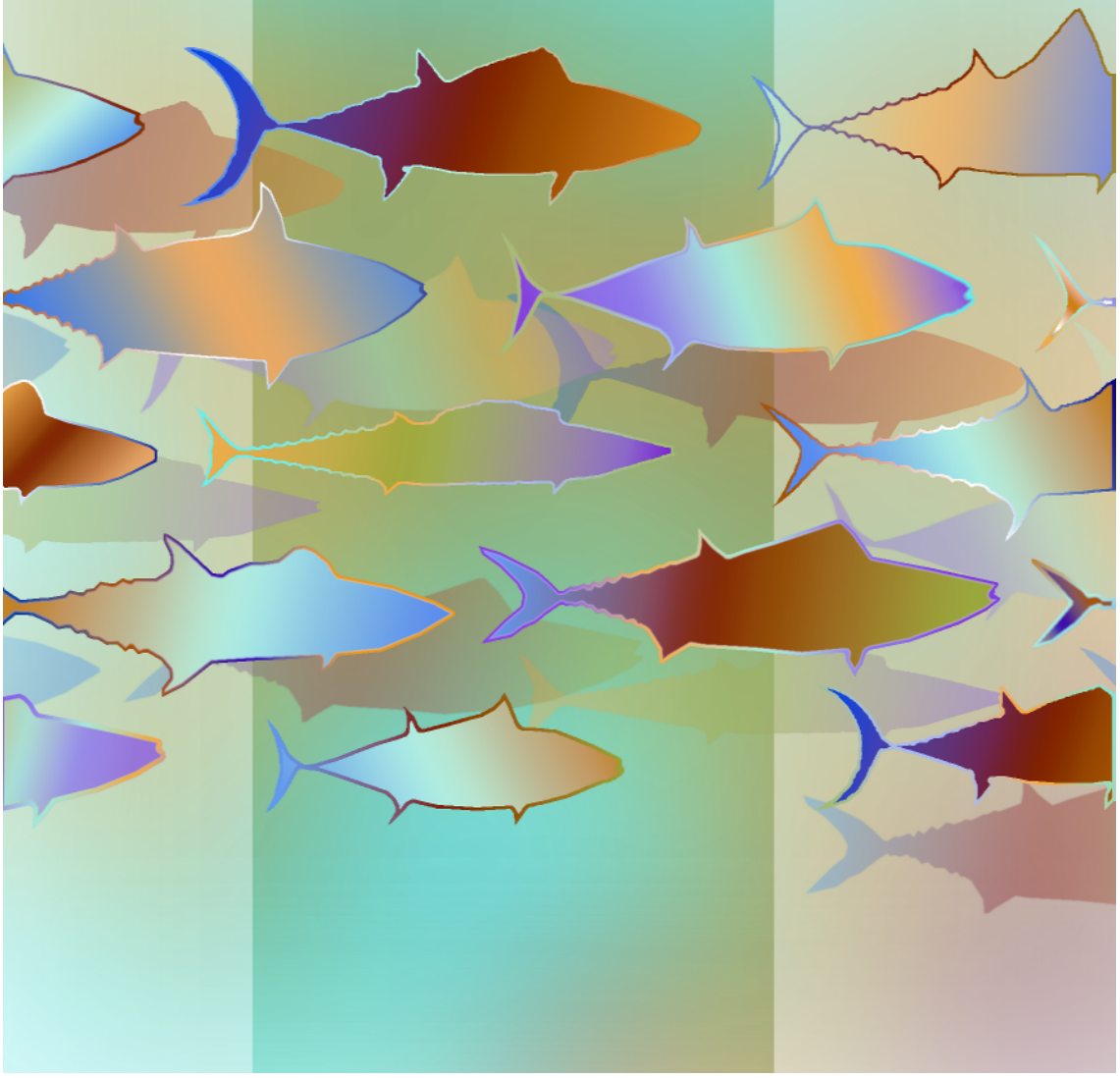
Status of Exploited Marine Fishery Resources of India



STATUS OF EXPLOITED MARINE FISHERY RESOURCES OF INDIA

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Seaweeds

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1. Introduction

Seaweeds are macroscopic marine algae attached to solid substratum, growing in the shallow waters of sea. They belong to the primitive group of Thallophyta and are classified into three major Classes viz. Chlorophyceae (green algae), Phaeophyceae (brown algae) and Rhodophyceae (red algae). Seaweeds are important marine resources exploited for their commercial value as the source of phycocolloids such as agar, agarose, algin and carrageenan (Table 1), besides their use as food, source of enzymes, dyes, drugs, growth promoters, etc. In India, seaweeds are harvested from the natural beds along the Tamil Nadu and Gujarat coasts since 1966. Seaweed resources in our coastal waters are inadequate to meet the growing demand for the supply of raw materials to the seaweed industries. There is thus the need to cultivate commercially important seaweeds to augment the supply of raw materials to the existing industries and for their sustenance. This article reviews the current status of seaweed resources in India, their farming and industrial utilization.

Table 1. Commercially important seaweeds, phycocolloids and their composition

Phycocolloids	Important raw materials	Composition
Algin/Alginates	Turbinaria, Sargassum, Padina, Cystoseira	1,4 linked m-L guluronic acid and b-mannuronic acid subunits in GG, MM and MG domains.
Agars/Agaroses	Gracilaria, Gelidiella,	Alternating 1,4 linked µ-D-galactose and 3-6- anhydro -m-L-

	Gelidium	galactose backbone substituted with varying percentages of methoxyl estersulphate and ketal pyruvate groups.
Carrageenans	Hypnea Gigartina Eucheuma	1,3-linked m-D-galactose and 1,4-linked 3,6- anhydro b-D- galactose backbone substituted with varying percentages of ester sulphate.

2. Status

India, with coastline of 8,041km has a vast resource of seaweeds. The resource available in the Indian peninsular and the archipelagoes has been assessed by various workers at different regions using different methodologies (Table 2). The southeast and northwest coast of India and the Andaman-Nicobar and Laccadive archipelagoes harbour a variety of seaweeds with rich biomass and species diversity (Fig. 1). The standing stock of seaweeds in India is estimated to be 2,60,876 tonnes (Table 2).

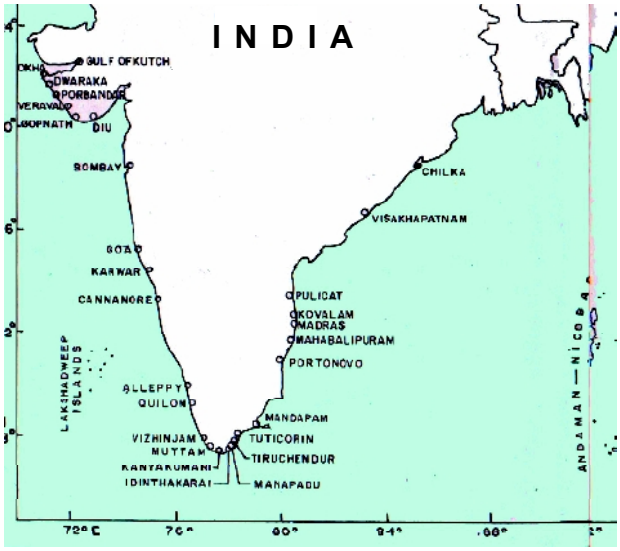

Fig. 1. Distribution of seaweeds in India

Table 2. Standing stock of seaweeds in India

Regions	Quantity (tonnes in wet wt.)
Andaman & Nicobar Islands	90,939
Tamil Nadu (Shallow, 0-5 m)	22,044
Tamil Nadu (Deep, 5-22 m)	75,372
Gujarat	20,155
Maharashtra	20,000
Lakshadweep Islands	19,345
Andhra Pradesh	7,500
Orissa	2,521
Goa	2,000
Kerala	1,000
Total	2,60,876

It is estimated that seaweed resource of India comprise 6% agarophytes, 8% carrageenophytes, 16% alginophytes and the remaining 70% green and other non commercial seaweeds. Indian coastline has 624 species of marine algae belonging to 215 genera and 64 families. Of these, nearly 60 species only are commercially important (Table 3). However, in a revised checklist 844 species of marine algae have been reported from India, comprising 216 species of Chlorophyta, 191 species of Phaeophyta , 434 species of Rhodophyta and 3 species of Xanthophyta indicating a considerable increase in the species of seaweeds of India (Table 4).

Table 3. Marine algae from coastal seas around India

Taxa	Cyano-phyceae	Chloro-phyceae	Phaeo-phyceae	Rhodo-phyceae	Total
Order	2	4	5	6	17
Families	6	15	12	31	64
Genera	11	45	39	120	215
Species	17	159	141	307	624

Table 4. Marine algae from coastal seas around India (Revised list)

Taxa	Xantho-phyceae	Chloro-phyceae	Phaeo-phyceae	Rhodo-phyceae	Total
Order	1	7	6	16	30
Families	1	19	13	36	69
Genera	1	43	37	136	217
Species	3	216	191	434	844

Seaweeds are exploited for commercial purposes only from southeast coast of India, especially from Vedaranyam to Kanyakumari coast which resulted in the depletion of standing stock and species diversity (Table 5). Despite rich resources of the seaweeds, the exploitation is not uniform in many centres, as a result of which overexploitation is acutely felt in the Gulf of Mannar, southeast coast of Tamil Nadu. The major seaweed species exploited from the natural beds are Gelidiella acerosa, Gracilaria edulis, G. crassa, Sargassum wightii, S. myriocystum, S. ilicifolium, Turbinaria conoides, T. deccurens and T. ornata. Exploitation of Cystoseira trinodis has been going on since 1996. The first report available on the seaweed exploitation from Pamban, Periapattnam and Kilakarai is given in Table 6.

Table 5. Species diversity of marine algae in Krusadai Island

Year	No. of Species	Author
1955	134	Chacko, 1955
1970	103	Krishnamurthy and Joshi, 1970
1992	77	Kalimuthu et al.,1992

Table 6. Seaweed landings (dry wt. in tonnes) during 1966 – 1968

Year	Pamban	Periapattnam	Kilakarai	Quantity (tonnes dry wt.)
1966	15.19	No exploitation	No exploitation	15.19
1967	18.35	65.55	58.07	141.97
1968	16.59	8.00	304.65	329.24

Data on seaweed landings at the southeast coast of India collected by CMFRI from 1978 – 2001 (Fig. 2), show a pattern of inconsistency in the landings of commercially important seaweeds. This prompted the Central Marine Fisheries Research Institute (CMFRI) to formulate a timeframe for the harvest of these species from the seaweed beds of Gulf of Mannar and Palk Bay in Tamil Nadu. However, this time-frame and the conservation measures were not followed by the local people who were engaged in seaweed collection (Table 7) as it affected their livelihood.

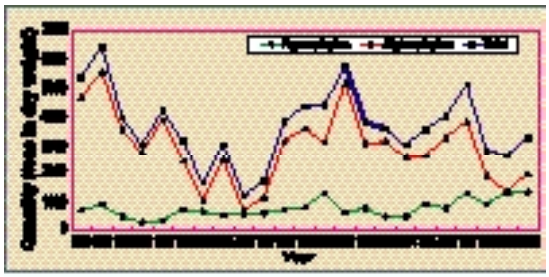

Fig. 2. Seaweed landings at southeast coast of India

Table 7. Details of seaweed collection, a major livelihood activity in Palk Bay and Gulf of Mannar

Details	Pamban	Thonithurai	Vedalai	Seenia-ppadarga	Periya-pattnam	Kilakarai
No. country crafts	40	25	30	20	20	25
Persons involved						
Men	200	325	500	150	150	250
Women	450	475	nil	nil	nil	nil
Total	650	800	500	150	150	250

Earnings/day: Men- Rs. 75-100; Women- Rs. 50-75

Introduction and culture of carrageenan yielding seaweed, Kappaphycus striatus from the Philippines by Central Salt and Marine Chemicals Research Institute (CSMCRI) is considered as a boon to seaweed cultivation in India. Presently this species is acclimatized and cultivated extensively along the Mandapam coast (east coast) and on Diu coast (west coast). A long thallus form of Gracilaria sp. from deep waters off Kottaipattinam – Chinnamanai area, hitherto unknown to the industry is being exploited on a large scale for agar production.

3. Sea farming

In India, mariculture of seaweed was attempted by the CMFRI, CSMCRI and the National Institute of Oceanography (NIO). In 1964, seaweed culture experiments

were conducted for the first time in ponds at Porbunder by attaching small plants of Sargassum to coir (palm ropes) net . The plants of Sargassum grew to height of 15 to 52 cm in 40 days. This experiment revealed good possibilities for cultivation of Sargassum and other seaweeds in India. Agar yielding seaweed Gracilaria edulis was first cultured by long line rope method in a sandy lagoon on the eastern side of the Kurusadi Island (Rameswaram). Since then, the R & D organizations of Govt. of India are engaged in the experimental mariculture of seaweeds such as Gelidiella acerosa, Gracilaria edulis, Sargassum wightii, Gelidiopsis variabilis, Acanthophora spicifera, Hormophysa triquetra, Hypnea valentiae and Ulva lactuca.

Cultivation of seaweeds is carried out by two methods: vegetative propagation using fragments from mother plants and reproductive method by different kinds of spores such as carpospores, zoospores and tetraspores. In the vegetative method, the fragments are inserted between the twists of ropes (Coir/ HDP) and cultivated in the near shore area of the sea. In the reproductive method, the spores are transplanted to the sea after a brief period of nursery rearing. Results of a few experimental attempts on the mariculture of seaweeds are given in Table 8.

Table 8. Details of experimental cultivation of seaweeds in India

Seaweeds cultivated	Location	Method adopted	Yield	Source
S. vulgare	Porbander	Coir net in pond	10-42 cm in 40 days	Thivy, 1964
S.wightii, G.edulis	Sandy lagoon of Kurusadi Island	Long line coir rope	3.5 kg m^{-1} yr^{-1}	Raju and Thomas, 1971
G. edulis & G.corticata	Mandapam	Aquarium tank & Coir net raft	4 kg m^{-2} 80 days	Rao, 1973
G.acerosa	Bhavnagar		0.01g day^{-1}	Bhandari, 1974
G.variabilis	Bhavnagar	Aquarium tank	0.04 g day^{-1}	Bhandari, 1974
G. acerosa	Lagoon of Kurusadi Island	Coir rope	3.13 g m^{-1}	Krishnamurthy et al, 1975
G. acerosa	Mandapam	Nailed on coral stone	3.1 fold in 5 months	Chennubhotla et al. 1977
H. triquetra	Bhavnagar	Aquarium tank	0.089 g day^{-1}	Bhandari & Trivedi, 1977
G. edulis	Inshore waters of Mandapam	Coir net raft	1.99 Kg m^{-2} in 45 days	Chennubhotla et al., 1978
G.pusillum	Bhavnagar	Aquarium tank	—	Mairh and Rao, 1978
G. acerosa	Ervadi	Coral stone	3.3 fold increase	Patel et al., 1979
H.musci-formis	Lagoon of Kurusadi Island	Long line coir rope	Four fold, increase	Rao and Subbaramaiah, 1980
G.verrucosa	Gulf of Kutch	Spore		Oza et al., 1994

G. edulis	Minicoy lagoon	Long line, Net rafts & cage	3.34-5.88 fold increase	Kaladharan et al., 1996
G.edulis	Inshore water Mandapam	Spore culture	3.1Kg m^{-2} & 65cm day^{-1}	Reeta and Ramamoorthy 1997;1999
Ulva fasciata	Coast of Diu	Inshore, net seeded with swarmers in lab	40-197g (dry wt) m^{-2}	Oza et al., 2001
Eucheuma sp.	Narakkal, Kerala Coast	Inshore, net bags	12 g day^{-1}	Reeta, 2001
G. edulis	-do	Spore culture floating raft	80 Kg in 135 days	Reeta et al., 2002; Reeta and Sally, 2002

In India, commercial scale mariculture of seaweeds is yet to be taken up by entrepreneurs. According to the estimates by the FAO (1997), world production of brown seaweeds through aquaculture is 4.9 million tonnes. The green and red seaweeds contribute 0.03 mn t and 1.7 mn t respectively. The main contributors are China, Japan, Korea, Chile, Canada, Norway, Indonesia, Phillipines, Thailand and other countries, while the share from India is nil.

It is evident that the landing of agarophytes is considerably low compared to that of the alginophytes (Fig. 2). However, the demand for agarophytes by the Indian industry has increased significantly resulting in overexploitation from the natural beds. This has prompted to resolve restoration measures through rational harvesting and mariculture. For mariculture, the agarophyte Gracilaria edulis is considered to be the important candidate species because of its high regenerative capacity and cosmopolitan distribution.

Constraints

Mariculture of agar yielding seaweeds in Indian waters experiences certain constraints such as: (1) grazing of cultivated seaweeds by fishes, crabs, turtles, etc, (2) vagaries of sea during the SW and NE monsoons due to which culture period is restricted to November to March, (3) the returns to the farmers being poor due to low price of raw materials (Rs.3-4/kg) they are not enthusiastic to undertake seaweed cultivation, (4) non availability of seaweed seed stock with high yield of colloids and (5) seaweed culture sites are felt as a hindrance for fishing activities

Fig. 3. Seaweed culture by womenfolk at Rameswaram

With the participation from local people from Pamban, Vedalai, Seeniappadarga and

Rameswaram villages around Mandapam, Gracilaria edulis is being cultivated on large scale and the technology is disseminated to the participants under the transfer of technology programme financed by the Department of Biotechnology (DBT), New Delhi. (Figs. 3&4). Pepsi Food Ltd (PFL) is now making a foray into large scale contract farming of carrageenan yielding Eucheuma cottonii. This seaweed is cultivated in an area of 100 ha, 10 km of sea front on the Palk Bay side towards Mandapam with the technical guidance and seed material provided from CSMCRI, Bhavnagar and permission from the Govt. of Tamil Nadu. The PFL has set up a carrageenan extraction unit at Paramakudi near Madurai and is expecting to export carrageenan worth Rs. 20 crores in 2003.

Fig. 4. Harvest of cultured seaweed

4. Seaweed industry

Although a number of competitive gelling and viscosifying hydrocolloids do exist, the unique properties of seaweed polysaccharides (phycocolloids) are the sustaining force behind the industry. In India, exploitation of seaweed for the extraction of soda ash, alginic acid and iodine was started during the second world war period. Production of agar commenced in 1966. A market for selling the seaweed was first established at Mandapam, Tamil Nadu in 1966 with the support of CSMCRI and CMFRI. Seaweeds were exported until 1975 which ceased following a ban by the Govt. of India.

The seaweed industry in India is mainly a cottage industry functioning without any sophisticated machinery and is based only on the natural stock of agar yielding red seaweeds such as Gelidiella acerosa, Gracilaria edulis and G.crassa and algin yielding brown seaweeds such as Sargassum and Turbinaria (Table 9). In India, there are 40 seaweed processing factories at present of which 22 produce agar, mainly of food grade. Except for the recent information available on an extraction unit of carrageenan at Paramakudi established by Pepsi Food Ltd, no factory in India is producing carrageenan.

Table 9. List of seaweed industries

Agar producing units	Algin producing units
1. Kavitha Agar Industries, State Bank Officer's Colony, 2, Bypass Road, Kalavasal, Madurai.	1. M/S.Meenakshi Chemicals, Industrial Estate, Kappalur, Madurai-625 005.

2. M/S. Bismi Agar, 5/129, Agraharam Street, Vilachery, Madurai-625005.
3. M/S. Vinayaka Agar Industries, 197/6, Sundar Nagar, Tirunagar, Madurai-625006.
4. M/S. Agar Industry, 9, Elanko Street, Sundar Nagar, Madurai-6.
5. M/S. Srinivasa Marine Chemicals, 239/2D, Vadakarai Village, Melakottai Post, Madurai.
6. M/S. Adithya Agar Valayanur, Chinnathadagam (via) Coimbatore-28.
7. M/S. Agar-Agar Industry, Kovilpatti Post, Tamil Nadu.
8. M/S. Bhrammavar Chemicals, P.B.No. 4, Bhrammavar Post, Karnataka.
9. M/S. Kanya Marine products, 6/124 Vilachery Main Road, Madurai-5.
10. M/S. Subbulakshmi Agar–Agar Industries, 179, Tharuvipatti Madurai - 5
11. M/S. Srinivas Industries, 106, 12th Main, Rajkumar Road, I st Block, Rajaji Nagar, Bangalore- 560010.
12. Marine Chemicals, 38A Railway Goodshed Road, Ramanathapuram.
13. M/S. Chendur Agar, T. Balakrishna Agar, Thiruvenkatam P.O, Sholavanthan Via Madurai.
14. M/S. Marine Products, D-26, Kappalore Industrial Estate, Madurai- 625006.

2. RajaganapathyChemicals, D-6, Industrial estate, Kappalur, Madurai
3. Sree Valli Marine Chemicals, Sadapathy Road, Kelavaneri Post, Thirumangalam, Madurai
4. M/S.Carbose India Pvt.Ltd., Periyar Nagammaiyar Nagar, Virudunagar Road, Melakottai Post, Madurai–9.
5. M/S. Sea Chem Industries, Amaravathipudur, Karaikudi Post, Sivagangai Dist.
6. SNAP Natural & Alginate Products Ltd.,Plot No.1, SIPCOT Industrial Complex, Ranipet- 632 403. Vellore
7. Cellulose Products of India Ltd., Kathuwada Marine Products, Ahmedabad P.O., Pin-382430, Gujarat.
8. M/S. Raj Impex (India), S.P.76 Industrial Estate, Ambathoor, Chennai-58
9. Viwas Industries, Venaikal Street, Sundaramudayan, Ramanathapuram.
10. M/S. Abirami Botanical Corpn., 55-P.S.S. Nadar Street, Tuticorin-1.
11. M/S. Surya Marine bi- products, 57-State Bank Officers Nagar, Kochadai, Madurai-10.
12. M/S. Omega Marine Chemicals, Austinpatti, Madurai-6.
13. M/S. Tamax Chemical Engineering, X/96, Nettoor, Kochi-4.
14. Marine Chemicals, Parambupatti Road, Nilayar, Madurai.

15. M/S. Quixcel Biochemicals,
Chemparuthivila, Vazhuthur,
Neyyatinkara P.O., pin-695121
Trivandrum Dist.

16. M/S. Foods, Fats and
Fertilizers Ltd., P.Box. 759,
Fountain Plaza, 7th Floor,
Pantheon Road, Egmore,
Chennai-8.

17. Shri A. Raju
30A, 11th Cross Road,
Vylikal, Bangalore-650031.

18. Masthan Bai Agar-Agar Co,
Thoppur, Kattumavadi, Madurai.

19. Madurai Agar Chemicals,
Adi Sivankoil Street,
Thirupramkuntram, Madurai-5.

20. Madurai Agar-Agar Industry,
171/9, Mandapam Road,
Manalur P.O, Tamil Nadu.

21. Sait Exporters,
Masjid complex, Kochangadi,
Cochin- 682005.

22. K. M. Agar, Sivananda Nagar,
Thoppur, Madurai-8.

23. Shri A. Bose, Srihari Extracts,
Uchempatti. Madurai

24. Lakshmi Agar products,
Silaman, Kandagi Road,
Madurai.

25. C-Pack Marine Industries,
Pulluthu, Ellis Nagar, Madurai-10.

26. M/S. Vinayaka Agar, Nagri,
Sholavanthan Road,
Iyyankottai P.O, Madurai.

27. Marine Chemicals,
Kochadai Chatram, Madurai

28. Marine Chemicals Ltd.
Chullikal, Fort, Cochin

29. Karthik Marine Algal Chemicals,
Therkutharavai, Ramanathapuram.

30. ANU Chemicals, Pamban,
Mandapam Algin producing units

15. M/S. Southern Sea Products,
Madapuram, Poovanthi Road,
Madurai.

16. Srinivasa Marine Chemicals,
P.B. No.24.Thirumangalam,
Madurai-6.

17. Selvam Marine Products,
7/58 SIDCO Industrial Estate,
Keelaagachi, Uchipuli-623534.

18. M/S. Golconda Agro Farm,
Plot No. 3 Pachagutta,
Hyderabad- 500482.

19. M/S. Bhandari & Co.9/2
Dever Lane, Calcutta-29.

20. Srinivas Chemicals,Plot No.16,
Thirumurugan Colony, Madurai-6.

21. Cellulose India Ltd.,
Mafatlal India Ltd.
SIDCO Complex, Kappalore,
Madurai.

Nearly 1,200 people are now engaged in seaweed based cottage industry, of which 70% are women. The total annual production of agar ranges from 110 - 132 t utilizing about 880 - 1100 t of dry red seaweeds and that of algin ranges from 360 - 540 t utilizing annually 3,600 - 5,400 t (Table 10) of dry Sargassum and Turbinaria . Fishing boats or dugout canoes are used to transport seaweeds collected from deeper areas and from islands located along the Tamil Nadu coast. There is a drying, sorting and packing yard for Sargassum in Sethukarai Road, Thirupullani Village of Ramnad district adjoining the seashore where the Sargassum collected from the entire Tamil Nadu coast is processed and transported to various algin producing industries (Figs. 5 & 6).

Fig. 5. Seaweeds being packed in gunny bags

Fig. 6. Seaweeds, to algin factories

Table 10. Phycocolloid production in India (after Kaladharan and Kaliaperumal, 1999)

Colloids	No. of units	Raw material (t dry wt.)	Colloid (t dry wt.)
Agar	22	880-1100	110-132
Algin	18	3600-5400	360-540
Carrageenan	–	–	–

The active season for exploitation of G. edulis is from January to March and July to September whereas for Sargassum it is from August to October. Over exploitation of seaweeds has led to scarcity of the agarophytes and poor quality of the products. The current requirement of the raw material for the Indian seaweed industries in a year is about 2,000 t dry weight of agarophytes and 12,000 t dry weight of alginophytes. Due to heavy demand, exploitation of agarophytes from the natural beds has increased considerably whereas alginophytes showed a declining trend probably due to lesser demand for alginate in the market. At the Regional Centre of CMFRI, Mandapam Camp, under the ICAR Revolving Fund Project an

agar plant was established and pilot scale production of agar was started in August, 1999 from the seaweed Gracilaria edulis. Agar is produced in the form of sheet and sold to traders (Fig. 7).

Fig. 7. Drying of agar gel

The major problem faced by the agar and algin factories in India is the poor quality of raw material available that yields less than 13% of phycocolloids. The quality remains low mostly due to adulteration with unwanted weeds, seagrass leaves, debris and stones. When the seaweed factories (16 agar making and 13 algin making) situated in and around Madurai and Ramnad districts of Tamil Nadu were contacted for their opinion, on any training/technology requirements, with the pre-tested interview schedules, the unanimous response pointed out the need for an urgent training in technology to improve the quality of product such as colour, gel strength, viscosity, etc.

The increase in gel strength, melting temperature and reduction in the sulphate content of agars extracted from Gelidiella acerosa, Gracilaria blodgettii and G.verrucosa were achieved by treating them with 0.5% sodium carbonate at 85-90^{0}C for 30 minutes. Similarly for G.edulis, pretreatment by 2-3 N sodium hydroxide at 80^0 C for one hour of the pre-soaked algae in water proved to be most ideal and optimum extraction procedure to obtain higher yield (14%); maximum gel strength (291g/cm^2), lowest sulphate (0.732%) and higher melting point (99^0 C).

5. Conclusion

Although India is endowed with a long coastline and wide shelf area for mariculture, large-scale cultivation of seaweeds for commerce is yet to take place. The major reasons are the low returns in monoculture of seaweed and inconsistent yield. Upgrading the mariculture technology, research on value addition for quality improvement of phycocolloids, increased utilization of seaweeds and their products in domestic market, etc could make the seaweed industry commercially attractive. As the large scale exploitation of seaweeds is species specific and centered around southeast coast, degradation in quality and quantity of agarophytes is obviously evident. Seaweeds are to be exploited rationally and evenly from other maritime states of India. Strengthening research and development on phycocolloid biosynthesis pathway and genetic engineering of Indian agarophytes for higher yield, in vitro production of phycocolloids, introduction of exotic varieties from tropical and subtropical waters and increased research on wider applications of possibly new polysaccharides from other seaweed strains should receive priority attention. Inherently the Indian seaweeds yield poor quality and quantity of polysaccharides. Introduction and acclimatization of subtropical species, Eucheuma to India for

carrageenan production is a welcome sign and has opened up windows for establishing new seaweed based industry in India. The introduction and establishment of high yielding strains of agarophytes such as Gracilaria NBR-10 and other species of Gelidium, Pterocladia, etc from tropical and subtropical regions have proved feasible. Efforts are on to improve the quality of agar through improvised post harvest technology and value addition as well as to develop improved strains that promise better yield and quality colloids.

6. Suggested reading

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