

CMFRI bulletin 41



DECEMBER 1987

SEAWEED RESEARCH AND UTILIZATION IN INDIA

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P. B. No. 2704, E. R. G. Road, Cochin 682 031, India

CHEMICAL COMPOSITION OF SEAWEEDS

N. KALIAPERUMAL, V. S. K. CHENNUBHOTLA, S. KALIMUTHU,
J. R. RAMALINGAM, M. SELVARAJ AND M. NAJMUDDIN

Considerable work has been done on the chemical aspects of Indian seaweeds during the last three decades, of which those up to 1970 have been reviewed by Umamaheswara Rao (1970). In this chapter the information so far collected on the mineral constituents, carbohydrates and other chemicals is presented.

Mineral Constituents

As seaweeds are utilized as food and fertilizer, many studies have been made on their chemical composition, such as by Chidambaram and Unny (1947 and 1953) and Joseph et al (1948). Chidambaram and Unny (1953) have analysed *Sargassum*, *Turbinaria* and *Gracilaria* collected from Madras for estimating the gross contents such as moisture, soluble and insoluble materials and protein. The compositions as given by them are as follows:

	<i>Sargas- sum</i>	<i>Turbi- naria</i>	<i>Graci- laria</i>
Moisture (in air-dried material)	11.7%	6.13%	10.71%
Loss on ignition	61.63%	63.07%	71.59%
Insolubles	0.17%	0.50%	2.41%
Solubles	26.4%	30.30%	15.29%
Nitrogen	1.02%	0.96%	1.48%

In the Central Marine Fisheries Research Institute, studies were carried out on the chemical composition of the marine algae growing in the vicinity of Mandapam (Pillai 1955 a, 1956 and 1957 a, b). Detailed information was gathered on the water-soluble minerals, trace elements (Pillai 1958), different

forms of sulphur and nitrogen and aminoacids (Pillai 1957 a, 1957 b) occurring in eleven green, brown and red seaweeds, namely *Chaetomorpha linum*, *Enteromorpha intestinalis*, *Gracilaria lichenoides* (= *G. edulis*), *Chondria dasyphylla*, *Acanthophora spicifera*, *Laurencia papillosa*, *Hypnea musciformis*, *Sarconema furcellatum*, *S. filiforme*, *Rosenvingea intricata* and *Padina tetrastrumatica*. Sitakara Rao and Tipnis (1967) analysed ten species of marine algae of the Gujarat coast. Recently Zingde et al (1976) studied the distribution of a few trace elements such as arsenic, copper, zinc and manganese in marine flora and fauna of Goa. Parekh et al (1977) studied the chemical composition of 27 species of green seaweeds of Saurashtra coast. Significant variations in chemical composition were observed among the different genera of seaweeds. The same species collected from different localities at different periods also showed considerable variations. The biochemical contents of *Ulva lactuca*, *Sargassum swartzii* and *Gelidiella acerosa* from Port Okha were studied in relation to ecological factors by Murthy and Radia (1978), and presented the month-wise protein, fat carbohydrate, crude-fibre, sodium, potassium, calcium and phosphorus contents of these species. Dhargalkaar (1979), estimating the major metabolites such as proteins, carbohydrates and lipids, found carbohydrate decreasing in *Ulva reticulata* in December, probably due to the spore formation and extensive growth of thallus. Protein values also followed the same trend while lipid did not show any significant seasonal variation. But C:N ratio and protein values showed inverse relationship. Seventeen species of marine algae collected from five localities

of Goa were analysed by Agadi et al (1978) for Co, Cu, Fe, Mn, Ni, Pb and Zn. All the seven metals showed considerable variations in their concentration. Seasonal variations in biochemical composition of some seaweeds from Goa coast was followed by Sumitra Vijayaraghavan et al (1980). She found that the carbohydrate contents in *Chaetomorpha media*, *Dictyota dichotoma*, *Ulva fasciata*, *Padina tetrastromatica*, *Hypnea musciformis* and *Gracilaria corticata* were almost similar, whereas caloric content, organic carbon and lipids were high in *Hypnea musciformis* and protein was rich in *Padina tetrastromatica*, *Chaetomorpha media* and *Ulva fasciata*. The biochemical constituents in these species in general did not show marked seasonal variations owing to the like reproductive pattern of the algae. Dhargalkar et al (1980) estimated protein, carbohydrate and organic carbon in 43 marine algal species from different stations along the Maharashtra coast. These species showed variation in their biochemical contents. Protein varied from 10% to 33%. Compared to brown algae, the green and red algae were rich in protein and carbohydrate. Chlorophyceae had the maximum organic carbon, average value being 33%. C:N ratio varied from 5.2 to 29.8 and showed inverse relationship with protein.

Solimabi et al (1980) studied the seasonal changes in biochemical constituents namely carbohydrate, protein and sulphate of *Hypnea musciformis* from Goa coast. Carbohydrate varied from 31% to 50% with maximum values in October, November and May and minimum in January and February. Protein ranged from 9.92% to 17% and showed a gradual increase from October to May. The sulphate content varied from 12.48% to 20.8% with the peak value in January.

Neela (1956) estimated the protein, fat calcium, phosphorus, iron, iodine and vitamin-C contents in *Gracilaria* sp., *G. lichenoides*, *Hypnea* sp. and *Ulva lactuca*. The chemical composition of *Porphyra* growing on Visakhapatnam coast has been worked out by Tewari et al (1968), comparing with that of Japanese species. Results obtained on the major constituents and trace elements of algae studied by these workers are shown in Tables 2

and 3. Pillai (1956) and Sitakara Rao and Tipnis (1967) estimated the water-soluble constituents from dry algae and Kappanna and Visweswara Rao (1963) from the ash of the algae.

Seaweeds like *Sargassum* and *Turbinaria* composted with fishoffal and shark-liver oil sediments in the ratio 15: 3: 4 by weight for a period of three months (Chidambaram and Unny 1947) showed that they contained 2.4% nitrogen, 3.5% potash and 0.7% phosphate. The nitrifiability of the organic nitrogen from *Ulva lactuca* and drift weeds collected from Veraval were studied by Mehta et al, (1967). Pillai (1955 b) carried out some interesting experiments to study the influence of water soluble extracts of seaweeds on the growth of blue-green algae. In these investigations considerable increase in growth was noticed when extracts of *Gracilaria lichenoides*, *Chondria dasyphylla* and *Hypnea musciformis* were added to the blue-green algal cultures.

Other chemical studies on Indian seaweeds are those of Langalia et al (1967) on the alkali contents of marine algae and Sitakara Rao and Tipnis (1967) and Dhandhukia and Seshadri (1969) on the arsenic content of seaweeds. Higher concentrations of arsenic, ranging from 14-68 ppm, were reported from brown algae whereas less than 1-2 ppm were observed in green and red algae (Dhandhuria and Seshadri 1969). Information regarding the naturally occurring radioactive substances in species of *Enteromorpha*, *Caculterpa* and *Gracilaria* was given by Unni (1967).

Quantitative Changes in Mineral Constituents

Marked changes in the chemical constituents were found to occur with change of seasons, environmental conditions as well as in the various phases of the plant's growth and fruiting cycle. Pillai (1956; 1957 a, b) studied the seasonal variations in the major and minor constituents of 11 green, brown and red algae. The maximum values obtained in different months as well as the seasonal range in the quantities of some of the major constituents are given in Table 4. Quantitative changes in the inorganic constituents were noticed in different growth stages of plant by Pillai (1956; 1957 a,

Table 2

Water soluble minerals in Indian seaweeds (g / 100 g of dry weed)

Plant	Sodium	Potassium	Calcium	Magnesium	Chloride	Nitrogen	Sulphate	Author
GREEN ALGAE								
1. <i>Enteromorpha intestinalis</i>	1.16	0.71	0.51	0.41	2.40	0.38	4.00	Pillai, 1956
2. <i>Ulva lactuca</i>	1.71	1.58	0.63	1.64	0.79	—	12.10	Sitakara Rao and Tipnis, 1967
3. <i>U. rigida</i>	1.11	0.68	0.34	0.98	0.27	—	7.74	-do-
4. <i>Cladophora monumentalis</i>	0.57	3.59	0.52	0.07	2.90	—	2.41	-do-
5. <i>Boodlea composita</i>	4.82	4.09	0.41	0.12	5.19	—	4.43	-do-
6. <i>Codium dwarkense</i>	10.74	2.35	1.19	0.18	15.63	—	5.99	-do-
BROWN ALGAE								
7. <i>Padina australis</i>	1.28	0.93	0.50	0.50	2.40	0.60	1.80	Pillai, 1956
8. <i>P. gymnospora</i>	1.40	1.06	0.16	0.02	0.87	—	1.39	Sitakara Rao and Tipnis, 1967
9. <i>Colpomenia sinuosa</i>	0.56	8.85	0.12	0.04	0.53	—	1.33	-do-
10. <i>Cystophyllum spp</i>	1.20	1.25	0.02	0.02	0.84	—	2.54	-do-
11. <i>Sargassum cinereum</i> <i>v. berberifolia</i>	1.67	7.35	0.02	0.08	7.20	—	1.50	-do-
12. <i>S. johnstonii</i>	1.47	1.67	0.02	0.01	1.39	—	1.82	-do-
RED ALGAE								
13. <i>Porphyra (P vietnamensis)</i>	5.66	1.11	0.30	0.45	3.58	—	0.11	Tewari <i>et. al.</i> 1968
14. <i>Gelidium micropterum</i> (= <i>Gelidiella acerosa</i>)	0.08	0.02	0.28	0.07	0.09	1.34	0.73	Kappanna and Visweswara Rao, 1963
15. <i>Gracilaria lichenoides</i>	0.23	2.01	0.40	0.16	3.84	0.70	4.50	Pillai, 1956
16. <i>G. lichenoides</i>	1.23	0.93	0.57	0.02	1.26	2.14	3.65	Kappanna and Visweswara Rao, 1963
17. <i>Sarconema furcellatum</i>	0.56	0.40	0.51	0.41	2.40	0.93	2.90	Pillai, 1956
18. <i>Acanthophora spicifera</i>	0.32	0.18	0.42	0.38	3.06	0.74	2.00	-do-
19. <i>Laurencia papillosa</i>	1.16	0.82	0.61	0.31	2.40	1.00	3.80	-do-

Table 3

Minor constituents in Indian seaweeds (mg/100g of dry weed)

Plant	Iron	Copper	Manganese	Boron	Zinc	Phosphorus	Author
GREEN ALGAE							
1. <i>Enteromorpha intestinalis</i>	14.00	0.25	13.00	0.60	4.40	—	Pillai, 1956
2. <i>Ulva lactuca</i>	0.37	0.89	8.23	15.60	0.74	277.60	Sitakara Rao and Tipnis, 1967
3. <i>U rigida</i>	257.20	4.66	38.40	10.00	1.62	286.30	do
4. <i>Chaetomorpha linum</i>	21.70	0.50	38.50	0.44	3.00	—	Pillai, 1956
5. <i>Cladophora monumentalis</i>	144.45	0.54	6.15	23.54	2.27	116.20	Sitakara Rao and Tipnis, 1967
6. <i>Boodlea composita</i>	468.55	1.05	17.62	4.50	1.86	258.35	do
7. <i>Codium dwarkense</i>	60.60	0.73	2.31	1.10	1.97	205.70	do
BROWN ALGAE							
8. <i>Padina australis</i>	50.40	1.12	45.00	1.10	4.40	—	Pillai, 1956
9. <i>P gymnospora</i>	456.10	1.96	24.75	3.21	3.46	28.63	Sitakara Rao and Tipnis, 1967
10. <i>Colpomenia sinuosa</i>	249.70	1.47	0.04	4.02	0.13	98.36	do
11. <i>Rosenvingea intricata</i>	22.40	0.50	57.50	0.74	3.20	—	Pillai, 1956
12. <i>Cystophyllum spp</i>	30.07	0.02	13.80	2.58	0.70	197.95	Sitakara Rao and Tipnis, 1967
13. <i>Sargassum cinereum</i> <i>v. berberifolia</i>	224.05	1.45	4.19	0.24	1.08	3.02	do
14. <i>S. Johnstonii</i>	107.40	0.61	9.07	1.64	2.14	203.60	do
RED ALGAE							
15. <i>Gracilaria lichenoides</i>	28.00	1.00	55.00	1.43	8.30	—	Pillai, 1956
16. <i>Sarconema filiforme</i>	19.60	0.65	18.70	0.73	6.40	—	do
17. <i>S. furcellatum</i>	14.00	3.00	39.00	0.94	5.80	—	do
18. <i>Hypnea musciformis</i>	28.00	0.90	19.50	0.80	8.00	—	do
19. <i>Chondria dasyphylla</i>	30.80	0.90	17.50	0.85	6.80	—	do
20. <i>Acanthophora spicifera</i>	28.00	1.20	8.50	0.43	7.00	—	do
21. <i>Laurencia papillosa</i>	37.80	0.50	24.00	0.46	5.50	—	do

Table 4
 Seasonal maxima and minima in the mineral contents of eleven Indian marine algae
 (From Pillai, 1956, 1957 a, b)

Mineral	Month		g/100g	
	Maximum	Minimum	Maximum	Minimum
<i>I. Enteromorpha intestinalis</i>				
Potassium	June	December	1.35	0.65
Sodium	October	April	0.75	0.35
Magnesium	December	April	0.70	0.15
Calcium	March	October	0.85	0.25
Chloride	February	September	1.40	0.75
Nitrogen	December	August	0.38	0.10
Sulphate	April	October	4.00	1.30
<i>II. Chaetomorpha linum</i>				
Potassium	June	December	1.55	0.60
Sodium	November	-do-	0.75	0.25
Magnesium	May	-do-	0.30	0.20
Calcium	June	October	0.35	0.20
Chloride	May	November	1.85	0.50
Nitrogen	-	-	-	-
Sulphate	June	December	4.30	1.30
<i>III. Padina australis</i>				
Potassium	January	August	2.00	0.80
Sodium	December	July	1.45	0.65
Magnesium	March	December	0.65	0.40
Calcium	February	July	0.65	0.30
Chloride	December	August	2.25	0.95
Nitrogen	October	May	0.60	0.15
Sulphate	November	April	1.70	1.00
<i>IV. Rosenvingea intricata</i>				
Potassium	December	April	4.40	1.75
Sodium	October	-do-	1.85	0.55
Magnesium	January	July	0.90	0.30
Calcium	February	September	0.85	0.25
Chloride	February	May	2.75	0.75
Nitrogen	-	-	-	-
Sulphate	May	October	1.10	0.40
<i>V. Gracilaria lichenoides</i>				
Potassium	June	August	3.25	0.80
Sodium	November	-do-	0.40	0.15
Magnesium	January	April	0.70	0.25
Calcium	December	-do-	0.50	0.10
Chloride	February	August	2.55	0.75
Nitrogen	December	April	0.73	0.18
Sulphate	April	May	4.40	1.20

Mineral	Month		g/100g	
	Maximum	Minimum	Maximum	Minimum
VI. <i>Sarconema filiforme</i>				
Potassium	June	September	2.45	0.80
Sodium	December	August	0.50	0.20
Magnesium	September	December	0.45	0.20
Calcium	May	November	1.10	0.30
Chloride	March	April	2.00	0.25
Nitrogen	-	-	-	-
Sulphate	October	December	3.40	1.30
VII. <i>Sarconema furcellatum</i>				
Potassium	May	August	3.20	0.85
Sodium	November	January	1.40	0.25
Magnesium	April	August	0.70	0.20
Calcium	October	-do-	0.60	0.35
Chloride	November	May	2.05	0.30
Nitrogen	-do-	July	0.93	0.10
Sulphate	May	January	3.00	1.80
VIII. <i>Hypnea musciformis</i>				
Potassium	May	December	2.65	0.80
Sodium	January	April	0.25	0.05
Magnesium	August	-do-	0.55	0.20
Calcium	February	-do-	1.00	0.35
Chloride	January	September	2.50	0.50
Nitrogen	November	March	0.93	0.13
Sulphate	September	June	3.20	2.50
IX. <i>Chondria dasyphylla</i>				
Potassium	June	September	3.05	0.07
Sodium	November	January	0.75	0.20
Magnesium	November	April	0.55	0.30
Calcium	June	-do-	0.95	0.10
Chloride	August	-do-	2.10	0.85
Nitrogen	November	-do-	1.00	0.18
Sulphate	May	September	4.40	1.20
X. <i>Acanthophora spicifera</i>				
Potassium	May	September	2.60	0.65
Sodium	December	April	1.35	0.20
Magnesium	-do-	-do-	0.70	0.25
Calcium	August	December	0.95	0.25
Chloride	May	October	2.05	0.85
Nitrogen	-do-	February	0.73	0.25
Sulphate	July	January	2.10	1.50
XI. <i>Laurencia papillosa</i>				
Potassium	February	September	2.55	0.35
Sodium	December	April	1.35	8.28
Magnesium	September	October	0.70	0.35
Calcium	August	April	0.90	0.35
Chloride	February	-do-	0.95	0.25
Nitrogen	November	May	1.00	0.18
Sulphate	June	September	3.90	2.00

b) and in plants collected from different localities (Tables 2 and 3). Patel and Joshi (1967) determined seasonal fluctuations of carbohydrates, nitrogen and other major chemical constituents of *Ulva lactuca* and discussed the relationship between the chemical changes in the plant and in the metabolic environment and atmospheric temperature.

Iodine

Iodine is still extracted in small quantities from brown seaweeds in Japan, Norway and France, and from red seaweeds like *Phyllophora nervosa* in Russia. As seaweeds are good source to meet dietary requirements of iodine, goitre caused by iodine deficiency is less prevalent in countries where marine algae form part of the diet. The iodine that occurs in seaweeds is in the readily available form and, as such, is superior to the mineral iodine (Thivy 1960).

Some species of seaweeds, especially red and brown varieties, have the ability to accumulate iodine and thus are a more concentrated source of it.

Laminaria, *Phyllophora* and *Ecklonia* are the seaweeds from which iodine is extracted in Japan, Britain and other countries.

The iodine content of the Indian *Sargassum* was studied by Joseph et al. (1948). Pillai (1956) estimated in a more elaborate way the iodine contents of eleven species of algae growing around Mandapam. The iodine contents of five genera which are relatively richer in iodine, viz *Gelidium*, *Myriogloea*, *Sargassum*, *Asparagopsis*, and *Udotea*, are as follows:

<i>Gelidium</i>	38—54 ppm
<i>Myriogloea</i>	100—140 ppm
<i>Sargassum</i>	40—160 ppm
<i>Asparagopsis</i>	440—550 ppm
<i>Udotea</i>	215 ppm

The quantity of iodine present in many green, brown and red algae of the Gujarat coast was determined by Pillai (1956), Kappanna and Sitakara Rao (1962), Sitakara

Rao and Tipnis (1967) and Dave et al (1969). Values obtained by these authors along with the localities from where the seaweeds were collected are shown in Table 5. The iodine content was observed to be generally lower in the brown algae than in the red and green (Solimabi and Das 1977) (Table 5). But the brown algae *Myriogloea sciurus* and *Padina australis* are exceptions in that 104.5 mg and 500 mg of iodine were respectively, reported, from these. (Table 5). Maximum quantity of 566.70 mg/100 g was observed in a small red alga, *Asparagopsis*. Other algae in which high amounts of iodine (above 200 mg/100 g) were observed are *Udotea indica*, *Gracilaria lichenoides* and *Sarconema furcellatum*. Solimabi et al (1981) found that the iodine content in 16 species of algae (red, brown and green) of the Andaman Sea varied from 0.003% to 0.0119%.

Proteins, Peptides and Free Amino Acids

The protein contents in the marine algae were estimated by Chidambaram and Unny (1953), Neela (1956), Pillai (1957 a) and Sitakara Rao and Tipnis (1964, 1967). In the species of *Sargassum*, *Turbinaria* and *Gracilaria* analysed by Chidambaram and Unny (1953) the protein content was found to be less than 10%. Data collected on the protein contents of different green, brown and red algae are summarised in Table 6. It may be seen from this that protein is high in the green and red algae than in the brown algae. In *Ulva fasciata*, *Acanthophora muscoides* and *Centroceras clavulatum* protein was estimated to be 22-26%. Lewis and Gonzalves (1960) reported more than 28% protein in the algae collected from Bombay coast. Dave and Parekh (1975), studying 8 genera of green algae of Saurashtra coast, found significant variation in protein in same species of algae grown in different localities and at different periods. The algae which form rich sources of protein are *Ulva rigida*, *U. fasciata*, *U. stenophylla*, *Caulerpa scalpelliformis*, *Cladophora monumentalis* and species of *Bryopsis*.

Table 5

Iodine contents of Indian seaweeds

Species	Locality	mg of iodine/ 100 g dry weed	Author
GREEN ALGAE			
1. <i>Enteromorpha intestinalis</i>	Mandapam	58.00	Pillai, 1956
2. <i>Enteromorpha spp</i>	Porbandar	4.16	Dave <i>et. al.</i> , 1969
3. <i>Ulva fasciata</i>	Veraval	7.40	-do-
4. <i>U. lactuca</i>	Okha	3.31	-do-
5. <i>U. lactuca</i>	Porbandar	6.27	-do-
6. <i>U. rigida</i>	Gopnath	4.83	Sitakara Rao and Tipnis, 1967
7. <i>Chaetomorpha linum</i>	Mandapam	72.00	Pillai, 1956
8. <i>Cladophora expansa</i>	Porbandar	18.06	Dave <i>et. al.</i> , 1969
9. <i>C. monumentalis</i>	Okha	64.64	Sitakara Rao and Tipnis, 1967
10. <i>Cladophora spp</i>	Porbandar	18.83	Dave <i>et. al.</i> , 1969
11. <i>Boodlea composita</i>	Okha	29.77	-do-
12. <i>Udotea indica</i>	-do-	215.30	-do-
13. <i>Halimeda tuna</i>	-do-	31.30	-do-
14. <i>Codium dwarkense</i>	-do-	5.31	Sitakara Rao and Tipnis, 1967
15. <i>Chamaedoris auriculata</i>	Veraval	10.43	Dave <i>et. al.</i> , 1969
BROWN ALGAE			
16. <i>Myriogloea sciurus</i>	Okha	104.50	Kappanna and Sitakara Rao, 1962
17. <i>Stoechospermum marginatum</i>	Okha	5.44	Dave <i>et. al.</i> , 1969
18. <i>Spatoglossum variabile</i>	-do-	16.44	Kappanna and Sitakara Rao, 1962
19. <i>Dictyopteris australis</i>	-do-	23.48	Dave <i>et. al.</i> , 1969
20. <i>Dictyopteris spp</i>	-do-	25.81	-do-
21. <i>Padina australis</i>	Mandapam	500.00	Pillai, 1956
22. <i>P. gymnospora</i>	Okha	7.95	Dave <i>et. al.</i> , 1969
23. <i>Colpomenia sinuosa</i>	-do-	8.99	Sitakara Rao and Tipnis, 1967
24. <i>Cystophyllum spp</i>	Porbandar	34.19	Dave <i>et. al.</i> , 1969
25. <i>Cystophyllum spp</i>	Veraval	16.53	-do-
26. <i>Sargassum cinereum</i> <i>v. berberifolia</i>	Sikka	33.20	Sitakara Rao and Tipnis, 1967
27. <i>S. johnstonii</i>	Okha	39.80	Sitakara Rao and Tipnis, 1967

Species	Locality	mg of Iodine/ 100 g dry weed	Author
28. <i>S. swartzii</i>	Okha	28.18	Dave <i>et. al.</i> , 1969
29. <i>S. tenerrimum</i>	-do-	37.21	-do-
30. <i>S. vulgare</i>	Porbandar	29.29	-do-
RED ALGAE			
31. <i>Scinaia indica</i>	Okha	5.62	Kappanna and Sitakara Rao 1962
32. <i>Asparagopsis taxiformis</i>	-do-	499.30	Dave <i>et. al.</i> , 1969
33. <i>Asparagopsis</i> spp	-do-	556.70	-do-
34. <i>Gelidiella acerosa</i>	Porbandar	54.00	-do-
35. <i>Amphiroa anceps</i>	Okha	5.15	-do-
36. <i>Halymenia venusta</i>	-do-	25.00	-do-
37. <i>Gracilaria corticata</i>	Porbandar	18.41	-do-
38. <i>G. foliifera</i>	Okha	8.07	-do-
39. <i>G. lichenoides</i>	Mandapam	208.00	Pillai, 1956
40. <i>Sarconema filiforme</i>	-do-	107.00	-do-
41. <i>S. furcellatum</i>	Okha	8.63	Kappanna and Sitakara Rao, 1962
42. <i>S. furcellatum</i>	Mandapam	357.00	Pillai, 1956
43. <i>Solieria robusta</i>	Okha	15.54	Kappanna and Sitakara Rao, 1962
44. <i>Agardhiella tenera</i>	-do-	12.65	-do-
45. <i>Hypnea musciformis</i>	Mandapam	100.00	Pillai, 1956
46. <i>H. musciformis</i>	Okha	12.74	Dave <i>et. al.</i> , 1969
47. <i>Centroceras clavulatum</i>	-do-	20.79	-do-
48. <i>Heterosiphonia muelleri</i>	-do-	10.01	Kappanna and Sitakara Rao, 1962
49. <i>Polysiphonia ferulacea</i>	-do-	39.06	-do-
50. <i>Polysiphonia</i> spp	-do-	4.78	-do-
51. <i>Acanthophora delilei</i>	-do-	5.78	-do-
52. <i>A. spicifera</i>	Mandapam	90.00	Pillai, 1956
53. <i>Laurencia papillosa</i>	-do-	137.00	-do-

Table 6
Protein contents of Indian seaweeds

Seaweed	Protein/ 100 g of seaweed	Author
GREEN ALGAE		
1. <i>Ulva fasciata</i>	25.48	Sitakara Rao and Tipnis 1964
2. <i>U. lactuca</i>	7.69	—
3. <i>U. rigida</i>	22.42	—
4. <i>Cladophora monumentalis</i>	16.28	—
5. <i>Boodlea composita</i>	10.32	—
6. <i>Udotea indica</i>	13.00	—
7. <i>Codium dwarkense</i>	7.22	—
8. <i>Chamaedoris auriculata</i>	13.67	—
BROWN ALGAE		
9. <i>Dictyopteris australis</i>	8.14	—
10. <i>Spatoglossum variabile</i>	15.66	—
11. <i>Padina gymnospora</i>	12.27	—
12. <i>Colpomenia sinuosa</i>	6.62	—
13. <i>Cystophyllum</i> spp	11.21	—
14. <i>Sargassum cinereum v. berberifolia</i>	9.61	—
15. <i>S. johnstonii</i>	10.90	—
16. <i>S. tenerrimum</i>	12.14	—
RED ALGAE		
17. <i>Porphyra</i> sp.	16.01	Tewari <i>et. al</i> 1968
18. <i>Scinaia indica</i>	12.51	Sitakara Rao and Tipnis, 1964
19. <i>Asparagopsis taxiformis</i>	16.19	—
20. <i>Gracilaria lichenoides</i>	7.62	Neela, 1956
21. <i>Hypnea</i> spp.	7.50	—
22. <i>Centroceras clavulatum</i>	20.12	Sitakara Rao and Tipnis, 1964
23. <i>Acanthophora muscooides</i>	21.83	—

Extensive works were carried out by Lewis and Gonзалves (1959 a-c, 1960, 1962 a-c) and Lewis (1962 a, b, 1963 a-d and 1967) on aminoacids present in free state and on portein and peptide hydrolysates in many green, brown and red seaweeds. Lewis (1967) pointed out that Indian marine algae have all the essential aminoacids needed in human diet, including methionine and triptophane, which are not available in vegetable food materials.

Extraction of protein : Parekh and Visweswara Rao (1964) devised a method to extract proteins from the green alga *Ulva rigida*. The powdered seaweed is first treated with either-water mixture (1:4 ratio) for about 3 hours and then with 1 N sodium hydroxide solution. The protein is then precipitated with 10% solution by trichloro acetic acid at pH 4-5. The precipitated protein is washed, dried and powdered. Among the different precipitating agents tried by these authors, trichloro acetic acid gave best results, giving a concentrate containing 60% of protein.

Vitamins

Different vitamins, such as Vitamin-B 12, Vitamin-C, Vitamin-D and Vitamin-E, have been reported from marine algae growing in other parts of the world. In India, a few studies were made on the ascorbic acid content (Vitamin-C). The results obtained by Thivy (1960) on the algae of Mandapam are presented in Table 7. As revealed by this study, the amount of ascorbic acid present in *Sargassum myriocystum* is high and is, infact, more than that present in citrus fruit. Variation in ascorbic acid content in relation to growth and reproduction of *Ulva fasciata* was studied by Subbaramaiah (1967). Highest concentration, 2.4 mg/g, was in very young plants of about 5mm in length. With increase in length of the frond, the ascorbic acid content was found to decrease, dimini-shing to 0.73mg/g in plants more than 7.0 cm in length. The concentration of Vitamin-C was higher in the reproductive parts of thallus than in the vegetative parts.

Table 7

Ascorbic acid content in Indian marine algae
(From Thivy, 1960)

Alga	mg/100g of fresh weed
<i>Chaetomorpha brachygonia</i>	5.92
<i>Cladophora fritschii</i>	6.04
<i>Ulva reticulata</i>	5.69
<i>Ulva lactuca</i>	6.10
<i>Enteromorpha prolifera</i>	0.22
<i>Padina australis</i>	7.86
<i>Sargassum myriocystum</i>	66.60
<i>Hypnea musciformis</i>	8.58
<i>Gracilaria lichenoides</i>	7.25
<i>Acanthophora spicifera</i>	4.00
<i>Laurenica papillosa</i>	5.92

Bromine

Nineteen species of seaweeds consisting of green, red and brown algae, from Goa coast were examined by Naqvi et al (1979) for bromine content. The bromine content, on a dry-weight basis, varied between 0.024% and 0.247% in the green algae, 0.020% and 0.4% in the red algae and 0.015%–0.055% in the brown algae (Table 8). Only two species namely *Chondria armata* and *Codium elongatum*, had relatively high bromine content, 0.4% and 0.247%, respectively. The bromine content of 16 species of algae (red, brown and green) of the Andaman Sea varied between 0.008% and 0.128% (Solimabi et al. 1981).

Carbohydrates

Laminarin, mannitol, fucoidin, alginic acid, agar, carrageenan and many other varieties of carbohydrates were isolated from green, brown and red algae elsewhere (Black 1954, Percival 1968). In India, on the other hand, much attention was paid only on the economically important carbohydrates, namely agar and algin. Investigations carried out on these and a few other carbohydrates are given below.

Agar and agaroid: During and after the Second World War, some attempts were made to extract agar from Indian seaweeds (Bose et al 1943; Chakraborty 1947; Joseph and Mahadevan 1948; Karunakar et al 1948). These authors used different techniques for purification of agar gel. In the method developed by Bose et al (1943), the whole weed was leached for 18 hours before extraction and the gel was maintained at 60°C to remove the

suspended impurities, Starch present in the gel was removed by treating with 0.2% acetic acid for 1 hour and then washing the gel in water. Karunakar et al (1948) employed bacterial method for purification of gel and Chakraborty (1945) used freezing technique to remove the suspended material. Mahonty (1956) found that heating under pressure at 230°F was necessary for the removal of impurities in the gel of *Gracilaria verrucosa*.

At Central Marine Fisheries Research Institute, more detailed investigations were made to extract agar-agar from different species of *Gracilaria* and from *Gelidiella acerosa* and to know physical properties of the agar obtained from them (Thivy 1951, 1960). As a result, *Gelidiella acerosa* was found to be an excellent source for manufacture of high quality agar. The yield, gel strength and other physical properties of agar-agar obtained from these species are summarised in Table 9.

Table 8

Bromine content of marine algae from the coast of Goa (From Naqvi et al. 1979)

Species	Bromine % (on dry weight basis)
CHLOROPHYTA	
<i>Cladophora</i> sp	0.024
<i>Chaetomorpha media</i>	0.105
<i>Enteromorpha</i> sp	0.032
<i>Caulerpa racemosa</i>	0.130
<i>Caulerpa sertularioides</i>	0.027
<i>Codium elongatum</i>	0.247
RHODOPHYTA	
<i>Gracilaria corticata</i>	0.078
<i>Hypnea musciformis</i>	0.027
<i>Acanthophora spicifera</i>	0.095
<i>Chondria armata</i>	0.400
<i>Chondrococcus</i> sp	0.054
<i>Corallina</i> sp	0.020
<i>Centroceras clavulatum</i>	0.063
PHAEOPHYTA	
<i>Sargassum tenerrimum</i>	0.040
<i>Dictyota dumosa</i>	0.022
<i>Padina tetrastratica</i>	0.022
<i>Spatoglossum asperum</i>	0.055
<i>Dictyota bartayresii</i>	0.015
<i>Dictyopteris australis</i>	0.039

Table 9

*Yield and physical properties of agar obtained from
Gelidiella and Gracilaria species*

Agarophyte	Yield (%)	Gel strength (1.5% solution)	temp. (1.5% solution)	Melting temp. (1.5% solution)
<i>Gelidiella acerosa</i>	45	300 g/cm ²	40°C	92°C
<i>Gracilaria lichenoides</i>	43	120 g/cm ²	45°C	84°C
<i>G. crassa</i>	23	140 g/cm ²	48°C	84°C
<i>G. corticata</i>	38	20 g/cm ²	44°C	68°C
<i>G. foliifera</i>	12	15 g/cm ²	40°C	—

Pillai (1955 C), during the course of chemical studies on marine algae carried out in Central Marine Fisheries Research Institute, observed that in *Gracilaria lichenoides* there were 60–90% of minerals and a good amount of sulphur, nitrogenous matter and carbohydrates occurring in water-soluble form and these compounds, which come as impurities while extracting agar, could be removed by pulverising, soaking and washing the weed. Based on this important observation, a cottage industry method was developed in the Institute for manufacture of pure agar from *Gracilaria lichenoides* (Pillai 1955 c and Thivy 1960), of which the details are given in the Appendix II. In this method, the impurities are removed from the seaweed before extraction and not from the gel. The leaching process will minimise the cost of production since large-scale equipments are not used for freezing the gel. The yield from the pulverised weed is also higher than that obtained by the earlier methods reported.

Another method was also described by Thivy (1960) for the extraction of agar-agar from *Gelidiella acerosa* (= *Gelidium mycrop-terum*), in which freezing technique is employed to retain the coldwater-soluble fraction of agar, but, without being able to remove the impurities from the weed effectively as in the case of *Gracilaria lichenoides* (= *G. edulis*).

Several methods were described subsequently for large-scale extraction of agar, with

minor modifications in the process given by Thivy. Kappanna and Visweswara Rao (1963) suggested that the quality of agar could be improved by freezing and thawing. In the pilot-plant trials conducted later, Visweswara Rao, et. al. (1965) soaked the pulverised weed overnight in fresh water before wet-grinding and extracting the agar. Details of this method is given in Appendix III. The method suggested by Srinivasan and Santharaja (1967) is more or less similar to the one described by Kappanna and Visweswara Rao (1963) but for the seaweed having been pulverised into fine powder before extraction. To eliminate the cost of freezing, Desai (1967) suggested 90% industrial alcohol for the flocculation of agar from filtrate.

Monthly variations in agar content in *Gracilaria lichenoides* were reported by Pillai (1955 c). Changes were noticed in the gel-like extractives (Pillai, 1957 b) obtained from the red algae *Chondria dasyphylla*, *Acanthophora spicifera*, *Laurencia papillosa*, *Hypnea musci-formis* and *Sarconema filiforme* in close relationship with the changes in the hot-water fraction of sulphur and organic extractives of these.

Some preliminary studies were also made by Thivy (1951) and Pillai (1957) on the agaroid content of species of *Hypnea*, *Spyridia*, *Sarconema*, *Acanthophora*, *Leurenica* and *Chondria*. The available information indicates that the yield of *Sarconema filiforme* extractive was 10% with a gel strength of 5g/cm² and a gelling temperature of 38°C for 1.5% solution.

Rama Rao (1970), studying the seasonal changes in yield and gel strength of the agar from *Hypnea musciformis* in relation to the growth cycle of the alga, found the phycocolloid content to be increasing gradually from less than 35 g/100 g dry alga to about 48 g/100 g from October to March. The gel strength of 1.5%, 2% and 2.5% solutions increased from October with maximum values in March. The maximum yield of agar and gel strength were observed during October-March, when peak vegetative activity was prevalent as was indicated by fresh and dry weights of the plant. In *Gelidiella acerosa* periodicity in the production of agar was observed by Thomas et. al. (1975). Yield and gel strength of agar showed two peak values of 50% and 367 g/cm² in May-June and 53% and 286 g/cm² in September-October. The yield and gel strength of agar attained highest levels about a month prior to the peak periods of growth. Gelling and melting temperatures of agar varied from 44.5° to 52.5° C and 81° to 84° C, respectively. Seasonal variations in gelling and melting temperatures were irregular and peak values occurred at the same time as that of yield and gel strength. As for *Gracilaria edulis*, the yield and quality of agar were determined by Thomas and Krishnamurthy (1976) in cultivated plants (from 4 harvests). Extraction was carried out for periods ranging from one to six hours. The maximum yield was obtained in four-hour extraction. Though the percentage yield of agar in all the harvests was more or less uniform, it was found that gel strength and gelling and melting temperatures were greater in the agar obtained from the second and third harvests. The extractions over 2 to 4 hours gave a product with increased gel strength and gelling and melting points. In order to determine the most suitable time for harvesting the plants, the agar was extracted from monthly samples. It is evident from the results that the best yield of agar was from plants harvested 3 months after planting. The data regarding the details of agar obtained from plants of different age are as follows:

Age of plant	Percentage yield	Gel strength (g/cm ²) of 1.5% agar	Gelling temp (°C)	Melting temp (°C)
One month	40	31	42	73
Two months	38	36	42	75
Three months	33	119	45	82
Four months	32	85	43	80
Five months	31	85	43	78

* Duration of extraction was 2h in all the cases.

Thomas (1977) reported seasonal variation in yield and physical properties of agar-agar from *Gracilaria verrucosa*. A maximum yield of 43% with highest gel strength of 173 g/cm² was seen in July. The yield was lowest (26%) in March and gel strength lowest (95 g/cm²) in September. Gelling temperature of agar varied between 40° and 44° C and melting temperature between 80° and 83°C.

Listing the phyco-colloid contents and their properties in 6 species of red algae, viz. *Gelidiella indica*, *Gracilaria corticata*, *G. fergusonii*, *G. foliifera*, *Acanthophora spicifera* and *Laurencia papillosa*, Subba Rao et. al (1977) gave the methods of phycocolloid extraction from these species. According to them, the yield and physical properties of agar-agar from *Gelidiella indica* and 3 species of *Gracilaria* are as follows:

Seaweed	Percentage yield	Physical properties of 1.5% phyco colloid		
		Gel strength (g/cm ²)	Gelling temp. (°C)	Melting temp. (°C)
<i>Gelidiella indica</i>	44	30	52	76
<i>Gracilaria corticata</i>	44	19	33	51
<i>G. fergusonii</i>	35	19	22	38
<i>G. foliifera</i>	25	31	41	68

The maximum yield obtained from *Acanthophora spicifera* was 12% and from *Laurencia papillosa* 19%.

A comparative study was made (Chennubhotla *et al* 1977 a) on the yield and physical properties of agar-agar from three different agarophytes, namely *Gelidiella acerosa*, *Gracilaria edulis*, *G. verrucosa*. The results were as follows:

	Percentage yield	Physical properties of 1.5% agar		
		Gel strength (g cm ²)	Setting temp (°C)	Melting tem (°C)
<i>Gelidiella acerosa</i>	40	125	46	73
<i>Gracilaria edulis</i>	55	63	48	65
<i>G. verrucosa</i>	23	41	40	55

Similar studies were conducted also on three blends, B I, B II, B III, made by compounding the aforesaid three species in the following proportions:

	B I	B II	B III
<i>Gelidiella acerosa</i>	45%	25%	25%
<i>Gracilaria edulis</i>	15%	50%	25%
<i>G. verrucosa</i>	40%	25%	50%

The yield was found to be highest in Blend III, but gel strength and setting and melting temperatures were low. In Blend II, the gel strength and setting and melting temperatures were maximum, and were nearer to those of the agar from *Gelidiella acerosa*, and *G. pusillum* from Saurashtra coast yielded 24% agar with a gel strength of 169 g/cm², and the same species grown in culture yielded 22% agar having a gel strength of 210 g/cm² (Mairh and Sreenivasa Rao 1978). The yield and gel strength of agar extracted from *Gracilaria corticata* and *Pterocladia heteroplotos* (= *Gelidium heteroplotos*) collected from Visakhapatnam area (Umamaheswara Rao 1978) are given below:

Seaweed	Yield (%)	Gel strength (g/cm ²)	
		1.0% sol	1.5% sol
<i>Gracilaria corticata</i>	44.64	64	134
<i>Pterocladia heteroplotos</i> (= <i>Gelidium heteroplotos</i>)	15.57	297	602

Oza (1978) studied the seasonal variations in the gel strength and gelling and melting temperatures of agar from *Gracilaria corticata* occurring in Veraval coast. The yield of agar varied between 14.5% and 22.5% in different months. The lowest yield was in August, September, October and May whereas the highest yield was in June-July and November-April. The low yield coincided with shedding of branches after liberation of tetraspores in August-September. The gel strength showed a minimum value of 17 g/cm² in July and maximum value of 27 g/cm² in November. During August, September and November, the gel strength remained more or less the same, varying only between 20 and 25 g/cm². The melting temperature of phycocolloid showed a narrow range of monthly variation, from 60° to 62°C, and gelling temperature from 40° to 42°C.

Rama Rao and Krishnamurthy (1978) reported seasonal variation in yield and gel strength of phycocolloid from *Hypnea musciformis* and *Hypnea valentiae*. The yield of phycocolloid in *Hypnea musciformis* varied between 49.9% in March and 27.2% in May. The gel strength was better (37.4 g/cm² to 75.0 g/cm²) when the yield was high (48.4%) and poor (30.05-52.3 g/cm²) when the yield was low (27.2%). The yield of phycocolloid in *Hypnea valentiae* varied between 38.95% in April and 27.2% in August in a year. A correlation between the yield and the gel strength was also noticed, the latter being high in April (85.27-151.25 g/cm²) when the yield was high (38.95%) and low in October (30.11 to 50.19 g/cm²) when the yield was lowest (30.10%). Thus, the maximum values of yield and gel strength of agar approximately coincided with the luxuriant growth of alga.

Chennubhotla *et al* (1979) studied the seasonal variations in the yield and physical properties of agar-agar from some of the commonly occurring agarophytes around Mandapam, the result obtained of which are presented below:

The monthly variations in carrageen content of *Hypnea musciformis* from Goa coast were studied by Solimabi *et al* (1980). The maximum yield of 51.6% was obtained in

Seaweed and Location	Max. yield of agar (%)	Month of yield	Gel strength (g/cm ²)	Gelling temp. (°C)	Melting temp. (°C)
<i>Gelidiella acerosa</i>					
Pudumadam	48.0	Jan.	316	36-44	62-86
Kilakarai	46.8	Nov.	320	42-49	61-83
Krusadai	50.8	Jan.	325	43-52	67-84
<i>Gracilaria edulis</i>					
Rameswaram	49.2	Sept.	111	41-57	46-69
Krusadai	45.0	Nov.	139	44-50	61-78
<i>G. corticata</i>					
Pudumadam	42.8	June.	22	40-49	49-60
<i>G. foliifera</i>					
Rameswaram	50.4	Sept.	55	38-51	48-70

December and minimum of 29.23% in May. The carrageen content increased from October to December and then declined. The low values of phycocolloid from February to May coincided with the decline in vegetative growth of the alga.

Kaliaperumal and Umamaheswara Rao (1981) studied the phycocolloid of *Gelidium pusillum* and *Pterocladia heteroplotos* growing in the intertidal habitats of Visakhapatnam coast. The yield and properties of agar extracted from these two gelidioid algae are given below.

Species	Yield	Gel strength (g/cm ²)		Gelling temp (°C)		Melting temp (°C)	
		1.0% conc.	1.5% conc.	1.5% conc.	1.5% conc.	1.5% conc.	1.5% conc.
<i>Gelidium pusillum</i>	50.0	175	276	38	86		
<i>Pterocladia heteroplotos</i>	35.1	167	288	38	83		

The yield of agar from *Pterocladia heteroplotos* varied from 32.2% to 37.9% without any marked seasonal pattern, except that high values were obtained between November and March. The gel strength of 1.0% and 1.5% agar solutions also varied

slightly in different months with high values in the period from November to February and in August. Though there was no seasonal change in the gelling temperature, the melting temperature varied in different months between a minimum of 76°C and a maximum of 88°C, the high values being between March and June.

The sulphate content of seaweed plays a major role in determining the gel strength of agar. Marked increases in the stability and gel strength of agar were observed in the experiments conducted by Doshi and Sreenivasa Rao (1967 a, b) by exposing the seaweed samples to cobalt-60 gamma radiations. Small doses varying between 0.5X10¹⁸ eV/g and 3.0X10¹⁸ eV/g increased the gel strength (1-2.5 times) in *Gelidiella acerosa*, *Gelidium micropterum* and *Gracilaria millardetii* (Doshi and Sreenivasa Rao 1967 b). These changes caused by radiations have been described to be due to breaking up of the organic sulphate fraction in the agar molecule. As such, the sulphate content present in the extractives of *Gelidium* spp. *Gelidiella acerosa*, *Gracilaria foliifera*, *G. millardetii*, *G. corticata*, *Hypnea musciformis* and *Furcellaria sp.* was precipitated with barium chloride and gel strength of agar was determined (Doshi et al 1968). The increase in gel strength was found corresponding with the decrease in the sulphate content.

Rama Rao and Krishnamurthy (1968) found that the physical properties of phyco-colloids were alterable by the addition of potassium chloride. They found that there was no gel formation in 1.0% solution of extractive from *Hypnea musciformis*. But addition of 0.5% potassium chloride to the extractive resulted in a remarkable increase in gel strength. These authors therefore suggested that, for the preparation of *Hypnea* agar, potassium chloride should be added before filtering the hot extract and the gel obtained be subjected to repeated freezing and thawing. Nevertheless, Thomas and Krishnamurthy (1976) did not find such increase in gel strength on addition of 0.5% potassium chloride in the agar from *Gracilaria edulis*. Subba Rao et al (1977) obtained two fractions, the upper soluble and lower insoluble, when the extractives of *Acanthophora spicifera* and *Laurencia papillose* were treated with 0.5% potassium chloride. The effect of pH on the yield and properties of agar extracted from *Gelidium pusillum* and *Pterocladia heteroplata* was determined, by Kaliaperumal and Uma-

maheswara Rao (1981). In general, there was no marked difference in yield, gel strength and gelling and melting temperatures of the phyco-colloid extracted in acidic and alkaline pH ranging from 5 to 10. However, the melting-temperature values were not uniform in these algae and the gel strength was slightly more in the alkaline pH.

Alginic acid: Some studies were made on Indian alginophytes. Alginic acid content present in the brown algae of Mandapam (Valson 1955), Gujarat (Kappanna et al 1962), Goa (Solimabi and Naqvi 1975) and Andhra (Umamaheswara Rao, 1978) coasts was determined. Data gathered on the alginic acid content of Indian brown seaweeds along with the localities from where the weeds have been collected are shown in the Table 10. Values of Valson (1955) and Kappanna et al (1962) presented in Table 10 are based on the titration method of Cameron et al (1948) and those of others, except Solimabi and Naqvi (1975), Durairaj et al (1978) and Umamaheswara Rao (1978), are on the maximum yield obtained from fully grown plants.

Table 10

Alginic acid content in Indian brown seaweeds

Seaweed	Locality	Yield of alginic acid (%)	Author
<i>Dictyota</i> spp	Sikka	5.50	Kappanna et. al, 1962
<i>D. bartayresiana</i>	Goa	22.94	Solimabi and Naqvi, 1975
<i>D. dumosa</i>	"	13.34	"
<i>D. dichotoma</i>	Andhra Pradesh	21.79	Umamaheswara Rao, 1978
<i>Padina</i> spp	Mandapam	10.35	Valson, 1955
<i>P. tetrastrumatica</i>	Goa	8.48	Solimabi and Naqvi, 1975
"	Andhra Pradesh	23.34	Umamaheswara Rao, 1978
<i>P. gymnospora</i>	Pudumadam (Mandapam)	24.80	Chennubhotla et. al., 1977 b
<i>Cystophyllum muricatum</i>	Mandapam	15.63	Valson, 1955
"	Sikka	19.74	Kappanna et. al, 1962
<i>Cystoseira indica</i>	Port Okha	15.60	Mairh, 1982
<i>Hormophysa triquetra</i>	Mandapam	18.22	Valson, 1955
<i>Colpomenia sinuosa</i>	Goa	16.65	Solimabi and Naqvi, 1975
<i>Spatoglossum asperum</i>	"	17.14	"

Table 10 contd.

Seaweed	Locality	Yield of alginic acid (%)	Author
<i>Stoechosperum marginatum</i>	Pudumadam	23.80	Kalimuthu <i>et. al.</i> , 1980
<i>Sargassum cinereum</i> <i>v. berberifolia</i>	Dwarka	29.17	Kappanna <i>et. al.</i> , 1962
<i>S. ilicifolium</i>	Andhra Pradesh	34.93	Umamaheswara Rao, 1978
"	Mandapam	30.80	Chennubhotla <i>et. al.</i> , 1982
<i>S. johnstonii</i>	Okha	22.34	Kappanna <i>et. al.</i> , 1962
<i>S. myriocystum</i>	Pamban	34.50	Chennubhotla <i>et. al.</i> , 1982
"	Pudumadam	26.07	Kalimuthu, 1980
"	Andhra Pradesh	32.34	Umamaheswara Rao, 1978
<i>S. tenerrimum</i>	Dwarka	4.85	Kappanna <i>et. al.</i> , 1962
"	Okha	10.08	"
"	Sikka	14.77	"
"	Saurashtra coast	10.39	Chauhan, 1970
"	Goa	15.16	Solimabi and Naqvi, 1975
<i>S. vulgare</i>	Andhra Pradesh	25.46	Umamaheswara Rao, 1978
<i>S. wightii</i>	Mandapam	31.70	Umamaheswara Rao, 1969 c
<i>Sargassum</i> spp	Mandapam	19.22	Valson, 1955
<i>Sargassum</i> spp	Hare Island (Off Tuticorin)	26.00	Durairaj <i>et. al.</i> , 1978
<i>Turbinaria conoides</i>	Mandapam	18.08	Valson, 1955
"	"	35.60	Umamaheswara Rao, 1969 c
<i>T. decurrens</i>	"	26.30	Kaliaperumal and Kalimuthu, 1976
<i>T. ornata</i>	"	32.18	Umamaheswara Rao and Kalimuthu, 1972

Sadasivan Pillai and Varier 1952 studied the structure and properties and the optimum conditions for preparation of the alginic acid from *Sargassum tenerrimum* and *S. wightii*. Later, Pillai (1957 c) at the Central Marine Fisheries Research Institute described a simple method for the extraction of alginic acid from *Sargassum* species. Of the different bleaching agents tried in this study, potassium permanganate was found most suitable for alginic acid. Bleaching was effected by treating the precipitate of alginic acid with potassium permanganate solution in the presence of hydrochloric acid. This method is given in Appendix IV. A cottage-industry method was also reported for the extraction of calcium alginate and alginic acid by Sadasivan Pillai

(1961), which is given in Appendix V. In a study conducted on brown seaweeds of Saurashtra coast, Visweswara Rao and Mody (1964) observed that the alginic acid obtained from calcium alginate was superior to the alginic acid precipitated directly from the extract of sodium alginate. Details of this method is given in Appendix VI. A method for the production of commercial grades of sodium alginate using 90% industrial alcohol to coagulate sodium alginate was reported by Desai (1967). Other workers (Shah *et al* 1967) also pointed out that alcohol coagulation gave alginates high viscosity. However, this method may not be economical because of the large quantities of alcohol required for separation of sodium alginate. Preparation of

sodium alginate with improved viscosity from *Sargassum* spp has been reported by Durairaj et al (1978).

Some preliminary experiments, that has yielded some favourable results, were conducted by Pillai (1964) to control flavour changes, oxidation of fat, dehydration, etc, in frozen seafoods during storage, using sodium alginate as coating material. In these experiments fishes like *Sardinella gibbosa*, *Elops* sp. *Sillago* sp. and two species of prawns were coated with an alginate gelly prepared by mixing 2.5% solution of sodium alginate, sodium and phosphate salts and citric acid and were quick frozen and stored at low temperature.

Seasonal changes in the alginic acid contents and viscosity of sodium alginates of four species of *Sargassum* collected from Gujarat coast was studied by Shah et al (1967). They observed increase in degree of polymerisation with increase in growth of plants. Variations in the alginic acid contents of *Sargassum wightii* and *Turbinaria conoides* growing in Gulf of Mannar were followed by Umamaheswara Rao (1969 c) for two and a half years. In *Sargassum wightii* the alginic acid content varied from 21.3% to 31.7% and in *Turbinaria conoides* from 23.2% to 35.6%. Peak quantities were found in these two brown algae during their maximum growth periods, from October to December or to January. Chauhan (1970) studied the variations in alginic acid content in relation to growth in two species of *Sargassum*. In *Sargassum tenerrimum* the alginic acid was found to vary from 7.1% to 10.39%, maximum in mature plants and minimum in young plants. But, Umamaheswara Rao and Kalimuthu (1972) found marked changes in the yield of alginic acid during the growth and development phases of *Turbinaria ornata*. They obtained high yield of alginic acid from both young and fully grown plants with minor variations from month to month. Kaliaperumal and Kalimuthu (1976), however, observed more marked monthly changes in the alginic acid content of *Turbinaria decurrens*, in which the yield during one year from March to February varied from 16.3% to 26.3%, with low values in April and May. Chennubhotla et al (1977 b) studied the seasonal variation of alginic acid in

Padina gymnospora for two years. The yield varied from 9.4% in September to 24.8% in following March. The alginic acid in *Stoechospermum marginatum* collected from Pudumadam varied from 14.5% to 23.8%, with maximum yield from September to December (Kalimuthu et al 1980). In *Sargassum myriocystum*, also collected from Pudumadam, the alginic acid content varied from 14.26% to 26.07%, with irregular yield during the entire period of study (Kalimuthu 1980). The alginic acid content in *Sargassum ilicifolium* collected from Mandapam ranged from 22.3% to 30.8% and that in *S. myriocystum* collected from Pamban ranged from 15.9% to 34.5%. In these two algae the yield of alginic acid was generally high during July to September, which almost coincided with the peak growth of the algae (Chennubhotla et al 1982). The alginic acid content in *Cytoseria indica* varied from 7.3% to 15.3% of dry weight (Mairh 1982), yielding highest value in September, when the aerial branches were mostly defoliated and the rhizomatous branches predominated. The next best values were found in June-July and November-December (about 10%), when the alga reached harvestable size and attained fruiting stage.

Mannitol

Mannitol, a sugar alcohol present in the cell sap of brown algae, has been reported from many brown seaweeds. Mannitol was extracted with 80% ethyl alcohol from two species of *Sargassum* growing at Cape Comorin by Varier and Sadasivan Pillai (1952), the details of which are given in Table 11. Highest values obtained of the mannitol contents of *Padina gymnospora* (Chennubhotla et al. 1977 b), *Stoechospermum marginatum* (Kalimuthu et al 1980), *Sargassum myriocystum* (Kalimuthu 1980; Chennubhotla et al 1982), *S. ilicifolium* (Chennubhotla et al 1982), *S. wightii* and *Turbinaria conoides* (Umamaheswara Rao 1969 c), *T. ornata* (Umamaheswara Rao and Kalimuthu 1972) and *T. decurrens* (Kaliaperumal and Kalimuthu 1976) by the titration method of Cameron et al (1948) are also given in this table. Shah and Rao (1969) determined the mannitol contents of several species of

Table 11

Mannitol content in Indian brown seaweeds

Seaweed	Locality	Mannitol (%)	Authors
<i>Padina gymnospora</i>	Pudumadam (Mandapam)	2.1	Chennubhotla <i>et. al.</i> , 1977 b Kalimuthu <i>et. al.</i> , 1980
<i>Stoechospermum marginatum</i>	"	2.8	Kalimuthu, 1980
<i>Sargassum myriocystum</i>	Pudumadam	5.0	Chennubhotla <i>et. al.</i> , 1982
"	Pamban	5.0	"
<i>S. ilicifolium</i>	Mandapam	5.0	Varier and Sadasivan Pillai, 1952
<i>S. tenerrimum</i>	Cape Comorin	9.4	"
<i>S. wightii</i>	"	7.3	Umamaheswara Rao, 1969 c
"	Mandapam	6.2	"
<i>Turbinaria conoides</i>	"	7.4	Umamaheswara Rao & Kalimuthu, 1972
<i>T. ornata</i>	"	7.1	"
<i>T. decurrens</i>	"	8.7	Kaliaperumal and Kalimuthu, 1976

Table 12

Values of Mannitol contents in different species and date of collection (Shah and Rao 1969)

Species	Habitat	Date of collection	Mannitol(%)
<i>Sargassum swartzii</i>	Okha Port reef	July. 1967	4.3
<i>S. tenerrimum</i>	"	Dec. 1967	4.6
"	Mandapam Camp	Nov. 1968	2.7
<i>Sargassum</i> (drift)	Idinthakarai	Sept. 1965	4.1
"	"	Oct. 1965	3.7
"	"	Nov. 1955	4.0
"	"	Dec. 1965	4.4
"	Pamban	Aug. 1965	2.5
"	"	Nov. 1965	3.4
<i>S. wightii</i>	Mandapam Camp	Nov. 1968	6.2
<i>S. johnstonii</i>	Okha Port reef	Dec. 1967	Traces
<i>S. cinereum</i>	Sikka	-	12.9
<i>Turbinaria</i> sp,	Pamban	Oct. 1965	2.6
Cystoseiraceae	Okha	Aug. 1967	Traces

brown seaweeds obtained from different localities, of which the data are given below.

The mannitol contents of 15 species of brown algae collected from various localities of Saurashtra coast such as Okha, Porbandar, Chorwad and Veraval from August 1964 to March 1966 were determined by Mehta and

Parekh (1978). Variations in mannitol content were observed among different genera of the seaweeds. The same species collected from different locations and at different periods also showed considerable variation. The maximum values of mannitol content in different species with the place and month of collection for each seaweed is given in Table 13.

Table 13

Maximum values of mannitol contents in different species of algae.

Alga	Place of collection	Month of collection	Mannitol content
<i>Dictyota bartayresiana</i>	Okha Port	March	7.10
<i>Dictyopteris australis</i>	Porbandar	December	7.37
<i>Iyengaria stellata</i>	Okha Port	January	7.32
<i>Levringia boergesenii</i>	Okha Port	March	10.80
<i>Padina tetrastromatica</i>	Porbandar	December	5.63
<i>Sargassum cinctum</i>	Porbandar	December	11.53
<i>S. swartzii</i>	Porbandar	December	11.11
<i>S. tenerrimum</i>	Okha Port	November	3.56
<i>S. vulgare</i>	Porbandar	December	11.59
<i>Spatoglossum asperum</i>	Okha Port	August	7.63
<i>S. variabile</i>	Okha Port	January	9.70
<i>Stoechospermum marginatum</i>	Okha Port	March	16.00
<i>Cystophyllum</i> sp.	Okha Port	November	5.63
<i>Cystoseira indica</i>	Porbandar	December	15.16
<i>Hydroclathrus clathratus</i>	Porbandar	December	6.50

Seasonal variation in the mannitol content was also recorded in different brown seaweeds by various workers. The amount of mannitol varied from 1.2 to 6.2% in *Sargassum wightii* and from 1.78 to 7.4% in *Turbinaria conoides* (Umamaheswara Rao 1969 c). Unlike the alginic acid, mannitol accumulated in the plants during the vegetative phase of the growth cycle and decreased to minimum during the maximum growth and fruiting periods of the algae. Monthly changes of mannitol in *Turbinaria ornata* was reported by Umamaheswara Rao and Kalimuthu (1972).

From the seasonal trends followed for four years, they found high mannitol content occurring during the early stages of growth, roughly from February to May. The amount of mannitol decreased with the development of receptacles. The estimated mannitol content in *T. decurrens* varied from 1.5% to 8.7% and the monthly changes were somewhat irregular (Kaliaperumal and Kalimuthu 1976). But, in general, the mannitol content of this alga appeared to be high during peak growth cycle. The mannitol content showed a variation from 0.5% in July to 2.1% in December in *Padina*

gymnospora, (Chennubhotla et. al 1977 b). In *Stoechospermum marginatum* the amount of mannitol varied from 1.2% to 2.7%. The mannitol content was found to be highest in October and during the months of May and June secondary peaks were noted (Kalimuthu et. al 1980). In *Sargassum myriocystum* collected from Pudumadam, the mannitol content ranged from 1.8% to 5.0% and the yield was irregular throughout the period of investigation (Kalimuthu 1980). Mannitol content ranged from 2% to 5% in *S ilicifolium* collected from

Pamban. There was no relationship between the seasonal changes of the mannitol and growth in these two species studied by Chennubhotla et. al (1982).

From the studies conducted by various workers on the variations in growth, yield of agar, algin and mannitol in many agarophytes and alginophytes of different localities, it is clear that the stature of plants at the time of collection in each locality determines the yield of agar or algin and mannitol.

BIBLIOGRAPHY

- AGADI, V. V. AND A. G. UNTAWALE. 1978. Marine algal flora of Goa coast. *Seaweed Res. Util.*, 3 (1 & 2): 56-70.
- AGADI, V. V., N. B. BHOSLE AND A. G. UNTAWALE. 1978. Metal concentration in some seaweeds of Goa (India). *Bot. Mar.*, 21 (4): 247-250.
- AGHARKAR, S. P. 1923. The present position of our knowledge of the aquatic flora of India. *Jour. Indian. bot. Soc.*, 3: 252-260.
- ANON, 1983. Proven Technology 7. Technology of cultured seaweed production. *Mar. Fish. Infor. Ser. T & E. 54*: 19-20.
- BACKGROUND, A 1976. "Nori" farming in Japan (cultivation of the edible seaweeds of the genus *Porphyra*). In: *Farming marine organisms low in the food chain. Development in Aquaculture and Fisheries Science*. Vol. 1 (Ed. P. Korringa) Elsevier Scientific Publishing Co. Amsterdam. pp 17-48.
- BALAKRISHNAN Nair, N., N. SHOBA AND M. ARUNACHALAM. 1982. Algae from southern Kerala coast. *Indian J. Mar Sci.*, 11 (3): 266-269.
- BARDACH, J. E. J., H. RYHTER AND W. O. MCLARNEY. 1972. Seaweed culture. In: *Aquaculture. The Farming and husbandry of Freshwater and Marine organisms*. Wiley-Interscience. A division of John Wiley & Sons, Inc. New York pp 790-840.
- BHANDERI, P. P. 1974 a. An estimate of the iodine yielding seaweed *Asparagopsis taxiformis* (Delile) Collins and Harvey from some subtidal reefs of Saurashtra coast. *J. mar. biol. Ass. India.*, 16 (1):288-289.
- BHANDERI, P. P. 1974 b. Culture of the agar yielding seaweeds on ropes from Gujarat. *J. mar. biol. Ass. India*, 16 (3):847-849.
- BHANDERI, P. P. AND Y. B. RAVAL. 1975. Possibility of seaweed cultivation along the Gujarat coast. *Seafood Export Jour.*, 7 (12):33-36.
- BHANDERI, P. P. AND Y. A. TRIVEDI. 1975. Seaweed resources of Hanumandandi reef and Vumani reef near Okha Port. *Indian J. mar. Sci.*, 4 (1):97-99.
- BHANDERI, P. P. AND Y. A. TRIVEDI. 1977. Rope culture of algin yielding seaweed *Hormophysa triquetra* (Linnaeus) Kuetzing. *Bot. Mar.* 20 (3):183-185.
- BHOSLE, N. B., V. K. DHARGALKAR AND A. G. UNTAWALE. 1975. Effect of seaweed extract on the growth of *Phaseolus vulgaris* L. *Indian J. mar. Sci.*, 4:207-210.
- BISWAS, K. 1932. Census of Indian algae. Scope of algological studies in India. *Rev. Algol.*, 6:197-219.

- BISWAS, K. 1934. Progress of algological studies in India. *Curr. Sci.*, 3:237-241.
- BISWAS, K. 1945. A general review of the marine algae of the western coast of India. *Jour. Bombay nat. Hist. Soc.* 45:515-530.
- BLACK, W. A. P. 1954. Constituents of the marine algae. *Ann. Rep. Chem. Soc.*, 50:322-335.
- BLANCO, G. J. 1973. Status and problems of coastal aquaculture in the Philippines. In: *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay) F. A. O. Fishing News (Books) Ltd., pp. 60-67.
- BLUNDEN, G., C. J. BARWELL, K. J. FIDGEN AND K. JEWERS. 1981. A survey of some British marine algae for anti-influenza virus activity. *Bot. Mar.*, 14 (5) 267-272.
- BOERGESEN, F. 1930. Some Indian green and brown algae especially from the shores of the Presidency of Bombay. *Jour. Indian bot. Soc.*, 9:151-174.
- BOERGESEN, F. 1931. Some Indian Rhodophyceae especially from the shores of the Presidency of Bombay—I. *Kew. Bull.*, No. 1: 1-24.
- BOERGESEN, F. 1932a. Some Indian Rhodophyceae especially from the Presidency of Bombay—II. *Kew. Bull.*, No. 3: 113-134.
- BOERGESEN, F. 1932 b. Some Indian green and brown algae especially from the Presidency of Bombay. *Jour. Indian. bot. Soc.*, 11: 51-70.
- BOERGESEN, F. 1933 a. Some Indian Rhodophyceae especially from the Presidency of Bombay III. *Kew. Bull.*, No. 3: 113-142.
- BOERGESEN, F. 1933 b. Some Indian green and brown algae from the Presidency of Bombay. *Jour. Indian bot. Soc.*, 12: 1-16.
- BOERGESEN, F. 1934 a. Some Indian Rhodophyceae especially from the Presidency of Bombay-IV. *Kew. Bull.*, No. 4: 1-30.
- BOERGESEN, F. 1934 b. Some marine algae from the northern part of the Arabian Sea with remarks on their geographical distribution. *Kgl. Dansk. Vidensk. Selskab Biol. Meddel.* 11 (6): 1-72.
- BOERGESEN, F. 1935. A list of marine algae from Bombay. *Kgl. Dansk. Vidensk. Selskab Biol Meddel.*, 12 (2): 1-64.
- BOERGESEN, F. 1937 a. Contributions to a South Indian Marine Algal flora-1. *Jour. Indian bot. Soc.*, 16: 1-56.
- BOERGESEN, F. 1937 b. Contributions to a South Indian Marine Algal flora-II. *Jour. Indian bot. Soc.*, 16: 311-357.
- BOERGESEN, F. 1938. Contributions to a South Indian Marine Algal flora-III. *Jour. Indian bot. Soc.*, 17: 205-242.
- BOKIL, K. K., V. C. MEHTA AND D. S. DATAR. 1972. Seaweed as manure. III, Field manurial trials on *Pennisetum typhoides* S. H. (Pearl Millet) and *Arachis hypogaea* (Groundnut). *Bot. Mar.*, 15 (3): 148-150.

- BOKIL, K. K., V. C. MEHTA AND D. S. DATAR. 1974. Seaweed as manure: II. Pot culture manurial experiments on wheat. *Phykos*, 13 (1): 1-5.
- BOSE, J. L., KARIMULLAH AND S. SIDDIQUE. 1943. Manufacture of agar in India. *J. Sci. Industr. Res.*, (India) 1: 98.
- BURELLY, P. 1968. Les algues d'eau douce Bou bee et. Cie, Paris. Tomes 1, 2 and 3.
- BUKHARI, S. S. AND A. G. UNTAWALE. 1978. Seaweeds as liquid fertilizer and foliar spray. *Seaweed Res. Util.*, 3 (1&2): 71-78.
- CACCAMESE, S., R. AZZOLINA, G. FURNARI, M. CORMACI AND S. GRASSO. 1980. Antimicrobial and antiviral activities of extracts from Mediterranean algae. *Bot Mar*, 23 (5): 285-288.
- CACCAMESE, S., R. AZZOLINE, G. FURNARI, M. CORMACI AND S. GRASSO. 1981. Antimicrobial and antiviral activities of some marine algae from eastern Sicily. *Bot Ma.*, 24 (7): 365-367.
- CAMERON, M. C., A. G. ROSS AND E. G. V. PERCIVAL. 1948. Methods of the routine estimation of mannitol, alginic acid and combined fucose in seaweeds. *Jour. Soc. Chem. Ind.* London, 67: 161-164. ◆
- CHACKO, P. I. AND C. MALU PILLAI. 1958. Studies on utilisation of the seaweed resources of Madras State. *Contr. Mar. Biol. St. Krusadai Island*, 6: 1-12.
- CHACKO, P. I., S. MAHADEVAN AND R. GANESAN, 1955. A guide to the field study of the fauna and flora of Krusadai Island, Gulf of Mannar. *Contr. Mar. Biol. St. Krusadai Island*, 3: 1-16.
- CHADEFAUD, M. 1960. *Traite de Botanique*, Tome 1, Masson et. cie, Paris.
- CHAKRABORTY, D. 1945. Agar-agar manufacture from *Gracilaria confervoides*. *Jour. Proc. Inst. Chem.* (India), 17: 188.
- CHAPMAN, V. J. 1962. *The algae*. London.
- CHAPMAN, V. J. AND D. J. CHAPMAN. 1975. *The algae*. English Language Book Society and Macmillan, 497 pp.
- CHAPMAN, V. J. AND D. J. CHAPMAN, 1980. *Seaweeds and Their Uses*. Third Edition, Chapman and Hall, London. pp 62-97.
- CHATURVEDI, D. K., S. S. VERMA AND S. P. KHARE. 1979. Studies on feeding marine algae (Gracilaria meal) to laying white leghorn birds. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. p. 51 (Abstract).
- CHAUHAN, V. D. 1970. Variation in alginic acid content with growth stages in two species of *Sargassum*. *Bot. Mar.*, 13 (1): 57-58.
- CHAUHAN, V. D. 1972. Physiological ecology of the early stages of *Sargassum swartzii* (Turner) C. Ag. *Bot. Mar.* 15 (1): 49-51.
- CHAUHAN, V. D. 1978. Report on the survey of marine algae resources of Maharashtra coast. *Salt. Res. Ind.*, 14 (1): 1-10.

- CHAUHAN, V. D. AND V. KRISHNAMURTHY. 1967. Observations on the output of oospores, their liberation, viability and germination in *Sargassum swartzii* (Turn) C. Ag. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar, pp. 197-201.
- CHAUHAN, V. D. AND V. KRISHNAMURTHY. 1968. An estimate of algin bearing seaweeds in the Gulf of Kutch. *Curr. Sci* 37: 648.
- CHAUHAN, V. D. AND O. P. MAIRH. 1978. Report on the survey of marine algae resources of Saurashtra coast, India. *Salt. Res. Ind.*, 14 (2): 21-41.
- CHAUHAN, V. D. AND H. V. JOSHI. 1979. Effect of Indole-3-Acetic acid and Gibberellic acids on the early growth of *Sargassum*. *Proc. Int. Seaweed Symp. Marine Algae of the Indian Ocean Region*. CSMCRI, Bhavnagar, India. p. 23 (Abstract).
- CHEN, T. P. 1976. Culture of *Gracilaria*. In: *Aquaculture practices in Taiwan*. Page Bros. (Norwich) Ltd. pp. 145-149.
- CHENNUBHOTLA, V. S. K. 1976. Seaweed Culture. *Indian Science Congress 63rd Session, Waltair (Abstract)*.
- CHENNUBHOTLA, V. S. K. 1977. Food from the sea: food from the seaweeds. *Seafood Export Jour.*, 9 (3): 1-4.
- CHENNUBHOTLA, V. S. K., M. NAJMUDDIN AND BIDYADHAR NAYAK. 1977 a. A comparative study of the yield and physical properties of agar-agar from different blends of seaweeds. *Seaweed Res. Util.*, 2 (2): 87-90.
- CHENNUBHOTLA, V. S. K., S. KALIMUTHU, N. KALIAPERUMAL AND J. R. RAMALINGAM. 1977 b. Studies on the growth variation, alginic acid and mannitol contents in *Padina gymnospora* (Kuetzing) Vickers. *Seaweed Res. Util.* 2 (2): 91-94.
- CHENNUBHOTLA, V. S. K., S. KALIMUTHU, M. NAJMUDDIN AND M. SELVARAJ. 1977 c. Field culture of *Gelidiella acerosa* in the inshore waters of Gulf of Mannar. Supplement to *Jour. Phycol.* Vol. 13, Abstract No. 454.
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL AND S. KALIMUTHU. 1978 a. Culture of *Gracilaria edulis* in the inshore waters of Gulf of Mannar (Mandapam). *Indian J. Fish.*, 25 (1 & 2): 228-229.
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL AND S. KALIMUTHU. 1978 b. Seasonal changes in growth, fruiting cycle and oospore output in *Turbinaria conoides* (J. Ag.) Kuetzing. *Bot. Mar.*, 21 (1): 67-69
- CHENNUBHOTLA, V. S. K., KALIMUTHU, M. NAJMUDDIN, R. PANIGRAHY AND M. SELVARAJ. 1979. Seasonal variation in growth, yield of agar-agar and its physical properties in some agarophytes of Tamil Nadu Coast. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*. CSMCRI, Bhavnagar, India p. 41 (Abstract).
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL AND S. KALIMUTHU. 1981. Seaweed recipes and other practical uses of seaweeds. *Seafood Export Jour.*, 13 (10): 9-16
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL, S. KALIMUTHU, M. SELVARAJ, J. R. RAMALINGAM AND M. NAJMUDDIN. 1982. Seasonal changes in growth and alginic

- acid and mannitol contents in *Sargassum ilicifolium* (Turner) J. Agardh and *S. myriocystum* J. Agardh. *Indian J. Mar. Sci.*, 11 (2): 195-196.
- CHENNUBHOTLA, V. S. K. 1981. *Status of seaweed industry in India*. U N D P Report on the Training Course on *Gracilaria* algae of the South China Sea Fisheries Development and co-ordinating Programme, Manila, Philippines. No SCS/Gen/81/29: 139-145.
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL, S. KALIMUTHU AND PVR. NAIR. 1983. Biology of the economically important Indian seaweeds. Collected Abstracts of the International Seaweed Symposium, Qingdao, China.
- CHENNUBHOTLA, V. S. K., S. KALIMUTHU, M. NAJMUDDIN, R. PANIGRAPHY AND M. SELVARAJ. 1986. Changes in growth and phycocolloid content of *Gelidium acerosa* and *Gracilaria edulis*. *Seaweed Res. Utiln.* 9 (1 & 2): 45-48.
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL, J. R. RAMALINGAM AND S. KALIMUTHU. 1986. Growth, Reproduction and spore output in *Gracilaria foliifera* (Forsk.) Boergesen and *Gracilariaopsis sjoestedtii* (Kylin) Dawson around Mandapam. *Indian J. Fish.* 33 (1): 76-84.
- CHENNUBHOTLA, V. S. K., S. KALIMUTHU AND M. SELVARAJ. 1986. Seaweed culture—its feasibility and industrial utilization *Proc. Symp. Coastal Aquaculture* 4: 1206-1209.
- CHENNUBHOTLA, V. S. K., B. S. RAMACHANDRUDU, P. KALADHARAN AND S. K. DHARMARAJ. 1987. Seaweed resources of Kerala coast. Seminar on Fisheries Research and Development in Kerala. Trivandrum (Abstract).
- CHENNUBHOTLA, V. S. K., M. NAJMUDDIN, J. R. RAMALINGAM AND N. KALIAPERUMAL. 1987. Biochemical composition of some marine algae of Mandapam coast (South India). Symposium on Research and Development in Marine Fisheries. Mandapam camp.
- CHENNUBHOTLA, V. S. K., N. KALIAPERUMAL AND M. S. RAJAGOPALAN. 1987. Seaweed culture in India—An appraisal. *Ibid.*
- CHIDAMBARAM, K. AND M. M. UNNY. 1947. Note on the value of seaweeds as manure. *Madras Agri. Jour.* (July).
- CHIDAMBARAM, K. AND M. M. UNNY. 1953. Note on the value of seaweeds as manure. *Int. Seaweed Symp.*, pp. 67-68.
- CHRISTENSEN, T. 1962. *Alger*. In *systematisk Botanik* (Ed. T. W. Bocher, M. Lange and T. Sorenson) Vol. 2. No. 2. Munkagaard, Copenhagen. 178 pp.
- DAVE, H. M., V. SITAKARA RAO AND U. K. TIPNIS. 1969. Iodine content of marine algae from Saurashtra coast. *Phykos*, 8: 68-70.
- DAVE, M. J. AND R. G. PAREKH. 1975. Protein content of green seaweeds from Saurashtra coast. *Salt. Res. Indi.*, 11 (2): 41-44.
- DEVE, M. J., S. K. GARG AND E. R. R. IYENGAR. 1977. Assessment of the possibility of seaweeds to be utilised as supplementary animal feed. *Salt. Res. Ind.*, 13 (1&2): 33-40.

- DAVE, M. J., R. G. PAREKH, S. K. GARG AND D. J. METHA. 1979. Preparation of seaweed meal for the feeding of farm animals. *Salt Res. Ind.*, 15 (2): 34-38.
- DAVIDSON, F. E. 1950. The effect of auxin on the growth of marine algae. *Amer Jour. Bot.*, 37: 502-510.
- DAWSON, E. Y. 1966. *Marine Botany: An introduction*. Holt, Rinehart and Winston Inc, New York, 371 pp.
- DE JUSSIEU, A. L. 1789. *Genera plantarum secundum ordines naturales disposita*, Paris. 498 pp.
- DESAI, B. N. 1967. Seaweed resources and extraction of alginate and agar. *Proc. Semi Sea Salt and Plants*, CSMCRI, Bhavnagar, pp. 343-351.
- DEVEAU, L. E. AND J. R. CASTLE. 1979. The industrial development of farmed marine algae. The case history of *Euchenuma* in the Philippines and USA. In: *Advances in Aquaculture* (Ed. T. V. R. Pillay and Wm. A. Dill) F. A. O. Fishing News Books Ltd. England. pp 410-415.
- DHANDUKIA, M. M. AND R. SESHADRI. 1969. Arsenic content in marine algae. *Phykosa*, 8: 108-111.
- DHARGALKAR, V. K. 1979. Biochemical studies on *Ulva reticulata* Forsskal. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, p. 40 (Abstract)
- DHARGALKAR, V. K., T. G. JAGTAP AND A. G. UNTAWALE. 1980. Biochemical constituents of seaweeds along the Maharashtra coast. *Indian. J. Mar. Sci.*, 2 (4): 297-299.
- DHARGALKAR, V. K., V. V. AGADI AND A. G. UNTAWALE. 1981. Occurrence of *Porphyra vietnamensis* (Bangiales, Rhodophyta) along the Goa coast. *Mahasagar*, 14 (1): 75-77.
- DIXIT, S. C. 1964. Species list of Indian marine algae determined by Boergesen. *J. Uni. Bombay*, 32 (2-5): 1-23.
- DIXIT, S. C. 1968. Species list of Indian marine algae- II *J. Univ. Bombay*, 36 (3-5): 9-24.
- DODGE, J. D. 1969. A review of the fine structure of algal eye spots. *Br. phycol. J.* 4 199-210.
- DOSHI, Y. A. AND P. SREENIVASA RAO. 1967 a. Stable agar by gamma irradiation *Nature* 216: 931.
- DOSHI, Y. A. AND P. SREENIVASA RAO. 1967 b. Radiation induced enhancement of gel strength in red seaweeds. *Indian Jour Chem.*, 5: 342-343.
- DOSHI, Y. A., P. V. RAJU AND P. SREENIVASA RAO. 1968. A relation between the sulphate content in red seaweeds and the gel strength of agar. *Sci. Cul.*, 34: 493.
- DOUGHERTY, E. G. AND ALLEN, M. B. 1960. In: *Comparative biochemistry of photoreactive systems* (Ed. M. B. Allen). Academic Press, New York and London. pp. 129-143.
- DURAIRAJ, S., K. G. JOSEPH AND M. KINGSLEY LAINE. 1978. Preparation of sodium alginate with improved viscosity. *Seaweed Res. Util*, 3 (1&2): 5-8.

- EICHLER, A. W. 1886. Syllabus der Vorlesungen über speciella and Medicinisch-pharmaceutische Botanik, 4th Ed. Berlin
- ENDLICHER, S. 1836. Genera plantarum secundum ordines naturales disposita. Vindbonae
- FELDMANN, G. 1963. In *Precis de Botanique*. (Ed. M. Chadeaud and M. Emberger) Masson et. Cie, Paris. pp 83-249.
- FOTT, B. 1959. Algenkunde, Gustav Fisher, Jena.
- FRITSCH, F. E. 1935. *The structure and reproduction of algae*, Vol. I. University Press, Cambridge. pp. 1-791.
- FURUKAWA, A. 1973. Present status of Japanese marine aquaculture. In: *Coastal Aquaculture in Indo-Pacific Region* (Ed. T. V. R. Pillay). F. A. O Fishing News (Books) Ltd., pp. 29-47.
- GARBER, P., J. D. DUTCHER, E. G. ADAMS AND J. R. SHERMAN. 1958. Protective effects of seaweed extracts for chicken embryos infected with influenza B or mumps virus. *Proc. Soc. Exp. Biol. Med.*, 99. 590-593.
- GOLDSTEIN, M. E. 1973. Regeneration and vegetative propagation of the agarophyte *Gracilaria debilis* (Forsk.) Boergesen. (Rhodophyceae) *Bot. Mar.*, 26 (4): 226-228.
- GOPALAKRISHNAN, P. 1969. Some marine algae from the Gulf of Kutch. *Phykos*, 8: 61-67.
- GOPALAKRISHNAN, P. 1970. Some observation on the shore ecology of the Okha coast. *J. mar. biol. Ass. India*. 12 (1 & 2): 15-34.
- GUIST, G. G., C. J. DAWES AND J. R. CASTLE. 1982. Mariculture of the red seaweed, *Hypnea musciformis*. *Aquaculture*, 28 (3, 4): 375-384.
- HARVEY, W. H. 1836. Algae. In *Flora Hibernica*, Mackay, J. T. Dublin.
- HENRIQUEZ, P., A. CANDIA, R. NORAMBUENA, M. SILVA AND R. ZEMELMAN. 1979. Antibiotic properties of marine algae. II. Screening of Chilean marine algae for antimicrobial activity. *Bot. Mar.*, 22 (7): 461-463.
- HORNELL, J. 1918. *Report on the further development of fishery resources of Baroda State*.
- HUMM, H. J. 1951. The red algae of economic importance. Agar and related phycocolloids. In: *Marine Products of Commerce* (Ed. Tressler, D. K.). New York.
- IYENGAR, M. O. P. 1957. Algology in progress of science in India. Sn. VI. Botany. *Natn. Inst. Sci. India*. New Delhi: 229-251.
- JAGANNATHAN, V. AND R. VENKATAKRISHNAN. 1979. Nutritional investigations of seaweeds in chick ration. *Proc. Int. Symp on Marine Algae of the Indian Ocean Region CSMCRI, Bhavnagar, India* pp. 49-51 (Abstract).
- JAMES, P. S. B. R., V. S. K. CHENNUBHOTLA AND RODRIGO. 1980. Studies on the fauna associated with the cultured seaweed *Gracilaria edulis*. *Proc Symp. Coastal Aquaculture, M. B. A. I., Cochin, India*, p. 111 (Abstract)

- JOSEPH, I. AND S. MAHADEVAN, 1948. Production of agar-agar. *Dept. Res. Univ. Travancore, Rep. for Septen.*, pp. 55-60.
- JOSEPH, I., K. GANAPATHY AND S. RAMAMURTHY. 1948. Recoverable iodine from Indian *Sargassum*. *Dept. Res. Univ. Travancore, Rep. for Septen.*, pp. 60-61.
- JOSHI, A. C. 1949. Indian Botany; present position and prospects. Presidential Address. *Four. Indian bot. Soc.*, 28: 1-15.
- JOSHI, H. V. AND V. KRISHNAMURTHY. 1971. The species of *Enteromorpha* from India *Bot. J. Linn. Soc.*, 65 (1): 119-128.
- KALE, S. R. AND KRISHNAMURTHY. 1967. Effect of different media on the germlings of *Ulva lactuca* var. *rigida*. *Phykos*, 6 (1 & 2): 32-35.
- KALIAPERUMAL, N. AND M. UMAMAHESWARA RAO. 1975. Growth, fruiting cycle and oospore output in *Turbinaria decurrens* Bory. *Indian J. Fish.*, 22 (1 & 2): 225-230.
- KALIAPERUMAL, N. AND S. KALIMUTHU. 1976. Changes in growth, reproduction, alginic acid and mannitol contents in *Turbinaria decurrens* Bory. *Bot. Mar.*, 19: 157-159.
- KALIAPERUMAL, N. AND M. UMAMAHESWARA RAO. 1981. Studies on the standing crop and phycocolloid of *Gelidium pusillum* and *Pterocladia heteroplata* *Indian J. Bot.*, 4 (2): 91-95.
- KALIAPERUMAL, N. AND M. UMAMAHESWARA RAO. 1982. Seasonal growth and reproduction of *Gelidiopsis variabilis* (Greville) Schmitz *J. Exp. Mar. Biol. Ecol.*, 61: 265-270.
- KALIAPERUMAL, N., V. S. K. CHENNUBHOTLA AND S. KALIMUTHU. 1977. Growth, reproduction and liberation of oospores in *Turbinaria ornata* (Turner) J. Agardh. *Indian J. Mar. Sci.*, 6 (2): 178-179.
- KALIMUTHU, S. 1980. Variations in growth and mannitol and alginic acid contents of *Sargassum myriocystum* J. Agardh *Indian J. Fish.*, 27 (1 & 2): 265-266.
- KALIMUTHU, S., V. S. K. CHENNUBHOTLA, M. SELVARAJ, M. NAJMUDDIN AND PANIGRAHY, 1980. Alginic acid and mannitol contents in relation to growth in *Stoechospermum marginatum* (C. Agardh) Kuetzing. *Indian Fish*, 27 (1 & 2): 267-269.
- KANNAN, L. AND K. KRISHNAMURTHY. 1978. A survey of the algae of the Porto-Novo region (Coromandel Coast. Bay of Bengal). *Seaweed. Res. Util.* 3 (1 & 2): 1-4.
- KAPPANNA, A. N. AND V. SITAKARA RAO. 1932. Iodine content of marine algae from Gujarat coast. *Jour. Sci. Indust. Res. (India)*, 21: 559-560.
- KAPPANNA, A. N. AND A. VISWESWARA RAO. 1963. Preparation and properties of agar-agar from Indian seaweeds. *Indian Jour. Tech.* 1: 224.
- KAPPANNA, A. N., A. VISWESWARA RAO AND I. C. MODY. 1962. Alginic acid content of some of the brown seaweeds of Sourashtra coast. *Curr. Sci.*, 31: 463-464.
- KARUNAKAR, P. D., M. S. RAJU AND S. VARADARAJAN. 1948. Manufacture of agar-agar from seaweed, *Gracilaria lichenoides*. *Indian Vet. J.*, 24: 274.

- KOSHY, T. K. AND C. C. JOHN. 1948. Survey of *Gracilaria* resources of Travancore coast. *Dept. Res Unia. Travancore. Rep. for Septen..* pp 53-55.
- KOW, T. A., Y. S. LING AND T. W. HIN. 1973. Experiments in coastal aquaculture in Singapore. In: *Coastal Aquaculture in the Indo-Pacific Regions* (Ed. V. V. R. Pillay) F. A. O. Fishing News (Books) Ltd., England pp. 375-383.
- KRISHNAMURTHY, V. 1967. Marine algal cultivation—necessity, principles and problems. *Proc. Semi. Sea Salt and Plants* CSMCRI, Bhavnagar. pp. 327-333.
- KRISHNAMURTHY, V. 1980. The marine algae of Tiruchendur, South India. *Seaweed Res. Util.*, 4 (1): 49-58.
- KRISHNAMURTHY, V. AND H. V. JOSHI. 1969. The species of *Ulva* Indian waters. *Bot J. Linn. Soc.* 62: 123-130.
- KRISHNAMURTHY, V. AND H. V. JOSHI. 1970. A Check-list of Indian Marine Algae, CSMCRI, Bhavnagar. pp. 1-36.
- KRISHNAMURTHY, V. R. VENUGOPAL, J. G. THIAGARAJ AND H. N. SHAH. 1967. Estimating drift seaweeds on the Indian coasts. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar, pp. 315-320.
- KRISHNAMURTHY, V., P. V. RAJU AND R. VENUGOPAL. 1969. An aberrant life history in *Gracilaria edulis* (Gmel.) Silva and *Gracilaria corticata* J. Ag. *Curr. Sci.*, 38 (14): 343-344.
- KRISHNAMURTHY, V., P.V. RAJU AND P. C. THOMAS. 1975. On augmenting seaweed resources of India. *J mar. biol. Ass. India.*, 17. (2): 181-185.
- KUROGI, M. 1963. Recent laver cultivation in Japan. *Fishing News Intl.*, 2 (3): 269-274.
- LANGALIA, J. K., K. SESHADRI AND D. S. DATAR. 1967. The alkali contents of the marine algae. *Proc. Semi Sea. Salt and Plants*, CSMCRI, Bhavnagar pp. 289-295.
- LEVRING, T., H. A. HOPPE AND O. J. SCHMID. 1969. *Marine Algae. A survey of Research and Utilization.* Gram, be Gruyter & Co., Hamburg, pp. 1-421.
- LEWIS, E. J. 1962 a. Studies on the proteins, peptides, and free aminoacid contents in some species of *Padina* from south-eastern coast of India. *Curr Sci.*, 31. 90-92.
- LEWIS, E. J. 1962 b. Studies on the proteins peptides and free aminoacid contents in some species of brown algae from south-eastern coast of India. *Rev. Algal.*, 6: 209-216.
- LEWIS, E. J. 1963 a. Studies on the proteins, peptides and free aminoacid contents in some species of marine algae from south-eastern coast of India. *Rev., Algal.*, 7: 15-25.
- LEWIS, E. J. 1963 b. The proteins, peptides and free aminoacid composition in species of *Acanthophora* from south east coast of India *Rev., Algal.*, 7: 237-241.
- LEWIS, E. J. 1963 c. Studies on the proteins, peptides and free aminoacid contents in some species of red algae from south-eastern coast of India. *Proc. natn. Inst. Sci. India*, 29: 137-145.
- LEWIS, E. J. 1963 d. Studies on fortnightly analysis of the proteins, peptides and free aminoacids in some marine algae from Bombay. *Proc. natn. Inst. Sci. India*, 29: 363-286.

- LEWIS, E. J. 1967. A review of protein, peptide, and free aminoacid contents of Indian Marine Algae. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar, pp. 296-308.
- LEWIS, E. J. AND E. A. GONZALVES. 1959 a. Studies on the free aminoacid contents of some marine algae from Bombay. *Jour. Univ. Bombay*, 28: 1-5.
- LEWIS, E. J. AND E. A. GONZALVES. 1959 b. Aminoacid contents of the erect and creeping fronds of species of *Caulerpa* from Bombay. *Jour. mar. biol. Ass. India*, 1: 54-56.
- LEWIS, E. J. AND E. A. GONZALVES. 1959 c. Studies on the free aminoacid contents of species of *Caulerpa* from Bombay. *Jour. mar. biol. Ass. India*, 1: 203-205.
- LEWIS, E. J. AND E. A. GONZALVES. 1960. Aminoacid contents of some marine algae from Bombay. *New Phytol.*, 59: 109-115.
- LEWIS, E. J. AND E. A. GONZALVES. 1962 a. Studies on the protein, peptide and free aminoacids in cystocarpic and tetrasporic plants of *Agardhiella roubusta* from Bombay. *New Phytol.*, 61: 288-290.
- LEWIS, E. J. AND E. A. GONZALVES. 1962 b. The protein, peptide and aminoacid contents of some species of marine algae from Bombay. *Ann. Bot. N. S.*, 26: 301-316.
- LEWIS, E. J. AND E. A. GONZALVES. 1962 c. Periodic studies of the proteins, peptides and free aminoacid in *Enteromorpha prolifera*, f. *capillaris* and *Ulva lactuca* var. *rigida*. *Ann. Bot. N. S.*, 26: 317-327.
- LING, S. W. 1973. A review of the status and problems of coastal aquaculture in the Indo-Pacific Region. In: *Coastal Aquaculture in the Indo-Pacific Region*. (Ed. T. V. R. Pillay) F. A. O. Fishing News (Books) Ltd., pp. 2-25.
- LINNAEUS, C. 1754. *Genera plantarum*. Holmiae. 500 pp.
- MAHONTY, C. B. 1956. Fishery byproducts industry in India—Seaweeds. in : *Progress of Fisheries Development in India-Cuttack*.
- MAIRH, O. P. 1982. Seasonal variation in alginic acid and viscosity of sodium alginate from a brown alga *Cystoseira indica* (Thivy et Doshi) Mairh, from Port Okha. *Seaweed Res Util.*, 2 (1) : 43-46.
- MAIRH, O. P. AND V. KRISHNAMURTHY. 1988. Observations on the germination of spores and growth of germlings in a *Cystoseira*. *Jour. Indian bot. Soc.* 47 : 256-263.
- MAIRH, O. P. AND P. SREENIVASS RAO. 1978. Culture studies on *Gelidium pusillum* (Stack). *Le Jolis. Bot. Mar.*, 21 (3) : 169-174.
- MAIRH, O. P., P. C. THOMAS, B. K. RAMAVAT AND P. SREENIVASA RAO. 1979. Fertilizer pellets and their application in the field cultivation of *Gelidiella acerosa* (Forssk.) Feld et Hamel. *Proc. Int. Symp. Marine Algae of Indian Ocean Region*, CSMCRI, Bhavnagar, India. Abstract No. 12.
- MATHIESON, A. C. 1969. The promise of seaweed. *Oceanology Intl.*, Jan/Eeb. 1969. pp. 37-39.
- MEHTA, B. R. AND R. G. PAREKH. 1978. Mannitol content in brown algae of the coast of Sourashtra. *Bot. Mar.*, 21 (4) : 251-252.

- MEHTA, V. C., B. S. TRIVEDI, K. K. BOKIL AND M. R. NARAYANA. 1967. Seaweeds as manure: I- Studies on nitrification. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar. pp. 357-365.
- MICHANEK, G. 1975. Seaweed resources of the Ocean, F. A. O. *Fish. Tech. Rep.* No. 138. pp 1-126.
- MISRA, J. N. 1966. *Phaeophyceae in India*. I. C. A. R. New Delhi, pp. 1-203.
- MITRA, G. 1946. *Development of Chilka Lake, Cuttack*
- MIURA, A. 1975. *Porphyra* cultivation in Japan. In : *Advance of phycology in Japan*. (Ed. J. Tokida AND H. Hirose) Dr. W. Jung b. v. Publishers, The Hague. pp. 273-304.
- MOHAN JOSEPH, M. AND V. KRISHNAMURTHY. 1977. Studies on the shedding of carpospores in *Gracilaria corticata* J. Ag. *Seaweeds Res Util.*, 2 (1) : 1-8.
- MURTHY, M. S. AND P. RADIA. 1978. Eco-biochemical studies on some economically important intertidal algae from Port Okha (India). *Bot. Mar.*, 21 (7) : 417-422.
- NAQVI, S. W. A., MITTAL, S. Y. KAMAT, SOLIMABI AND C. V. G. REDDY. 1979. Bromine content in some seaweeds of Goa (central west coast of India). *Bot. Mar.*, 22 (7) : 455-457.
- NAQVI, S. W. A., SOLIMABI, S. Y. KAMAT, L. FERNANDES AND C. V. G. REDDY. 1981. Screening of some marine plants from the Indian coast for biological activity. *Bot. Mar.*, 24 (1) : 51-55.
- NEELA, M. V. 1956. Analysis of seaweeds. *Home. Sci. Bull. Women's Christian Coll.*, Madras.
- NEISH, I. C. 1979. Developments in the culture of algae and seaweeds and the future of the industry. In : *Advances in Aquaculture* (Ed. T. V. R. Pillay and Wm. A. Dill) FAO Fishing News (Books) Ltd. England pp. 395-402.
- OZA, R. M. 1971. Effect of IAA on the growth of fragment of *Gracilaria corticata*, J. Ag. *Seaweed Res. Util.*, 1 : 48-49.
- OZA, R. M. 1978. Studies on Indian *Gracilaria*. V. Seasonal variation in agar and gel strength of *Gracilaria corticata*. J. Ag. occurring on the coast of Veraval. *Bot. Mar.*, 21 (3) : 165-167.
- OZA, R. M. AND V. KRISHNAMURTHY. 1968. Studies on carposporic rhythm of *Gracilaria verrucosa* (Huds.) Papenf. *Bot. Mar.*, 11 (1-4) : 118-121.
- OZA, R. M. AND P. SREENIVASA RAO. 1977. Effect of different culture media on growth and sporulation of laboratory raised germlings of *Ulva fasciata* *Bot. Mar.*, 20 (7):427-431.
- PAPENFUSS, G. F. 1955. Classification of the algae. In: *A Century of Progress in the Natural Sciences, 1853-1953*. Calif. Acad. Sci. San Francisco. pp. 115-224.
- PAREKH, R. G. AND VISWESWARA RAO. 1964. Extraction of bulk proteins from the green seaweed, *Ulva rigida*. *Indian Jour. Tech.*, 2: 387.
- PAREKH, R. G., L. V. MARU AND M. J. DAVE. 1977. Chemical composition of green seaweeds of Saurashtra Coast. *Bot. Mar.* 20 (6): 359-362.
- PARIJA, P AND B. PARIJA. 1946. Algal succession on a rocky island named Charai Guha in the Chilka Lake. *Jour. Indian bot. Soc.* (M. O. P. Iyengar Commemo. Vol.) pp. 375-379.

- PARKER, H. S. 1974. The culture of red algal genus *Eucheuma* in the Philippines *Aquaculture*, 3 (4): 425-439.
- PASCHER, A. 1914. *Ber. dtsh. bot. Ges.* 32, 136.
- PATEL, B. A. AND G. V. JOSHI. 1967. Seasonal variations in chemical composition in *Ulva lactuca* and seawater. *Indian. Jour. exp. Biol.*, 5: 236-238.
- PATEL, J. B., B. V. GOPAL, V. R. NAGULAN, K. SUBBARAMAIAH AND P. C. THOMAS. 1979. Experimental field cultivation of *Gelidiella acerosa* at Ervadi, India. *Proc. Int Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. pp. 24-25 (Abstract).
- PATEL, J. B., B. V. GOPAL, V. R. NAGULAN, K. SUBBARAMAIAH AND P. C. THOMAS, 1980. Experimental field cultivation of *Gelidiella acerosa* at Ervadi, India. *Symp. Coastal Aquaculture*, Marine Biological Association of India, Cochin p. 189 (Abstract).
- PERCIVAL, E. 1968. Marine algal carbohydrates. *Oceanogr. Mar. biol. Ann. Rev.*, 6: 137-161.
- PILLAI, V. K. 1955 a. Observations on the ionic composition of bluegreen algae growing in saline lagoons. *Proc. natn. Inst. Sci. India*, 21: 90-102.
- PILLAI, V. K. 1955 b. Utilization of natural byproducts for the cultivation of blue-green algae. *Curr. Sci.*, 24: 21.
- PILLAI, V. K. 1955 c. Water soluble constituents of *Gracilaria lichenoides*. *Jour. Sci. Indust. Res. (India)*, 14 B. 473-477.
- PILLAI, V. K. 1956. Chemical studies on Indian seaweeds. I: Mineral constituents. *Proc. Indian Acad. Sci.*, B. 44: 3-29.
- PILLAI, V. K. 1957 a. Chemical studies on Indian seaweeds. II: Partition of Nitrogen. *Proc. Indian Acad. Sci.*, B 45: 43-63.
- PILLAI, V. K. 1957 b. Chemical studies on Indian seaweeds. III: Partition of Sulphur. *Proc. Indian Acad. Sci.*, B 45: 101-121.
- PILLAI, V. K. 1957 c. Alginic acid from *Sargassum* seaweeds. *Res. Ind.* 2: 70-71.
- PILLAI, V. K. 1964. Studies on the use of alginates in frozen fishery products. *Fishery. Tech.* 1: 176-179.
- PRESCOTT, G. W. 1968. *The algae: A review*. Houghton Mifflin Co., Boston 436 pp.
- PROVASOLI, L. 1957. Effect of plant hormones on *Ulva*, *Biol. Bull.*, 114: 375-384.
- QASIM, S. Z. AND M. V. M. WAFAR. 1979. Occurrence of living corals at several places along the west coast of India. *Mahasagar*. 12 (1): 53-58.
- RAGOTHAMAN, G. 1979. Littoral algal survey of south Gujarat coast (Devka, Golvad and Daman). *Proc. Int. Symp. Marine Algae of the Indian Ocean Region* CSMCRI, Bhavnagar, India. p. 6 (Abstract).

- RAJU, P. V. 1971. The effect of in situ application of growth hormones and fertilizers on photosynthetic c^{14} incorporation in some marine algae. *Bot. Mar.* 14 (2): 129-131.
- RAJU, P. V. AND P. C. THOMAS. 1971. Experimental field cultivation of *Gracilaria edulis* (Gmel.) Silva. *Bot. Mar.*, 14 (2): 71-75.
- RAJU, P. V. AND R. VENUGOPAL. 1971. Appearance and growth of *Sargassum plagiophyllum* (Mert.) C. Ag. on a fresh substratum. *Bot. Mar.* 14 (1): 36-38.
- RAMA RAO, K. 1970. Studies on growth cycle and phycocolloid content in *Hypnea musciformis* (Wulf.) Lamour. *Bot. Mar.*, 13 (2): 163-165.
- RAMA RAO, K. 1979. Studies on Indian Hypneaceae—V. Spores and natural propagules in the selected species of *Hypnea*, the potential Indian Carrageenophyte, for its field cultivation. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*. CSMCRI, Bhavnagar, India. pp 30-31 (Abstract).
- RAMA RAO, K AND V. KRISHNAMURTHY. 1968. Study of the preparation and properties of phycocolloid from *Hypnea musciformis* (Wulf.) Lamour. from Veraval, Gujarat coast, *Bot. Mar.*, 11: 129-133.
- RAMA RAO, K. AND P. C. THOMAS. 1974. Shedding of carpospores in *Gracilaria edulis* (Gmel.) Silva. *Phykos*, 13 (1) : 54-59.
- RAMA RAO, K. AND V. KRISHNAMURTHY. 1978. Studies on Indian Hypneaceae. I. Seasonal variation in phycocolloid content in two species of *Hypnea* (Gigartinales, Rhodophyceae). *Bot. Mar.*, 21 (4): 257-259.
- RAMA RAO, K. AND K. SUBBARAMAIAH. 1980. A technique for the field cultivation of *Hypnea musciformis* (Wulf.) Lamour., a carrageenophyte. *Symp. Coastal Aquaculture*. M. B. A. I., Cochin, India. p. 189 (Abstract).
- RANDHAWA, M. S. 1930. Historical review. Address; in: *Proc. Symp. Algology*, ICAR, New Delhi, pp. 4-24.
- ROUND, F. E. 1973. *The Biology of the Algae*, Edward Arnold, London-278 pp.
- RYTHER, J. H. 1968 a. *Porphyra* (Nori) culture in Japan. The status and potential of aquaculture particularly invertebrate and algae culture. Part II. Invertebrate and algae culture. (Reproduced by National Technical Service, Springfield, Va. 22151). pp. 228-241.
- RYTHER, J. H. 1968 b. *Undaria* culture in Japan. The status and potential of aquaculture; particularly invertebrate and algae culture. Part II. Invertebrate and algae culture (Reproduced by National Technical Information Service, Springfield, Va. 22151). pp. 242-248.
- SADASIVAN PILLAI, K. 1961. Alginic acid from *Sargassum* seaweeds of Indian coasts—Its extraction on a cottage industry basis. *Chemical age of India*, 12 : 425-430.
- SADASIVAN PILLAI, K. AND N. S. VARIER. 1952. Studies on the structure of alginic acid from the *Sargassum* seaweeds of Cape Comorin. *Jour. Proc. Inst. Chem.*, (India), 24 : 205.
- SAITO, Y. 1975. *Undaria*. In : *Advance of Phycology in Japan* (Ed. J. Tokida and H. Hirose) Dr. W. Jung b. v. Publishers, The Hague. pp. 304-320.

- SAITO, Y. 1979. Seaweed aquaculture in the North West Pacific. In : *Advance in Aquaculture* (Ed. T. V. R. Pillay and Wm. A. Dill). F. A. O. Fishing News (Books) Ltd. England. pp. 402-410.
- SARMA, Y. S. R. K. AND M. KHAN. 1980. Algal taxonomy in India. Botanical records and monographs-2. Today and Tomorrow's Printers and Publishers, New Delhi. pp. 1-153.
- SHAH, H. N. AND A. V. RAO. 1969. Recovery of mannitol from Indian brown seaweeds. *Res. Ind.*, 14 (3) : 117-119.
- SHAH, H. N., I. A. Mody and A. VISWESWARA RAO. 1967. Seasonal variation of viscosity of sodium alginate from *Sargassum* species and the preparation of high viscosity alginates, *Indian Jour. Tech.*, 5 : 269-270.
- SITAKARA RAO, V. AND U. K. TIPNIS. 1964. Protein content of marine algae from Gujarat coast. *Curr. Sci.*, 33 : 16-17.
- SITAKARA RAO, V. AND U. K. TIPNIS 1967. Chemical composition of marine algae from Gujarat coast. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar, pp. 277-288.
- SMITH, G. A. 1955. *Cryptogamic Botany*; Vol. I. Mc Graw Hill Book Co., New York. 546 pp.
- SOLIMABI AND S. W. A. NAQVI. 1976. Alginic acid content of some brown seaweeds of Goa. *Mahasagar* 8 (1 & 2) : 97-99.
- SOLIMABI AND B. DAS. 1977. Distribution of iodine in marine algae of Goa region. *Indian J. mar. Sci.*, 6 (2) : 180-181.
- SOLIMABI, B. DAS, S. Y. KAMAT, L. FERNANDES AND C. V. G. REDDY. 1980. Seasonal changes in carrageenan and other biochemical constituents of *Hypnea musciformis*. *Indian. J. mar. Sci.*, 9 (2): 134-136.
- SOLIMABI, B. DAS, P. K. MITTAL AND S. Y. KAMAT, 1981. Bromine and iodine contents in sponges and algae of the Andaman Sea. *Indian J. mar. Sci.*, 10 (3): 301-302.
- SREENIVASA RAO, P. 1967. Laver cultivation in Japan. *Salt Res. Ind.*, 4 (4): 141-144.
- SREENIVASA RAO, P. 1969. Systematics, ecology and life history of Indian Gelidiales with special reference to agarophyte *Gelidiella acerosa* (Forsskal) Feldman et Hamel. *Salt Res. Ind.*, 6: 46-47.
- SREENIVASA RAO, P. 1970. Systematics of Indian Gelidiales. *Phykos*. 9: 63-78.
- SREENIVASA RAO, P. AND S. R. KALE. 1969 Marine algae from a little known place of Gujarat coast I. Algae from Gopnath. *Phykos*, 8: 71-82.
- SREENIVASA RAO, P. AND Y. A. Shelat. 1979. Antifungal activity of Indian seaweed extracts. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*. CSMCRI, Bhavnagar, India. p. 47 (Abstract).
- SREENIVASA RAO, P. AND K. S. PAREKH. 1981. Antibacterial activity of Indian seaweed extracts. *Bot Mar.*, 14 (11): 577-582.
- SREENIVASA RAO, P., E. R. R. IYENGAR AND F. THIVY. 1964. Survey of algin bearing seaweeds at Adatra reef, Okha. *Curr. Sci* 33: 464-465.

- SREENIVASA RAO, P., H. H. PAREKH, B. K. RAMAVAT AND S. B. BHATT. 1979 a. Preparation and properties of liquid seaweed fertilizer. *Proc. Int. Symp. Marine Algae of the Indian Ocean region*. CSMCRI, Bhavnagar, India p. 57 (Abstract).
- SREENIVASA RAO, P., S. J. TARWADE, K. S. R. SARMA, K. ANJANEYULU AND H. M. MODY, 1979 b. Seaweed as a source of energy: Production of fuel gas from seaweed, *Sargassum*. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. p. 56 (Abstract).
- SREENIVASA RAO, P., K. S. PAREKH AND H. H. PAREKH. 1979 c. Antibacterial activity of different fractions of seaweed extracts. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. p. 47 (Abstract).
- SREENIVASA RAO, P., K. S. PAREKH, H. H. PAREKH, S. B. TRIVEDI AND B. A. DAVE. 1979 d. Effect of seaweed extracts on *Mycobacterium tuberculosis*. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. p. 47 (Abstract).
- SRINIVASAN, K. S. 1946. Ecology and seasonal succession of the marine algae at Mahabalipuram (Seven Pagodas) near Madras. *Jour. Indian. bot. Soc.*, (M. O. P. Iyengar commemo. Vol.) pp. 267-278.
- SRINIVASAN, K. S. 1950. Distribution patterns of marine algae in Indian seas *Proc. Symp. Algology*, ICAR, New Delhi. pp. 219-242.
- SRINIVASAN, K. S. 1965. Indian botany in retrospect with particular reference to algal systematics. *Jour. Asiatic Soc., Bengal*, 7: 49-78.
- SRINIVASAN, K. S. 1966. Conspectus of *Sargassum* species from Indian territorial waters. *phykos*, 5: 127-129.
- SRINIVASAN, R. AND T. SANTHANARAJA. 1967. Studies on the extraction and properties of agar-agar from the seaweed *Gracilaria* species in Madras State. *Madras Jour. Fish.*, 3: 146-151.
- STANFORD, E. C. C. 1883. *Chem. News.*, 47: 254-257, 262-269.
- STANIER, R. Y. AND VAN NIEL, C. B. 1962. *Bact. Rev.*, 42, 17.
- SUBBARAMAIAH, K. 1937. Ascorbic acid content and growth in *Ulva fasciata* Delile, *Phykos*, 6: 115-117.
- SUBBARAMAIAH, K. 1970. Growth and reproduction of *Ulva fasciata* Delile in nature and in culture. *Bot. Mar.*, 13 (1): 25-27.
- SUBBARAMAIAH, K., AND V. KRISHNAMURTHY. 1967. Laboratory culture of seaweeds. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar pp. 321-326.
- SUBBARAMAIAH, K., S. R. KALE AND V. KRISHNAMURTHY. 1967. Gametes and germings of *Ulva fasciata* Delile. *Curr. Sci.*, 36: 128-129.
- SUBBARAMAIAH, K., K. RAMA RAO, P. C. THOMAS, M. R. P. NAIR, B. V. GOPAL AND V. R. NAGULAN. 1975. Cultivation of *Gelidiella acerosa*. *Salt Res. Ind.*, 11 (1): 33-36.

- SUBBARAMAIAH, K., K. RAMA RAO, M. R. P. NAIR, C. V. S. KRISHNAMURTHY AND M. PARAMASIVAM 1979 a. Marine algal resources of Tamil Nadu. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavanagar, India. p. 14 (Abstract.)
- SUBBARAMAIAH, K., K. RAMA RAO AND M. R. P. NAIR. 1979 b. Marine algal resources of Lakshadweep. *Proc. Int. Symp. Marine Algae of the Indian Ocean Region*, CSMCRI, Bhavnagar, India. pp. 6-7 (Abstract).
- SUBBA RAO, G. N. 1965. Use of seaweeds directly as human food. *Indo-Pacific Fish. Coun. Reg. Studies. No. 2*: 1-32.
- SUBBA RAO, P. V., K. RAMA RAO AND K. SUBBARAMAIAH. 1977. Screening of certain red seaweeds for phycocolloids. *Seaweed Res. Util.*, 2 (2): 82-86
- SUBRAHMANYAN, R. 1967. Methods of assessing seaweed resources and problems. *Proc. Semi. Sea Salt and Plants*, CSMCRI, Bhavnagar. pp. 311-314.
- SUMITRA VIJAYARAGHAVAN, M. D. RAJAGOPAL AND M. V. M. WAFAR. 1980. Seasonal variations in biochemical composition of seaweeds from Goa coast. *Indian J. mar. Sci.* 9 (1): 61-63.
- TAMIYA, H. 1960. Role of algae as food. *Proc. Symp. Algology*, ICAR, New Delhi, pp. 379-389
- TAYLOR, W. R. 1964. The genus *Turbinaria* in eastern seas. *Jour. Linn. Soc. London (Botany)*, 58: 475-490.
- TEWARI A. 1975. The effect of a morphactin on the vegetative growth of *Gelidiella acerosa* *Phykos* 14 (1 & 2) : 125-128.
- TEWARI, A., M. PRASADA RAO AND V. KRISHNAMURTHY. 1968. Chemical composition of a species of *Porphyra* from Visakhapatnam. S. India. *Curr. Sci.*, 37: 138.
- THIVY, F. 1952. Investigations of seaweed products in India with a note on properties of various Indian agars. *Proc. Indo-Paci. Fish. Council, Sec. 2* : 173-175.
- THIVY, F. 1958. Economic seaweeds. In *Fisheries of West Coast of India*, Bangalore. pp. 74-80.
- THIVY, F. 1960. Seaweed utilization in India. *Proc. Symp. Algology*, ICAR, New Delhi, pp. 345-365.
- THIVY F. 1964. Marine algal cultivation. *Salt Res Ind.*, 1 (1) . 23-28.
- THOMAS, P. C 1977. Seasonal variation in the yield and physical properties of agar-agar from *Gracilaria verrucosa* (Hudson) Papenfuss. *Seaweed Res. Util.*, 2 (2) : 78-81.
- THOMAS, P. C. AND V. KRISHNAMURTHY. 1976. Agar from cultured *Gracilaria edulis* (Gmel.) Silva. *Bot. Mar.*, 19 : 115-117.
- THOMAS, P. C., K. RAMA RAO AND K. SUBBARAMAIAH 1975. Periodicity in growth and production of agar of *Gelidiella acerosa* (Forssk.) Feldman et Hamel. *Indian J. Mar. Sci.*, 4 (2) : 210-212.

- UMAMAHESWARA RAO, M. 1969 a. Catalogue of marine algae in the reference collection of the Central Marine Fisheries Research Institute. *Bull. cent. mar. Fish. Res. Inst.*, 9 : 37-48.
- UMAMAHESWARA RAO, M. 1969 b. Agar and algin yielding seaweeds of India. *Proc. 6th Int. Seaweed Symp.*, pp. 715-721.
- UMAMAHESWARA RAO, M. 1969 c. Seasonal variations in growth, alginic acid and mannitol contents of *Sargassum wightii* and *Turbinaria conoides* from the Gulf of Mannar, India. *Proc. 6th Int. Seaweed Symp.* pp. 579-584.
- UMAMAHESWARA RAO, M. 1970. The economic seaweeds of India. *Bull. cent. mar. Fish. Res. Inst. No. 20* : pp. 1-68.
- UMAMAHESWARA RAO, M. 1972 a. Coralreef flora of Gulf of Mannar and Palk Bay. *Proc. Symp. Corals and Coral Reefs* (1969). pp. 217-230.
- UMAMAHESWARA RAO, M. 1972 b. On the Gracilariaceae of the seas around India. *Jour. mar. biol. Ass. India*, 14 (2) : 671-696.
- UMAMAHESWARA RAO, M. 1972 c. Ecological observations on some intertidal algae of Mandapam coast. *Proc. Indian natl. Sci. Acad.*, 38 B (3 & 4) : 298-307.
- UMAMAHESWARA RAO, M. 1973. The seaweed potential of the seas around India. *Proc. Symp. on Living Resources of the Seas Around India* (1968). pp. 687-692.
- UMAMAHESWARA RAO, M. 1974. a. On the cultivation of *Gracilaria edulis* in the nearshore areas around Mandapam. *Curr. Sci.*, 43 (20) : 660-661.
- UMAMAHESWARA RAO, M. 1974 b. Observations on fruiting cycle, spore output and germination of tetraspores of *Gelidiella acerosa* in the Gulf of Mannar. *Bot Mar.*, 17 (4) : 204-207.
- UMAMAHESWARA RAO, M. 1976. Spore liberation in *Gracilaria corticata* J. Agardh growing at Mandapam. *J. exp. Mar. Biol. Ecol.*, 21 : 91-98.
- UMAMAHESWARA RAO, M. 1978. Seaweed resources of Andhra Pradesh. *Seaweed Res. Util.*, 3 (1 & 2) : 51-55.
- UMAMAHESWARA RAO, M. AND T. SREERAMULU. 1963. Vertical zonation and seasonal and variation in the growth of *Porphyra* on Visakhapatnam coast. *Curr. Sci.*, 32 : 173-174.
- UMAMAHESWARA RAO, M. AND T. SREERAMULU. 1970. An annotated list of the marine algae of Visakhapatnam (India). *Bot. Jour. Linn. Soc.*, 63 : 23-45.
- UMAMAHESWARA RAO, M. AND S. KALIMUTHU. 1972. Changes in mannitol and alginic acid contents of *Turbinaria ornata* (Turner) J. Agardh in relation to growth and fruiting. *Bot Mar.*, 15 : 57-59.
- UMAMAHESWARA RAO, M. AND N. KALIAPERUMAL. 1976. Some observations on the liberation and viability of oospores in *Sargassum wightii* (Greville) J. Ag. *Indian J. Fish.*, 23 (1 & 2), 232-235.

- UNNI, C. K. 1967. Natural radioactivity of marine algae. *Proc. Semi. Sea Salt and Plants*, CSMCRI: Bhavnagar. pp. 265-273.
- UNTAWALE, A. G. AND V. K. DHARGALKAR. 1975. *Report on the seaweed resources of the Goa coast*. N. I. O , Dona Paula, Goa. pp. 1-10.
- UNTAWALE, A. G., N. B. BHOSLE AND V. K. DHARGALKAR. 1977. Properties of phycocolloid extraction from seaweeds of Goa. *Indian J. mar. Sci.*, 6 (2) : 181-183.
- UNTAWALE, A. G., V. K. DHARGALKAR, V. V. AGADI AND T. G. JAGTAP. 1979. Marine algal resources of the Maharashtra coast. *Tech. Report*. Natl. Inst. of Oceanography, Goa. 48 pp.
- UNTAWALE, A. G, V K DHARGALKAR AND V. V. AGADI. 1983. *List of marine algae from India* N. I. O , Dona Paula, Goa. pp. 1-42.
- VALSON, A. P. 1955. Alginic acid content of some of the common seaweeds of the Gulf of Mannar area. *Curr. Sci.*, 24: 343-345.
- VARIER, N. S AND K. SADASIVAN PILLAI. 1952. Mannitol from *Sargassum* seaweeds. II. Optimum conditions for extraction of alginic acid from *Sargassum* seaweeds of Cape Comorin. *Bull. cent. Res. Inst.*, 2: 39.
- VARMA, R. P. 1960. Flora of the pearl beds off Tuticorin. *Jour. mar. biol. Ass. India*, 2: 221-225
- VARMA, R. P. AND K. KRISHNA RAO. 1962. Algal resources of Pamban area. *Indian J. Fish.* 9: 205-211.
- VILHELM, J 1931. *Archaeophyta and Algophyta*. Prague.
- VINOGRADOV, A. P. 1953. The elementary chemical composition of marine organisms. *Sears, Foundation for Marine Res.*, No 11.
- VISWESWARA RAO, A. 1964. Protein from *Ulva*. *Salt Res. Ind.*, 1: 37.
- VISWESWARA RAO, A. AND I. C. MODY. 1964. Extraction of alginic acid and alginates from brown seaweeds. *Indian Jour. Tech.*, 3 (8): 261-262.
- VISWESWARA RAO, A. K. N. PATEL AND H. N. SHAH. 1965. Manufacture of agar-agar from red seaweeds. *Res. Ind.*, 10: 131-133.
- WHITTAKER, R. H. 1969. *Science*, N. Y., 163, 150.
- YAPHE, W. 1959. The determination of kappa carrageenan as a factor in the classification of Rhodophyceae. *Canad. Jour. Bot.*, 37: 751-757.
- ZINGDE, M. D., S. Y. S. SINGBAL, C. P. MORAES AND C. V. G. REDDY. 1976. Arsenic, Copper Zinc and Manganese in the marine flora and fauna of coastal and estuarine waters around Goa. *Indian J. mar. Sci.*, 5: 212-217.