000	Chacko & Malu Pillai (1958)
	(c) Pamban	1,000	Varma & Rao (1964)
	(d) Palk Bay	900	Umamaheshwara Rao (1968)
	(e) South East Coast	20,535	Subbaramiah et. al. (1977)
	(f) Entire Coast	22,044	Subbaramiah et. al. (1979)
7.	ANDHRA PRADESH	Figures not available	
8.	ORRISA		
	(a) Chilka Lake	5	Mitra (1946)
9.	LAKSHWADEEP ISLANDS	3,645 to 7,598	Subbaramiah et. al. (1979)
10.	ANDAMAN & NICOBAR ISLANDS		
	(a) Little Andaman	120	Gopinathan and Panigrahy (1983)

Source : Compiled from Published Reports.

phycocolloids from countries like Norway, Scotland, Chile, France, Spain, China, Japan, and The Philippines etc.

The uses of seaweed phycocolloids as emulsifier in dairy products, leather, textile and pharmaceutical industries have been well recognized (Table 4). Radioactive strontium 90 from the body along with radioactive barium, radium and other radioactive isotope as well as heavy metal poisoning can be effectively treated by sodium alginates. Alginates of seaweeds have a soothing and cleansing effect on the digestive tract in humans[8]. Sulphated polysaccharides from seaweeds have been used in the films that are placed between the bones to be grafted in order to accelerate the growth of the connective tissue. The combination of hydrocolloid dressing and alginate compress was found to have significant advantages as regards conditioning the exposed bone surface[9]. The polysaccharides are also used to treat arthritis as they are active in promoting and aiding the healing process of the body. The recent application of polysaccharide for the immobilization of biological catalyst in the industrial processes is one of the greatest prospects in modern biotechnology[10].

Renewable energy supplier

Remaining unused seaweed biomass can be utilized for the production of biogas through anaerobic digestion to methane[11]. Anaerobic digestion of biomass has been practiced for almost a century and is very popular in many developing countries such as China and India. The biogas is a reasonably clean burning fuel, which can be captured and put to many different end uses such as cooking, heating or electricity generation. Biomass currently supplies 14% of the world's energy needs. Most present day production and use of biomass for energy is carried out in a very unsustainable manner resulting in a great many negative environmental consequences. If biomass is to supply a greater proportion of the world's energy needs in future, the challenge will be to tap Various resources and to produce biomass sustainably. Technologies and processes available today will make biomass-based fuels eco-friendly unlike fossil fuels.

Food supplement for farm animals

Seaweeds can also be used to prepare seaweed meals as supplementary to the daily ration of the cattle, poultry

TABLE 4. Uses of Seaweed Phycocolloids.

Uses	Product	Function	Phycocolloid
Food Additives	Dairy Products	Gelation, foaming, suspension.	Agar, Carrageenan
	Baked food	Improving, quality, controlling moisture	Agar, Carrageenan
	Sweets	Gelation, increase viscosity, suspension	Agar, Carrageenan
	Juices and Sauces	Viscosity, emulsifier	Agar, Carrageenam
	Breweries	stabiliser	Alginate, Carrageenan
	Processed meat	Adhesion	Alginate
	Frozen Fish	Adhesion and moisture retention	Alginate
Medicinal-pharmaceutical	Tablets	Encapsulation	Alginate/Carrageenan
	Laxatives	Indigestibility &	Alginate- Carrageenan
		lubrication	Alginate
	Dental mould	Form retention	Alginate
	Metal poisoning	Binds metal	Carrageenan
	Herpes Simplex virus	Inhibit virus	Alginate
Cosmetics	Shampoos	Interface vitalisation	Alginate
	Toothpaste	Increases viscosity	Carrageenan-
	Lotions	Emulsification, elasticity & firmness to skin	Alginate Alginate
	Lipstick	Emulsification, viscosity	
Other Industrials uses	Paints	Viscosity and suspension Glazing	Alginate
	Thread making	Viscosity	Alginate
	Textiles	Sizing and glazing	Agar, Carrageenan,
	Paper making		Alginate
		Viscosity and thickening	Agar, Carrageenan,
	Adhesives and starch	Suspension	
		Coking	Alginate
	Pottery		Alginate
	Casting and welding rods	Chemical reactivity	
Chemicals	Analytical separation and purification of base.	Gelling	Carrageenan- Alginate
	Bacteriological media	Gelling	Agar
	Electrophoresis gel		Agar-carrageenan

Source : Compiled from Published Reports.

and other farm animals. It has been established that seaweed meal increases fertility and birth rate of animals and also improves yolk colour in eggs[12]. The meal prepared from *Gracilaria, Gelidiella, Hypnea* and *Sargassum* is added as feed ingredients for making compounded feed for fish and prawn culture. The feed helps in maintaining water quality in aquaculture and has more palatability enriched with minerals, amino acids and carbohydrates[7]. Besides its use as a feed, seaweeds can also be employed as water purifier, as it recycles the fish-waste polluted water in aquaculture.

Seaweed as an eco-friendly / Organic manure

An adequate amount of potassium, nitrogen, growth promoting hormones, micronutrients, humic acids etc. present in seaweeds make it as excellent fertilizer. Unlike chemical fertilizer, fertilizers derived from seaweeds *(Fucus, Laminaria, Ascophyllum, Sargassum* etc.) are biodegradable, non-toxic, non-polluting and non-hazardous to human, animals and birds. Chemical fertilizers have degraded the fertility of the soil by making it acidic, rendering it unsuitable for raising crops. Farmers, althroughout the world are switching over to organic

fertilizers. Seaweed manure besides increasing the soil fertility increases the moisture holding capacity and supplies adequate trace metals thereby improving the soil structure. This explains its worldwide use as manure along the coastal areas.

Recently adopted technique, of spraying fertilizer on the plants has increased nutrient absorption efficiency in the plants. The nutrients are not leached down in to the soil but are available to the plant through leaf openings such as lenticels, hydathods and stomata. Leaves absorb nutrients within 10 to 15 minutes of its application. Many brands of seaweed liquid fertilizers like Maxicrop (UK), Kelpak 66 (South Africa), Seagrow (New Zealand), Algifert (Norway), Plantozyme, Shaktizyme (India) etc. are available in the market. The diluted extract when sprayed on plants, show beneficial results in terms of health of plants, increase in rate of growth, resistance to pests, higher yield of 25 to 30% etc.[13]. The concept of spraying fertilizer on plants is gaining importance and many firms in India are coming forward to prepare seaweed bio-fertilizers. Technical know-how on seaweed bio-fertilizer is available with National Institute of Oceanography, Goa Central Salt Marine Chemical Research Institute, Bhavnagar, Gujarat and other industries working on seaweeds for commercialization.

Therapeutic health booster

Good health is the essence of life. History reveals that maritime countries have been using seaweeds as vermifuge, anesthetic and ointment as well as for the treatment of cough, wounds, gout, goiter, veneral disease etc. Sailors have been treating wounds for last several years with seaweeds. Sterols and related compounds present in seaweeds have an ability to lower blood plasma cholesterol level.

Seaweed dietary fibers perform varied range of functions such as anti-oxidant, anti-mutagenic, anticoagulant, anti-tumor etc. It also plays an important role in modification of lipid metabolism in the human body. High intake of calcium, potassium and sodium are associated with lower mean systolic pressure and lower risk of hypertension. All seaweeds offer an extraordinary level of potassium that is very similar to our natural plasma level. Worldwide research indicated that seaweed extract is similar to human blood plasma. Two Japanese surgeons used a novel technique of mixing seaweed compounds with water to substitute whole blood in transfusion and this was successfully tried in over 100 operations.

Seaweeds are best natural food source of bimolecular dietary iodine. Some seaweeds contain 1000 times as much iodine as cod, as average iodine containing fish. Seaweed provides di-iodotyrosin (DIT) which is precursor to forming the essential thyroid hormones, Thyrosin (T_4) and Tri-iodothyronine (T_3). The hormones produced by the thyroid gland regulate body metabolism. It also accelerates cellular reaction, increases oxygen consumption, influence growth and development, energy metabolism and protein synthesis[14]. It is a key factor in the control and prevention of many endocrine deficiency conditions such as breast and uterine fibroids, tumors, prostrate inflammation and toxic liver and kidney states. A study was carried out to demonstrate industrial feasibility of a naturally iodized salt, using seaweed ingredient as a source of iodine. The results indicated that the level of iodine in seaweed ingredient is constant, consumer acceptance is good, and clinical studies showed equal bioavailability of iodine[15].

Although, the use of seaweeds in medicine is not as wide spread as it once was, the use of seaweed polymer extract in pharmacy, medicine and biochemistry is well established. Clinical trials are also in progress to make diabetic patients injection free by injecting small insulin secreting "jelly capsule" made of seaweed alginic acid[16]. The capsule renders protection from white blood cells and the patient's immune system.

Beauty Enhancer

An astonishing similarity between human skin tissue and algal cellular structure has helped to solve numerous cosmetic and dietetic problems. Presently, seaweeds have become a key ingredient in cosmetic products such as soaps, shampoos, powders, creams and sprays. France and UK make extensive use of seaweeds in cosmetic products. A manufacturer of the skin products has found seaweeds to be naturally revitalizings, moisturizing and comprising of amino acids, minerals and vitamins that nourish the skin. Extracts of brown seaweed like *Fucus* spp. are used in thalassotherapy, a massage therapy, which eliminates impurities from the body and simultaneously balances the pH of the skin. Some seaweed possesses molecules similar to that of collagen, a substance that gives skin elasticity and firmness. Due to its therapeutic properties, seaweeds and other marine products have become natural alternative to the chemical based cosmetics.

A Need for Awareness

In the Indian context, seaweeds are not used that extensively except for extraction of phycocolloids, however, there exists great potential. Firstly, we should look for popularizing seaweeds as health food because they are

rich and easily available source of vitamins, minerals and trace elements for poor people. This will help to feed under nourished people in India. In this regards, research institutes / agencies and private entrepreneurs should come forward with scientific and technical knowledge and marketing expertise. The value added product is emerging recently as an area of high growth, wherein a small amount of seaweed material that produces high quality product, needs to be manufactured.

Secondly, use of seaweeds in recuperating the human body from various ailments needs to be emphasized. Inspite of the fact that many government institutes, agencies and private entrepreneurs are screening seaweeds and other marine organisms for drugs, we have not yet made any substantial seaweeds and other marine organisms for drugs, we have not yet made any substantial breakthrough in this field. Preliminary clinical trials have shown the effectiveness of seaweeds on human hleath. There exist great potential for developing drugs to treat cancer, AIDS and other diseases that are killing thousands of people every year[17,18]. A concentrated effort is required in this direction because seaweeds offer great promise.

Thirdly, India needs to take a cue from the western and oriental countries in harnessing the 'cosmetic 'potential of seaweeds. Of late, the burgeoning beauty consciousness among the Indian populace has given a terrific boost to the cosmetic industry. Use of seaweeds, a natural beauty aid, in manufacture of "herbal" cosmetics, could prove to be a great boon to these industries. Some of the Indian seaweed species are already being exploited for the same.

Biotechnological Perspective

All these and many other uses of seaweeds will demand continuous supply of good quality seaweeds raw material. To meet this challenge, it is required to develop an appropriate cultivation technology, suited to Indian conditions that must have a blend of traditional knowledge and modern biotechnological tools. Recent bio-technological methods such as tissue culture, protoplast fusion, genetic engineering etc. are being employed to produce genetically altered and improved strains with faster growth rate, altered phycocolloid composition and high yield. Japan, China and some South East Asian countries have mastered seaweed cultivation technique for commercial exploitation. However, in India no commercial cultivation is being done, except for the cultivation of carrageenan yielding seaweeds, *Eucheuma* and *Kappaphycus* spp. have been introduced for cultivation in Mandapam, Tamil Nadu, introduction of new species, alien to Indian waters and newly constructed strains to a specific environment warrants impact assessment studies.

The above mentioned steps will be a precursor to sustainable development of ocean resources, as mankind will have to depend on them for their livelihood in near future. It is envisaged that, the industries based on seaweeds have the potential to contribute to the socio-economic upliftment of the coastal inhabitants. The incredible number of uses that have been documented, has surprised many researchers as well as the specialist involved, serves to underline the importance of seaweeds in today's world. No doubt that seaweed is one of the most fascinating, mysterious and complex living resource of the oceans and we still need to unveil many things from these wonder weeds. Many uses of seaweeds are published and many of the records are in specialized journals that are not accessible to the common man. This article is aimed at giving an over all view of these wonder weeds.

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