Seaweed Mariculture: Scope And Potential In India

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Seaweeds are macrophytic algae, a primitive type of plants lacking true roots, stems and leaves. Most seaweeds belong to one of three divisions - the Chlorophyta (green algae), the Phaeophyta (brown algae) and the Rhodophyta (red algae). There are about 900 species of green seaweed, 4000 red species and 1500 brown species found in nature[1]. The greatest variety of red seaweeds is found in subtropical and tropical waters, while brown seaweeds are more common in cooler, temperate waters.

Economic importance

Some 221 species of seaweed are utilized commercially. Of these, about 145 species are used for food and 110 species for phycocolloid production (eg. agar). Seaweed has been a staple food in Japan and China for a very long time. The green seaweeds *Enteromorpha*, *Ulva*, *Caulerpa* and *Codium* are utilized exclusively as source of food. These are often eaten as fresh salads or cooked as vegetables along with rice. *Porphyra* (Nori), *Laminaria* (Kombu) and *Undaria* (Wakame) are used for making fish and meat dishes as well as soups and accompaniments.

Agar-agar, agarose and carrageenan are commercially valuable substances extracted from red seaweeds and find extensive use in many industries. The greatest use of agar is in association with food preparation and in the pharmaceutical industry as a laxative or as an outer cover of capsules. With the advent of modern molecular biology and genetic engineering, agar gums producing an 'agarose' factor are used extensively in electrophoresis in most laboratories around the world. Carrageenans are generally employed for their physical functions in gelation (include for example, foods such as ice cream), viscous behavior, stabilization of emulsions, suspensions and foams, and control of crystal growth[2].

Chemicals from brown seaweeds such as alginic acid, mannitol, laminarin, fucoidin and iodine have been extracted successfully on a commercial basis. As the alginates can absorb many times their own weight of water, have a wide range of viscocity, can readily form gels and are non-toxic, they have countless uses in the manufacture of pharmaceuticals, cosmetic creams, paper and cardboard, and processed foods.

Being rich in minerals, vitamins, trace elements and bioactive substances, seaweeds are called medical food of the 21st century. *Digenea* (Rhodophyta) produces an effective vermifuge (kainic acid). *Laminaria* and *Sargassum* species have 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. Research is now being carried out into using *Undaria* extract to treat breast cancer and HIV. Another red alga *Ptilota* sp. produces a protein (a lectin) that preferentially agglutinates human B-type erythrocytes in vitro. Some calcareous species of *Corallina* have been used in bone-replacement therapy[3]. *Asparagopsis taxiformes* and *Sarconema* sp. are used to control and cure goiter while heparin, a seaweed extract, is used in cardiovascular surgery.

Global seaweed production and trade

Currently there are 42 countries in the world with reports of commercial seaweed activity. China holds first rank in seaweed production, with *Laminaria* sp. accounting for most of its production, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. These top ten countries contribute about 95 % of the world's commercial seaweed volume. About 90 % seaweed production comes from culture based practices. The most cultivated seaweed is the kelp *Laminaria japonica*, which alone accounts for over 60 % of the total cultured seaweed production while *Porphyra*, *Kappaphycus*, *Undaria*, *Eucheuma* and *Gracilaria* make up most of the rest to a total of 99 %. The most valuable crop is the red alga Nori (*Porphyra* species, mainly *Porphyra yezzoensis*), used as food in Japan, China and Pacific.

According to FAO[4], between 1981 and 2000, world production of aquatic plants increased from 3.2 million tons to nearly 10.1 million tons (wet weight), upholding US $ 6 billion world trade in 2000, compared to US $ 250 million trade in 1990. The contribution of cultured seaweeds is 15 % of total global aquaculture volume (45,715,559 tons) or nearly 5 % of total volume of world fisheries production (141,798,778 tons) for 2000. The seaweeds that are most exploited for culture are the brown algae with 4,906,280 tons (71 % of total production) followed by the red algae (1,927,917 tons) and a small amount of green algae (33,700 tons).

East and South-East Asian countries contribute almost 99 % cultured production, with half of the production (3 million tons) supplied by China. Most output is used domestically for food, but there is a growing international trade. The *Porphyra* cultivation in Japan is the biggest seaweed industry, with a turnover of more than US $1.8 billion per annum. Total EU imports of seaweed in 2001 amounted to 61,000 metric tons with the Philippines, Chile and Indonesia as the biggest suppliers. Significant quantities of Eucheuma are exported by the Philippines, Tanzania and Indonesia to USA, Denmark and Japan. The

Table 1: Different edible seaweeds with their local names

Species	Type	Country	Local name/product
Laminaria	Brown	Japan	Kombu
		China	Hai Dai
Porphyra	Red	Japan	Nori / Amanori / Hoshinori
		China	Zicai
		Korea	Kim
		UK (Wales)	Purple laver / Laver bread
Undaria stipes *Undaria pinnatifida*	Brown	Japan	Wakame
		China	Quindai cai
Rhodymenia palmata *Palmaria palmata*	Red	Scotland	Dulse
		Ireland	Dillisk
		Iceland	Sol
Chondrus crispus	Red	Europe	Irish Moss / Carraghean
Asparogopsis taxiformis	Red	Hawaii	Limu kohu
Misc. sp.	-	Hawaii	Limu

Philippines accounts for nearly 80 % of the world's total *Eucheuma cottonii* production of 1,30,000 tons, roughly 35 % of which is traded in dried form. It supply 14 % of the world's total raw seaweed production and holds first rank as producers of semi-refined carrageenan, contributing close to 60 % of the world market.

Seaweed resources of India

Seaweeds grow abundantly along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman and Nicobar islands. There are also rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu and Chilka in Orissa[5]. Out of approximately 700 species of marine algae found in both inter-tidal and deep water regions of the Indian coast, nearly 60 species are commercially important. Agar yielding red seaweeds such as Gelidiella acerosa and Gracilaria sp. are collected throughout the year while algin yielding brown algae such as *Sargassum* and *Turbinaria* are collected seasonally from August to January on Southern coast. A standing crop of 16,000 tons of *Sargassum* and *Turbinaria* has been reported from Indian waters[6].

The surveys carried out by Central Salt and Marine and Chemical Research Institute (CSMCRI), Central Marine Fisheries Research Institute (CMFRI) and other research organizations have revealed vast seaweed resources along the coastal belts of South India. On the West Coast, especially in the state of Gujarat, abundant seaweed resources are present on the intertidal and subtidal regions7. These resources have great potential for the development of seaweed-based industries in India.

Seaweed industry in India

The seaweed industry in India is mainly a cottage industry and is based only on the natural stock of agar-yielding red seaweeds, such as *Gelidiella acerosa* and *Gracilaria edulis*, and algin yielding brown seaweeds species such as *Sargassum* and *Tubineria*[6]. The production of total seaweeds in India in 2000 was approximately 600,000 tons (wet weight). India produces 110-132 tons of dry agar annually utilizing about 880-1100 tons of dry agarophytes. Annual algin production is 360 to 540 tons from 3,600 to 5,400 tons dry alginophytes.

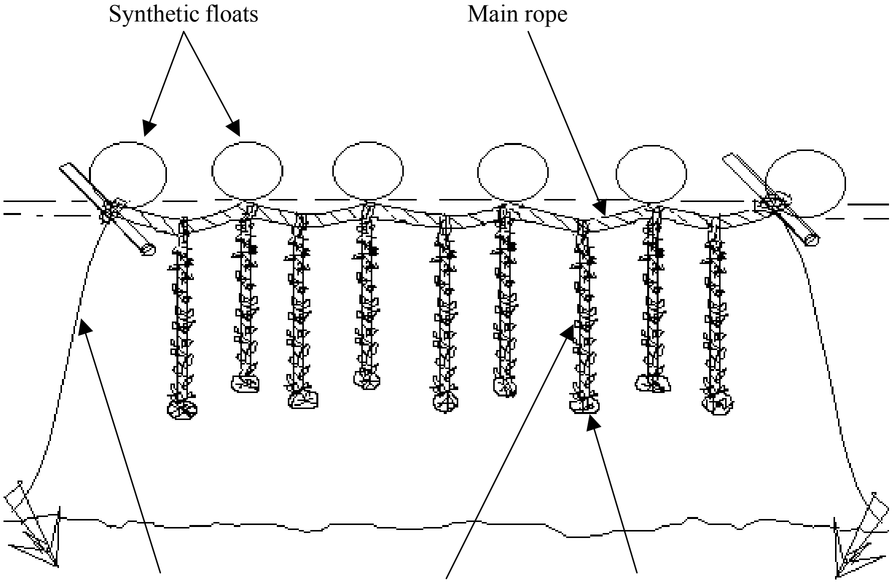
Perhaps, the first large scale commercial cultivation of seaweeds in India has been embarked upon by Pepsi Foods Ltd. (PFL) along a 10 km stretch of the Palk Bay side towards Mandapam (Ramanathapuram Dist.) in Tamil Nadu, with technical support from Marine Algal Research Center, CSMCRI, Mandapam. They have started cultivating *Eucheuma cottoni* and *Hypnea musciformis* in an area of 100 hectares through a contract farming system in which seaweeds are grown in individual plots of 0.25 ha (40 m x 60 m). Each harvest cycle from planting to harvesting takes 45 days with an annual yield of 100 tons (wet weight) per hectare, which translates into 10 tons of dry seaweed or 2.5-3 tons of carrageenan. The company has plans to expand culture operations to over 5,000 to 10,000 ha in the near future. Furthermore, many agar and algin extracting industries have been established in different places in maritime states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Gujarat the seaweed industry is certainly on its way towards establishing itself well in India.

Seaweed mariculture

Large-scale seaweed mariculture is carried out only in Asia, where there is a high demand for seaweed products and burgeoning populations to create market growth. Cultivation of seaweeds in Asia is a relatively low-technology business in that the whole, attached plants are placed in the sea and there is a high labor content in the operation. Except for the large kelp harvesters of Southern California and Baja California or in Philippines and Taiwan Province of China, most seaweed are grown or harvested from wild stocks using manual techniques.

The demand from the phycocolloid industry of India is great but the present production from natural habitats is very low and insufficient to cater to the needs of the local industry. This gap between the demand and supply can be bridged through mariculture practices for seaweeds by cultivating the useful species on commercial scale. Continuous supply, improved yield and quality as well as conservation of natural seaweeds beds are some of the important advantages of seaweed mariculture.

Figure 1: Single Rope Floating Raft culture technique



The main culture methods involve either vegetative propagation using fragments from mother plants or by different kinds of spores such as zoospores, monospores, tetraspores and carpospores. Kelps (brown algae) cannot be grown from fragments as there is a high level of specialization and fragments of sporophytes do not regenerate whereas the agarophyte cultivation can be done by vegetable propagation starting from fragments. Fragments of adult plants, juvenile plants, sporelings or spores are seeded onto ropes or other substrata and the plants grown to maturity in the sea.

Amongst the many culture techniques, the Single Rope Floating Raft (SRFR) technique developed by CSMCRI is suitable for culturing seaweeds in wide area and greater depth (fig. 1). A long polypropylene rope of 10 mm diameter is attached to 2 wooden stakes with 2 synthetic fiber anchor cables and kept afloat with synthetic floats. The length of the cable is twice the depth of the sea (3 to 4 m). Each raft is kept afloat by means of 25-30 floats. The cultivation rope (1 m long x 6 m diameter polypropylene) is hung with the floating rope. A stone is attached to the lower end of the cultivation rope to keep it in a vertical position. Generally 10 fragments of Gracilaria edulis are inserted on each rope. The distance between two rafts is kept at 2 m. Floating raft technology has been recommended to be used on the Kerala coast for agarophyte cultivation[8]. Certain areas in the Gulf of Kutch have been suggested as suitable for deep-water seaweed cultivation[7]. In addition, CMFRI has developed and perfected techniques for culturing *Gelidiella acerosa*, *Gracilaria edulis*, *Hypnea musciformis* and *Acanthophora spicifera*, and now attempts are being made to find improved techniques for propagation and large scale culture of other economically important seaweeds.

Problems and Prospects

The major problems in the seaweed industry include overexploitation leading to a scarcity of raw material, poor quality raw material, labor shortages during the paddy harvesting and transplanting season, lack of technology to improve processed product quality, and a lack of information on new and alternative sources of raw materials.

Despite the great number of sheltered bays and lagoons suitable for mariculture, no large-scale attempts to grow seaweed have been made in India so far. Efforts are needed to increase production through improving harvesting techniques, removal of competing species, creation of artificial habitats and seeding of cleared areas. As the technology for reliable methods for the cultivation of different commercially important seedstocks and their improvement has either already been developed or presently being in research, it needs to be disseminated effectively to the target community. Extensive surveys need to be conducted to identify suitable sites for large-scale seaweed culture.

There is great potential for the agarophyte cultivation because of its low availability from the wild stock due to over-exploitation. Many edible seaweed species are available on the Indian coast; attempts should be made to develop products suitable for the Indian palate and to popularize the same amongst the public. With regard to pharmaceutical substances, heparin analogues (heparinoids) that are inhibitory to thrombin activities have been reported from Chlorophyta of Indian coasts[9]; this and many other important types of seaweed are available on Indian coast that can be utilized for production of many important pharmaceutical products through extraction of bioactive compounds.

Attention should also be given towards developing hybrid species with superior growth and nutritional characteristics, as the same has been proved successful in countries like Japan. Rather opting for high-volume-low-value seaweeds, culture of high-value seaweeds should be aimed for, as part of integrated coastal and national development programmes[10].

Seaweed polyculture in association with molluscs and fishes seems to have good prospects to increase harvest and profits. Pond and canal culture of seaweeds (e.g. *Gracilaria*) in shrimp farming areas can help to treat the effluent water. The problem of eutrophication of culture ponds due to overfeeding and excreta released by fish/shrimp can be tackled by culturing seaweeds in such ponds.

Out of estimated around US $ 3 billion global phycocolloid and biochemical business, India's share is meager. We can surely grab a bigger part in this lucrative business with sincere efforts towards large-scale cultivation of commercially important species and processing. To facilitate this, more technologically sophisticated extraction plants with easy access to markets and marketing organizations need to be established nearby cultivation areas to utilize the resources efficiently with greater profits.

Since it requires low inputs, and provides good returns and can employ many people seaweed culture is a good industry for coastal communities. The efforts in seaweed cultivation and its utilization through product and process development could help in meeting the food and nutritional security of Indian population as well as augmenting value of total fisheries export. Seaweed has a very important role to play towards betterment of coastal fishing communities and as a valuable foreign exchange earner. The need of the present hour is to train, encourage and promote coastal fishermen population at suitable sites, through combined efforts of respective State Governments, research institutes, seaweed industry, Marine Products Export Development Authority and local NGOs, to adopt commercially viable large-scale culture technologies, and to provide them with good marketing facilities through proper channels.

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Shrimp harvesting technology on the south west coast of Bangladesh

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Shrimp farming is an ancient traditional practice along the southwest coast of Bangladesh. This kind of farming is a natural rearing process in its simplest form. The main species grown are the black tiger shrimp *Penaeus monodon* along with other finfish as by-catch.

The ownership patterns of extensive shrimp farming systems are complex and vary from area to area in Bangladesh. The major categories of shrimp farm ownership are:

- *Individual owner:* The land in the farm is owned and operated by one person. The landowner invests cash according to his capability and enjoys total returns from the farms.
- *Farmers group:* The land in the farm is owned by a number of persons who all pay an active role in operating the farm. They contribute land and money and do the farming jointly. They also share the returns on shrimp from the farm proportionate to their contribution of land, cash and physical labor. However during paddy cultivation each farmer in the group cultivate paddy singularly.
- *Outsider lease:* The land in the farm is leased out by owners to a person or persons living outside the Polder area. The outsiders provide capital, and usually set up shrimp farms taking most of the land from small and medium landowners. They usually ally themselves with neighboring medium landowners by taking their land and give them a share in the farm operations and income. This is done to gain influence over the land and control over the local people.

Shrimp farms are located in the inter-tidal range. Farm design is highly dependent on the characteristics of the site selected and there is no consistent design. However, most farms follow an open system with no treatment ponds. The bottom of the ponds is generally irregular.

The farming period starts from February to the end of November with multiple stocking and harvesting methods. The different categories of shrimp farmers described above use almost the same type of management activities for pond preparation and grow out. However, the application rate of fertilizer, stocking density of post larvae, and water exchange rates vary from farmer to farmer.

The average water depth in the pond is 0.6 meters. Generally the depth is reduced around 10-15 cm at two-week intervals. 10-30% of the pond volume is exchanged during tidal regimes and farm outflows are discharged directly to the common flushing cum drainage canal.

The farms are usually rectangular or irregular with a large surface area. The actual farm size is highly variable. Shrimp farms under individual ownership are generally smaller in size (average 2.3 ha) than that of the farm owned by the farmers group (average 4.6 ha). The largest farms are occupied under outside lessee (19.6 ha) ranging from 10.8 ha. - 36.4 ha. Yields of *Penaeus monodon* are variable ranging from 109 kg/ha to 146 kg/ha.

Harvesting is generally carried out after 90-120 days of extensive shrimp farming. Harvest is usually done early in the morning and a number of different methods are used. The harvesting techniques also vary among farm owners. The harvesting usually takes place during full and new moon of a lunar cycle. A cycle consists of 5-7 days. The used water from the farm is partially drained out through the canal and fresh tidal water introduced into the farm. The shrimp become excited and start moving towards the entry point of the tidal water as shrimp by habit like to swim against the current.