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Proximate Composition of Different Group of Seaweeds from Vedalai Coastal Waters (Gulf of Mannar): Southeast Coast of India

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Abstract: The aim of the present study was concentrates on different group of seaweeds like green (*Ulva reticulata*, *Enteromorpha compressa*, *Cladophora glomerata*, *Halimeda macroloba* and *Halimeda tuna*) brown (*Dictyota dichotoma*, *Turbinaria ornata* and *Padina pavonica*) and red (*Gelidiella acerosa*, *Gracilaria crassa* and *Hypnea musciformis*) were collected from Vedalai coastal waters, Southeast coast of India for analyzed proximate composition. The protein content was recorded maximum in *G. acerosa* and minimum in *D. dichotoma*; carbohydrate level was observed in *T. ornata* and minimum in *P. pavonica*. The lipid content was acquired higher level in *H. tuna* and minimum in *H. macroloba*.

Key words: Proximate composition % Various group of seaweeds % Vedalai coastal waters and Southeast coast of India

INTRODUCTION

Seaweeds are marine macro algae and primitive type of plants, growing abundantly in the shallow waters of sea, estuaries and backwaters. They flourish wherever rocky, coral or suitable substrata are available for their attachment. They belong to three groups namely green, brown and red based on pigmentation, morphological and anatomical characters.

Seaweeds have been used since ancient times as food, fodder, fertilizer and as source of medicinal drugs, today seaweeds are the raw material for industrial production of agar, algin and carrageenan but they continue to be widely consumed as food in Asian countries [1]. They are nutritionally valuable as fresh or dried vegetables, or as ingredients in a wide variety of prepared foods [2]. In particular, certain edible seaweeds contain significant quantities of lipids, protein, vitamins and minerals [3-5], although nutrient contents vary with species, geographical location, season and temperature [6, 7].

The seaweeds show great variation in the nutrient contents, which are related to several environmental factors as water temperature, salinity, light and nutrients [8]. Most of the environmental parameters vary according to season and the changes in ecological conditions can stimulate or inhibit the biosynthesis of several nutrients [9]. The nutritional properties of seaweeds are poorly known and normally are evaluated from the chemical composition [10]. In the context, the chemical composition (protein, carbohydrate, lipids, fiber, ash and nitrogen) of two seaweeds (*Gracilaria cervicornis* and *Sargassum vulgare*) from North-east Brazil was investigated in order to evaluate their potential nutritive value.

Seaweeds are traditionally consumed in the orient as part of the daily diet. Currently, human consumption of green algae (5%), brown algae (66.5%) and red algae (33%) is high in Asia, mainly Japan, China and Korea [8]. However demand for seaweed as food has now also extended to North America, South America and Europe. The different species consumed present a great nutritional value as source of proteins, carbohydrates, minerals and vitamins.

Extensive works were carried out by Lewis and Gonazalves [11-15]; Lewis [16-21] on aminoacids present in free state on protein and peptide hydrolysates in many green, brown and red seaweeds. The considerable amount of work on the volatile components, biochemical composition, proteins, amino acids, nutritive values, fats, lipids, vitamins and mineral composition of different species of *Enteromorpha* have been reported [22, 23].

Seasonal variation of carbohydrate, protein and lipid in seaweeds has been carried out from different localities of southeast coast of India [24-26]. Studies of fatty acids in seaweeds have investigated their seasonal variation [27, 28]. Kaliaperumal *et al*. [26] observed the seasonal variation in growth and biochemical constituents such as protein, carbohydrate and lipid in *Hypnea valentiae*,

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Acanthophora spicifera, *Laurencia papillosa*, *Enteromorpha compressa*, *Ulva lactuca* and *Caulerpa racemosa*. Sukran *et al*., [29] has studied 12 taxa (175 species) from the Chlorophyta, Phaeophyta and Rhodophyta collected from different depths at Gemlik-Karacaali and Erdek-Ormanh for total protein, total soluble carbohydrate, chlorophyll a, chlorophyll b, chlorophyll c and carotenoid contents. Poppy Mary Vimalabai [30] was analyzed carbohydrate and vitamin-C from monthly samples of 26 species of macro algae collected from the intertidal habitats of Tuticorin coast. Hannah Vasanthi and Rajamanickam [31] studied the chemical analysis of the red algae *Hypnea valentiae*, a carrageenan yielding seaweed collected from Tuticorin and Mandapam coasts in the Gulf of Mannar region was carried out for proteins, carbohydrates, lipids, fats and water soluble vitamins and the major, minor and trace mineral elements. The fatty acid profile of selected seaweeds namely *Ulva reticulata*, *Padina boergesenii* and *Hypnea valentiae* were estimated using gas chromatography by Hannah Vasanthi *et al*. [32].

Seaweeds belonging to the Rhodophyta possess high levels of proteins (10–30% DW) [33]. In some red seaweeds, such as *Palmaria palmata* (L.) Kuntze (dulse) and *Porphyra tenera* Kjellman (nori), the protein contents are 35 and 47% DW, respectively [34]. These levels are even comparable to that of the soybeans (35% DW).

However, only a few studies have been undertaken on the quality of seaweed protein [35-37] because of the difficulties of extraction and preparation of seaweed protein concentrates (PCs). The extraction of seaweed protein by classical procedures is hindered by the presence of large amounts of cell wall polysaccharides, such as the alginates of the brown seaweed or the carrageenans of some red seaweed. The present study endeavor on variation of proximate composition (protein, lipid and carbohydrates) of different group of seaweeds from Vedalai coastal regions, southeast coast of India.

MATERIALS AND METHODS

Collection of Seaweeds: Different species of seaweed (Chlorophyceae, Phaeophyceae and Rhodophyceae) was collected from Vedalai coastal waters (Gulf of Mannar); southeast coast of India. Collected seaweed was washed thoroughly with seawater to remove all the unwanted impurities, adhering sand particles and epiphytes. Then the sample was washed thoroughly using tap water to remove all the salt on the surface. The water was drained off and the seaweed was spread on blotting paper to remove excess water.

Preparation of Seaweed Powder: The seaweeds were collected from Vedalai coast Gulf of Mannar Marine Biosphere Reserve, southeast coast of India near Mandapam. The seaweed was shade dried and then kept in an oven 60°C for 4hrs dried seaweeds was ground to make powder approximately 10g of seaweeds powder was obtain form 1 kg of raw seaweeds.

Protein Estimation: The total protein was estimated using the Biuret method of Raymont *et al*., [38].

Lipid Estimation: The extraction of lipid was done by the chloroform-methanol mixture Folch *et al.*, [39].

Carbohydrate Estimation: The total carbohydrate was estimated by following the Phenol-sulphuric acid method of Dubois *et al*. [40].

RESULTS

Eleven species of seaweeds belongs to 5 species like *Enteromorpha compressa, Ulva reticulata, Cladophora glomerata*, *Halimeda macroloba* and *Halimeda tuna* from green seaweeds (Chlorophyceae); 3 species from brown seaweeds (Phaeophyceae) such as *Dictyota dichotoma, Padina pavonica* and *Turbinaria ornata*; 3 species (*Gelidiella acerosa, Gracilaria crassa* and *Hypnea musciformis* from Rhodophyceae (Red algae) collected from Vedalai coastal waters, southeast coast of India for proximate composition analysis.

The protein content was ranged from 9.65 ± 0.92 to 31.07 ± 0.33%; higher protein was found in *G. acerosa* (31.07 ± 0.33%) followed by *H. macroloba* (28.94 ± 0.68%), *H. tuna* (23.12 ± 0.86) and *C. glomerata* (20.38 ± 0.73%). The lower value of protein content was ranged from (9.65 ± 0.92) followed by *E. compressa* (12.27 ± 0.88), *U. reticulata* (13.47 ± 0.60%) and *P. pavonica* (13.63 ± 0.43%) Fig 1.

The carbohydrate concentration of different seaweeds ranged from 14.73 ± 0.07 to 17.49 ± 1.18%, in that the highest carbohydrate concentration was recorded from brown seaweeds *T. ornata* (17.49 ± 1.18%) followed by green alga *H. macroloba* (17.20 ± 0.71%), *H. tuna* (17.12 ± 0.44%), *G. crassa* (17.07 ± 0.75%), *E. compressa* (17.0 ± 0.65%) and red seaweed *G. acerosa* (16.62 ± 0.75%). The lowest value of carbohydrate content was observed from brown seaweed *P. pavonica* (14.73 ± 0.07%) followed by *C. glomerata* (14.83 ± 0. 61%), *U. reticulata* (15.37 ± 0.41%) and *D. dichotoma* (16.86 ± 0.97%) Fig 2. The lipid content of seaweeds ranged from 0.26 ± 0.07 to 3.53 ± 0.25; in that the maximum lipid content was recorded from green alga

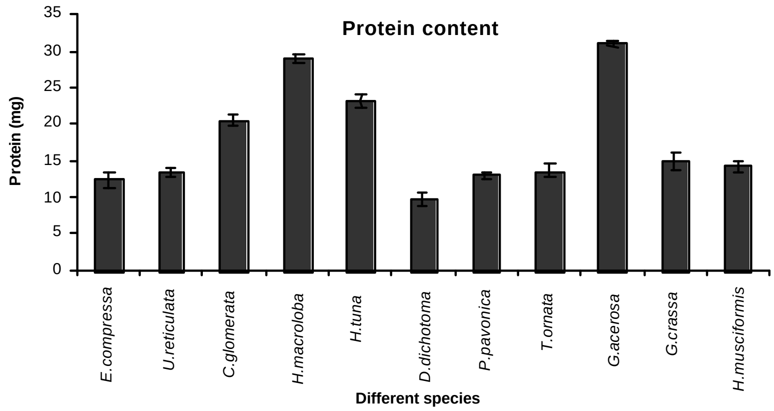

Fig. 1: Shows the protein concentration of different seaweeds

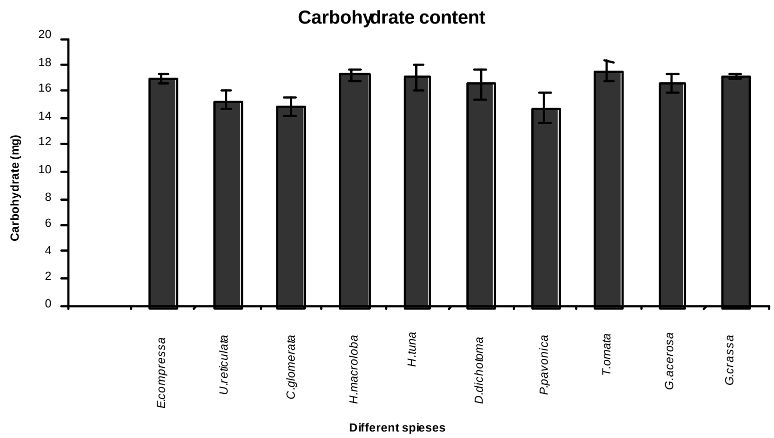

Fig. 2: Shows the carbohydrate concentration of different seaweeds

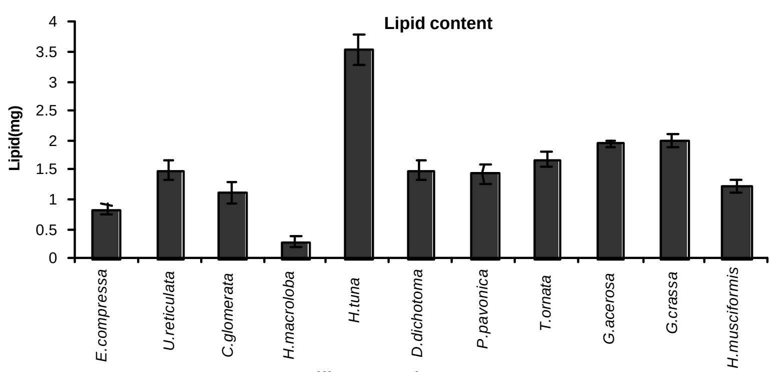

Fig. 3: Shows the lipid concentration of different seaweeds

H. tuna (3.53 ± 0.25%) followed by red seaweed *G. crassa* (1.99 ± 0.12%), *G. acerosa* (1.94 ± 0.06%) and brown seaweed *T. ornata* (1.67 ± 0.14%). The minimum lipid concentration was recorded from green seaweed *H. macroloba* (0.26 ± 0.07%) followed by the same green seaweed *E. compressa* (0.81 ± 0.07%) and *C. glomerata* (1.1 ± 0.16%) Fig 3.

DISCUSSION

The biochemical contents of *Ulva lactuca*, *Sargassum wightii* and *Gelidiella acerosa* from Port Okha were studied in relation to ecological factors by Murthy and Radia [41]. They presented the month-wise proteins, carbohydrates, fat, crude-fibre, sodium, potassium, calcium and phosphorus contents of these species. Dhargalkar [42], estimating the major metabolites such as proteins, carbohydrates, lipids, found carbohydrate is decreasing in *Ulva reticulata* in December, probably due to the extensive growth of the thallus. Protein values also followed the same trend while lipids did not show any significant seasonal variation. Marked changes in the chemical constituents were found to occur with change of seasons, environmental conditions as well as in the various phases of plants growth and fruiting cycle. In Central Marine Fisheries Research Institute studies were carried out on the chemical composition of the marine algae growing in the vicinity of Mandapam [43-46]. The present investigation is almost related to earlier study; here the proximate composition is varied within and between the species.

Poppy Mary Vimalabai [30] was analyzed carbohydrate and vitamin-C from monthly samples of 26 species of macro algae collected from the intertidal habitats of Tuticorin coast. Hannah Vasanthi and Rajamanickam [31] studied the chemical analysis of the red algae *Hypnea valentiae*, a carrageenan yielding seaweed collected from Tuticorin and Mandapam coasts in the Gulf of Mannar region was carried out for proteins, carbohydrates, lipids, fats and water soluble vitamins and the major, minor and trace mineral elements. The fatty acid profile of selected seaweeds namely *Ulva reticulata*, *Padina boergesenii* and *Hypnea valentiae* were estimated using gas chromatography by Hannah Vasanthi *et al*. [32]. The present study is contrast to earlier studies; here only concentrates proximate composition of within and between the species level from only one locality and same time which does not focused the seasonal variation.

Studies on the biochemical constituents such as protein, carbohydrate and lipid in green and brown marine algae have been carried out from different parts of Indian coast [47-51], biochemical studies of protein, amino acids, carbohydrate and iodine on three species like *Sargassum ilicifolium*, *S. liniarifolium* and *S. polycystum*. Reeta Jayasankar [52] studied the seasonal variation in chemical constituents of *S. wightii* with reference to alginic acid content has been reported. Amino acids in free and combined state have been quantitatively estimated in three species of green algae viz., *Halimeda tuna*, *Spongomorpha indica* and *Udotea indica* collected from Okha Port by Dave and Parekh [53]. Some biochemical investigations on economically important species have been carried out [54-56].

In the present study protein contents different species of seaweeds ranged from 9.65±0.92 to 31.07±0.33% which is entirely contrast to the earlier works in several marine algae estimated by Chidambaram and Unny [57]; Sitakara Rao and Tipnis (58, 59). Species of *Sargassum*, *Turbinaria* and *Gracilaria* were analyzed by Chidambaram and Unny [57], the protein content was found to be less than 10%. Whereas in *Acanthophora muscoides* and *Centroceras clavulatum* it was estimated as 22-26%. Dave and Parekh [60]studied 8 genera of green algae of Saurashtra coast, found significant variation in protein in same species of algae grown in different localities and different periods.

In the present investigation is dissimilar to the earlier study of Solimbi *et al*. (1980) studied the biochemical constituents namely carbohydrate of *Hypnea musciformis* from Goa coast. Carbohydrate varied from 31% to 50% the present study exhibit 14.73±0.07 to 17.49±1.18%. According to the results obtained in this present investigation, the protein, lipid and carbohydrate level was optimum. Although the results of chemical composition of seaweed analysis had demonstrated that can be potentially good and same time more study is necessary to evaluate the nutritional value of this seaweed as food ingredients.

REFERENCES

1. Mishra, V.K., F. Temelli, P.F. Ooraikul Shacklock and J.S. Craigie, 1993. Lipids of the red alga *Palmaria palmata*. Botanica Marina, 36(2): 169-174.
2. Robeldo, D. and Y.F. Pelegrin, 1997. Chemical and mineral composition of six potentially edible seaweed species of Yucatan. Botanica Marina, 44: 301-306.
3. Norziah, M.H. and Y. Ching Ch, 2002. Nutritional composition of edible seaweeds *Gracilaria changgi*. Food Chemistry, 68: 69-76.
4. Sanchez-Machado, D.I., J. Lopez-Hernandez and P. Paseiro-Losada, 2002. High-performance liquid chromatographic determination of "-tocopherol in macroalgae. Journal of Chromatography, 976: 277-284.
5. Wong, K.H. and P.C.K. Cheung, 2000. Nutritional evaluation of some subtropical red and green seaweeds. Part I-proximate composition, amino acid profiles and some physico-chemical properties. Food Chemistry, 71: 475-482.
6. Dawes, C.J., A.O. Lluisma and G.C. Trono, 1993. Clonal propagation of *Eucheuma denticulatum* and *Kappaphycus alvarezii* for Philippines farms. Hydrobiologia, 260/261: 379-383.

7. Kaehler, S. and R. Kennish, 1996. Summer and winter comparisons in the nutritional value of marine macroalgae from Hong Kong. Botanica Marina, 39: 11-17.
8. Dawes, C.J., 1998. Marine Botany. John Wiley & Sons, Inc. New York, pp: 480.
9. Lobban, C.S., P.J. Harrison and M.J. Duncan, 1985. The physiological ecology of seaweeds, Cambridge University Press, Cambridge.
10. Mabeau, S. and J. Fleurence, 1993. Seaweed in food products: Biochemical and nutritional aspects. Trends in Food Science Technology, 4: 103-107.
11. Lewis, E.J. and E.A. Gonzalves, 1959 a. Studies on the free amino acid contents of some marine algae from Bombay. Journal of Bombay. University, 28: 1-5.
12. Lewis, E J. and E.A. Gonzalves, 1962 b. The protein, peptide and free amino acid contents of some species of marine algae from Bombay. Annals of Botany, *N.S*., 26: 301-316.
13. Lewis, E.J. and E.A. Gonzalves, 1959 c. Studies on the free aminoacid contents of species of *Caulerpa* from Bombay. Journal of Marine Biological Association of India, 1: 203-205.
14. 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 Phytolology, 61: 288-290.
15. Lewis, E.J. and E.A. Gonzalves, 1962 b. The protein, peptide and free amino acid contents of some species of marine algae from Bombay. Annals of Botany, *N.S*., 26: 301-316.
16. 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. Current Science, 31: 90-92.
17. 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. Review of Algology, 6: 209-216.
18. Lewis, E.J., 1963 a. Studies on the proteins, peptides and free aminoacid contents in some species of marine algae form South-eastern coast of India. Review of Algology., 7: 15-25.
19. Lewis, E.J., 1963 b. Studies on the proteins, peptides and free aminoacid contents in some species of *Acanthopora* from South east coast of India. Review of Algology, 7: 37-241.
20. 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. Proceedings on Natural Institutional Science, India, 29: 137-145.
21. Lewis, E.J., 1963 d. Studies on fortnightly analysis of the proteins, peptides and free amino acids in some marine algae from Bombay. Proceedings on Natural Institutional Science, 29: 363-386.
22. Miller, C.D., 1927. Food values of Poi Tard and Limu. Bernice P Bishopmus Bulletin, 37: 1-25.
23. Katayama, A., 1962. Volatile constituents. In (R.A. Lewin, Ed.) Physiology and Biochemistry of Algae, Academic Press International, New York, pp: 467-473.
24. Reeta Jayasankar and G. Kulandaivelu, 1999. Seasonal variation in the biochemical constituents of *Gracilaria* spp. with reference to growth. Indian Journal of Marine Science, 28: 464-466.
25. Sarogini, Y. and F. Subbarangaiah, 1999. Seasonal variation in biochemical composition of some macroalgae along Visakhapatnam, East coast of India. Phykos, 38(1&2): 71-79.
26. Kaliaperumal, N., J.R. Ramalingam, S. Kalimuthu and R. Ezhilvalavan, 2002. Seasonal changes in growth, biochemical constituents and phycocolloid of some marine algae of Mandapam coast. Seaweed Research and Utilisation, 24(1): 73-77.
27. Floreto, E.A.T., H. Hirata, S. Ando and S. Yamasaki, 1993. Fatty acid composition of *Ulva pertusa* Kjellman (Chlorophyta) and *Gracilaria incurvata*. Okamura (Rhodophyta) in Japanese coastal water. Botanica Marina, 36: 217-222.
28. Nelson, M.M., C.F. Phleger and P.D. Nichols, 2002. Seasonal lipid composition in macroalgae of the Northeastern Pacific ocean. Botanica Marina, 45: 58-65.
29. Sukran Dere, Nurhayat Dalkiran, Didem Karacaoglu, Gamze Yildiz and Egemen Dere, 2003. The determination of total protein, total soluble carbohydrate and pigment contents of some macro algae collected from Gemlik-Karacaali (Bursa) and Erdek-Ormanli (Balikesir) in the sea of Marmara, Turkey. Oceanologia, 45(3): 453-471.
30. Poppy Mary Vimalabai, C., S. Sudhadevarani and R. Nalina Devi, 2003. Carbohydrate and vitamin-C contents of some macroalgae of Tuticorin, Southeast coast of India. Seaweed Research and Utilisation, 25(1&2): 47-53.
31. Hannah, R. Vasanthi and G.V. Rajamanickam, 2003. Variation in the chemical constituents present in *Hypnea valentiae* at Tuticorin and Mandapam coast - An environmental impact. Seaweed Research and Utilisation, 25(1&2): 115-121.
32. Hannah, R. Vasanthi, G.V. Rajamanickam and A. Saraswathy, 2003. Fatty acid profile of some marine macro algae in and around Rameswaram coastal waters. Seaweed Research and Utilisation, 25(1&2): 123-126.

33. Darcy-Vrillon, B., 1993. Nutritional aspects of the developing use of marine macroalgae for the human industry. International Journal of Food Science and Nutrition, 44: 23-35.
34. Morgan, K.C., J.L.C. Wright and F.J. Simpson, 1980. Review of chemical constituents of the red algae *Palmaria palmata*. Economic Botany, 34: 27-50.
35. Dam, R., S. Lee, P.C. Fry and H. Fox, 1986. Utilization of algae as a protein source for humans. Journal of Nutrition, 65: 376-382.
36. Ito, K. and K. Hori, 1989. Seaweed: Chemical composition and potential uses. Food Review International, 5: 101-144.
37. Amano, H. and H. Noda, 1990. Proteins of protoplast from red alga *Porphyra yezoensis*. *Bull*. Japan Society of Science on Fish, 56: 1859-1864.
38. Raymont, J.E.G., J. Austin and E. Lineford, 1964. Biochemical studies on zooplankton. 1. The biochemical composition of *Neomycis integer*. J. Cans. Perm. Emplor. Mer., 28: 354-363.
39. Folch, J., M. Lees and G.H. Solane Stanley, 1956. A simple method for the isolation and purification of total lipids from animal tissues. Journal Biological Chemistry, 226: 497-509.
40. Dubois, M., K.A. Giles, J.K. Hamilton, P.A. Rebors and F. Smith, 1956. Calorimetric method for determination of sugars and related substances. Analytical Chemistry, 28: 350-356.
41. Murthy, M.S. and Radia, 1978. Eco-biochemical studies on some economically important intertidal algae from Port Okha (India). Botanica Marina, 21(7): 417-422.
42. Dhargalkar, V.K., 1979. Biochemical studies on *Ulva reticulata*Forsskal. Proceeding on International Symposium on Marine Algae of the Indian Ocean Region, CSMCRI, Bhavnagar, pp: 40.
43. Pillai, V.K., 1955. Observations on the ionic composition of bluegreen algae growing in saline lagoons. Proceedings on National Institutional Science, India, 21: 90-102.
44. Pillai, V.K., 1956. Chemical studies on Indian seaweeds. I: Mineral constituents. Proceedings on Indian Academic Science, B 45: 3-29.
45. Pillai, V.K., 1957 a. Chemical studies on Indian seaweeds. II: Partition of Nitrogen Proceedings on Indian Academic Science, B 45: 43-63.
46. Pillai, V.K., 1957 b. Chemical studies on Indian seaweeds. III: Partition of Sulphur. Proceedings on Indian Academic Science, B 45: 101-121.
47. Parekh, R.G. and V.D. Chauhan, 1987. Lipid content of some Indian seaweeds. Indian Journal of Marine Science, 16: 272-273.
48. Sobha, V., K. Mayadevi and T. Vasudevan Nair, 1988. Proximate composition of certain algae at Kovalam, SW coast of India. Seaweed Research and Utilisation, 11: 31-38.
49. Sobha, V., Meera Surendran and T. Vasudevan Nair 1992. Heavy metal and biochemical studies of different groups of algae from Cape Comorin and Kovalam. Seaweed Research and Utilisation, 15(1&2): 77-85.
50. Kumar, V., 1993. Biochemical constituents of marine algae from Tuticorin coast. Indian Journal of Marine Science, 22: 138-140.
51. Selvaraj, R. and K. Sivakumar, 1998. Biochemical studies on three species of *Sargassum*. Seaweed Research and Utilisation, 20(1&2): 59-62.
52. Reeta Jayasankar, 1993. Seasonal variation in biochemical constituents of *Sargassum wightii* (Grevillie) with reference to yield in alginic acid content. Seaweed Research and Utilisation, 16(1&2): 13-16.
53. Dave, M.J. and R.G. Parekh, 1997. Amino acids of some marine green algae of Okha coast. Seaweed Research and Utilisation, 19(1&2): 21-24.
54. Centingul, V.H. and Guner, 1996. Ekonomik degerdeki bazi yesil alglerin, kimyasal iceriklerinin saptanmasi, *Ege U. Su urun*. *Fak*. *Derg*., 13(1-2): 101-118.
55. Centingul, V., V. Aysel and Y. Kurumulu, 1996. *Cystoseira barbata* (Good et woodw) C. Ag., (Fucales, Fucophyceae)'nin amino asit iceriklerinin saptanmasi, *Ege U. Su urun*. *Fak*. *Derg*., 11(41): 11-18.
56. Centingul, V. and V. Aysel, 1998. Ekonomik degerdeki bazikahverengi ve kirmizi alglerin agir metal birikim duzeyleri, *Ege U. Su urun*. *Fak*. *Derg*., 15(1-2): 63-76.
57. Chidambaram, K. and M.M. Unny, 1953. Note on the value of seaweeds as manure. Ist *Int*. Seaweed Research and Utilisation, pp: 67-68.
58. Sitakara Rao, V. and U.K. Tipnis, 1964. Protein content of marine algae from Gujarat coast. Current Science, 33: 16-17.
59. Sitakara Rao, V. and U.K. Tipnis, 1967. Chemical constituents of marine algae from Gujarat coast. Proceedings and Seminar an Sea Salt and Plants, CSMCRI, Bhavanagar, pp: 277-288.
60. Dave, M.J. and R.G. Parekh, 1975. Protein content of green seaweeds from the Sourashtra coast. Salt Research and Industry, 11(2): 41-44.