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SEAWEED RESEARCH AND UTILIZATION IN INDIA

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COMMON SEAWEED PRODUCTS

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The seaweeds are the only source for agar and algin. They are also used as food material, livestock feed and fertilizer in many parts of the world. The various products obtained from Indian seaweeds and their uses are dealt with here.

Agar-Agar

Agar-agar is a gelatinous substance obtained from the red algae like *Gelidium, Gelidiella* and *Gracilaria*. and has a great commercial value. Agar is a colloidal carbohydrate present in the cell walls of some red algae and is a mixture of two polysaccharides, agarose and agaropection. Humm (1951) and Yaphe (1959) have defined agar as a gel-forming substance soluble in hot water and requiring one percent solution to set as a gel on cooling.

The important and commonly occurring agarophytes of India are *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. verrucosa, G. corticata* and *G. foliifera.* The yield and physical properties of agar extracted from these red seaweeds are given in the Appendix. Among these seaweeds only *Gelidiella acerosa, Gracilaria, edulis* and *G, crassa* are used at present as raw material for the production of agar-agar in India, since the yield and quality of agar are good and the plants are also available in harvestable quantities.

Agaroids

The gel-like extracts produced from certain types of red seaweeds are commonly known as agaroids. Carrageenan obtained from *Chondrus, Gigartina* and *Eucheuma* species come under this group. The organic sulphate content is very much higher in these compounds and the chemical nature and properties of agaroids vary from that of agar. Pure solutions of agaroids are viscous and do not form gel when cooled. However, various inorganic and organic solutes alter the properties and increase the gelling bower of agaroids.

Carrageenan-yielding plants have not been reported from Indian waters except tor a rare and less abundant species, *Gigartina acicularis,* occurring in the intertidal region. But *Hypnea musciformis*, other species of *Hypnea, Spyridia. Sarconema, Acanthophora, Laurencia* and *Chondria* growing along the Indian coast give gel-like extracts.

Algin or Alginic Acid

Algin is the main polysaccharide occurring in the cell walls of brown algae. It consists of D-mannuronic acid and 2-guluronic acid in various proportions. The sodium, potassium and magnesium salts of alginic acid are soluble in water and they give viscous solutions without gel formation. Calcium alginate and other salts of copper, cobalt, mercury, etc are insoluble in water.

Species of *Sargassum, Turbinaria, Dictyota, Padina, Cystoseira, Hormophysa, Colpomenia, Spatoglossum* and *Stoechospermum* are some of the algin-yielding seaweeds occurring in Indian waters. The alginic acid content of these seaweeds is given in Table 10. Of these, *Sargassum* and *Turbinaria* are utilised as raw material for the manufacture of algin in India, since they are high-yielding varieties and also available in large quantities.

Uses of Agar and Algin

Agar and algin are used in food, confectionary and dairy industries as gelling, stabilising and thickening agents, mainly in the manufacture of sweets, jellies, ice-creams, sherbats etc. They are also useful in a number of other industries.

Agar : Agar is extensively used in the making of food and medicines. The best known use of agar is as a solidifying agent in media used in bacteriological culture. It is also used as a stiffening agent in a number of food products, as a sizing material, and mucilage and in clarifying liquors. With its quality of keeping substances in suspension it goes in the manufacture of various pharmaceutical preparations, photographic film coatings and paints. It is employed in canning meat and in poultry, in laxative preparations, as a constituent of medical pills and capsules, in numerous pharmaceutical and cosmetic creams and jellies, as a dental-impression mould and as a lubricant for drawing tungsten in electrical bulbs.

Aalgin : Algin is also equally and extensively used in the preparation of various pharmaceutical, food and rubber products (natural and synthetic latex creaming and thickening, finished articles, automobile carpetting, electrical insulations, foam cushions, and rubber coating on tyres), textile products (size compound for cotton and rayon, textile print pastes and plastic laundry starch), adhesives (for all boards, paper bags, shipping containers, gummed tapes), paper products, food packages, pharmaceutical and detergent, packages, milk containers, butter cartons, frozen food packages, insulation boards, food wrappers, greaseproof paper and acoustical tiles) and miscellaneous products (paints, ceramic glazes, porcelain wares, leather finishers, autopolishes, welding-rod coatings, boiler compounds, batteryplate separators, wall-board-joint cement, beet-sugar processing and wax emulsions).

Some of the food products requiring agar and their method of preparation (Thivy, 1958) are given in Table 1.

Table 1

Food products requiring agar

(From Thivy, 1958)

Food stuff	Quantity of agar used	Method of addition
Ice-cream	1/8 teaspoonful (¼ g) per cup of ice-cream mix.	Dissolved in boiling water and added to warm ice-cream mix (Prevent it from melting soon)
Tomato sauce	½ teaspoonful (1 g) per 1b. of tomato sauce	Dissolved in boiling water and added to the sauce towards the end. boiling after adding agar should be avoided.
Jams, jelly, Marmalade	One level teaspoonful (2 g) per 1b. of these	Dissolved in boiling water and added to the sauce towards the end. Boiling after adding agar should be avoided.
Blancmange (without corn flour)	1½ level teaspoonful (3 g) per cup of milk with sugar	Dissolve agar in a small amount of water in a double boiler and pour in to warm milk, not vise versa.
Lime jelly	1½ level teaspoonful (3 g) per cup of water with sugar and lime juice	Dissolve agar in the water in a double boiler, add sugar and strain; keep aside and then, when somewhat cool, add lime-juice and pour into mould.

Algal Proteins

Some green and red seaweeds such as *Ulva fasciata, U. rigida, Porphyra vietnamensis* and *Centrocer asclavulatum* contain very rich proteins. These algal proteins have many essential amino acids including iodine-containing amino acids. Studies revealed that these seaweeds contain 16-30% of protein on dry weight basis and this amount is somewhat higher than that in other food materials such as cereals, eggs and fish (Visweswara Rao, 1964). Protein can be extracted from these seaweeds and as such dry powders of *Ulva, Porphyra, Acanthophora* etc. can be added to various foods deficient in protein or taken along with other food stuffs in small quantities.

Seweed as Food

Fresh, dried and processed seaweeds are utilised for human consumption. The algal carbohydrates are not easily digestible and the food value of the seaweeds depends on the minerals, trace elements, proteins and vitamins present in them. Many seeweeds such as species of *Caulerpa, Codium, Hydroclathrus, Sargassum, Porphyra, Gracilaria, Acanthophora* and *Laurencia* are used as food in Japan, Indonesia, China, Philippines and other countries of Indo-Pacific regions (Subba Rao, 1965; Levring *et. al,* 1969; Michanek, 1975 and Chapman and Chapman, 1980). They are eaten as salad, curry, soup or vegetables. There are large industries in Japan using edible seaweeds like *Porphyra. Thin* algal sheets are prepared by washing and drying *Porphyra* plants and this forms an important food item in Japan.

Some of the edible seaweeds occurring in different localities along the Indian coast are species of *Ulva, Enteromorpha, Chaetomorpha, Caulerpa, Codium, Dictyota, Padina, Colpomenia, Hydroclathrus, Rosenvingea, Chnoospora, Sargassum, Turbinaria, Porphyra, Halymenia, Grateloupia, Gracilaria, Hypnea, Rhodymeina, Centroceras, Acanthophora,* and *Laurencia*. The important edible red seaweed *Porphyra* has been reported from Madras (Boergesen, 1937 b), Visakhapatnam and Cape Comorin (Umamaheswara Rao and Sreeramulu, 1963 and Umamaheswara Rao, 1973) and Goa Coast (Dhargaikar *et. al.,* (1981). The methods of preparing different recipes from seaweeds are given in detail by Chennubhotla *et. al.* (1981). The seaweed *Gracilaria edulis* is being used since decades for making gruel in the coastal areas of Tamil Nadu.

Seaweed Meal

Seaweeds are cheap sources of minerals and trace elements. Hence the meals prepared from seaweeds can be given as supplements to the daily rations of the cattle, poultry and other farm animals, Seaweed meal can be obtained by grinding cleaned and washed seaweeds such as *Ulva, Enteromorpha, Sargassum, Padina, Dictyota, Gracilaria* and *Hypnea*. Thivy (1960) has described a simple method for the preparation of seaweed meal from *Gracilaria edulis (—G. lichenoides).* Seaweed meal can also be mixed with fish meal and used as a poultry feed. Seaweeds have been utilised as animal feed in some countries. Dave *et. al.* (1977) assessed the possibility of seaweeds being used as supplementary animal feed and they reviewed the feeding trials of animals with seaweeds conducted in Japan, Germany, U. K.. Norway and other countries. The seaweed meal prepared from *Sargassm* and the results of its feeding trials on chicks, sleep and cattle are given by Dave *et. al.* (1979). Studies on feeding *Gracilaria* meal to white leghorn egg laying birds were made by Chaturvedi *et. al.* (1979), to find out the effect of algal-feed on the contents of egg. The results of this feeding experiment indicated that there was no significant difference in the number of eggs produced, total egg mass, internal quality of eggs and the body weight of the birds in the conventional ration group and those kept on ration with 5 and 10% *Gracilaria* meal. The *Gracilaria* meal at the level of 10% can be included in the ration of egg-laying birds, replacing yellow maize. Feeding trials replacing *ragi (Eleusine* coracana) with 0, 5, 10 and 15% of seaweed were conducted in unsexed day-old white leghorn chicks (Jagannathan and Venkatakrishnan. 1979) using six species of seaweeds commonly available in Tamil Nadu coast. 120 to 240 numbers of chicks were randomly allotted to the four diets with three to six replicates in each treatment. The trails were run for ten weeks. It is found that all these six seaweeds, particularly *Hypnea musciformis* and *Gracilaria edulis*, can be beneficially used to replace ragi at 5% level.

Seaweed Manure

Use of seaweeds as manure is a common practice in coastal areas throuhout the world. In India it is used for coconut plantations especially in coastal Tamil Nadu and Kerala. The high amount of water soluble potash, other mineral and trace elements present in seaweeds are readily absorbed by plants and they control deficiency diseases. The carbohydrates and other organic matter present in seaweeds alter the nature of the soil and improve its moisture retaining capacity. Hence, large quantities of seaweeds including seagrasses such as *Cymodocea, Diplanthera, Enhalus* and *Halophila* can be used as manure in all parts of the country either directly or in rhe form of compost. A method for composting the seaweeds with cowdung has been described by Thivy (1958 and 1960). In the field trials conducted at the Central Marine Fisheries Research Institute, *Hypnea* compost when applied to bhendi, induced 73% increase in yield compared to cowdung and wood ash. Good results were also achieved with brinjal, tapioca, clustered beans, beans gouards, Amaranthus, Virdis lime, papaya and drumstick when manured with seaweed compost. Crotons and zinnias also grew well with seaweed treatment (Thivy, 1960). The nitrifiability of organic nitrogen from *Ulva lactuca* and drift seaweeds from Veraval was studied and found to be high compared to farmyard manure or a few other organic manures (Mehta *et. al*., 1937). Application of seaweed manure can maintain a high level of available nitrogen in soil. The easy decomposability of seaweed organic matter is beneficial for the growth of soil micro organisms. According to these authors, seaweeds, especially the drift seaweed, which is a mixture of a variety of species cast ashore, can be a promising supplementary organic manure. The results of seaweed manurial trials on *Pennisetum typhoides* (pearl millet) and *Arachis hypogea* (ground nut) are reported by Bokil *et. al.* (1972). The application of seaweed manure along with inorganic fertilizers have improved the quality of the produce. The use of seaweed manure had no significant influence over the yield of *Pennisetum typhoides* But the quality of its grains and fodder was favourably influenced. In the experiments on *Arachis hypogea* seaweed manure was comparable to that of farm yard manure and in general the performence of treatments in which seaweed manure was included was better than other treatments. With a view to find out the effect of seaweed manure on the uptake of inorganic nutrients by the wheat plant, a pot culture experiment was conducted (Bokil *et. al*., 1974). The performance of the seaweed manure was found to be superior to the conventional manures, the performance of the seaweed manure is significantly better than that of farm yard manure due to the easy decomposibility of its carbonaceous matter and presence of micro-nutrients. The performance of brown seaweed manure, which contains higher proportion of alginic acid and analogous compounds, is relatively superior to that of drift seaweed manure with respect to both the yield and quality attributed. Regarding the quality of grains, the use of brown seaweed manure in conjunction with the inorganic fertilizers is significantly better than the others. Bhosle *et. al*. (1975) studied the seaweed extract on the growth of *Phaseolus vulgaris*. Marine algal extracts obtained from *Spatoglossum asperum, Ulva fasciata* and *Enteromorpha intesstinalis* were found to promote germination in seeds and growth of seedlings of gram, ground nut and maize (Bukhari and Untawale, 1978). Dilute extracts were found to be more effective than the concentrated extracts. Foliar spray of *Spatoglossum* extract caused in an increase in the leaf size and better growth in *Hydrangia* sp. The method of preparation and properties of liquid seaweed fertrilizer from *Sargassum* was given by Sreenivasa Rao *et. al*. (1979 a).

Seaweed as a Source of Energy

Sreenivasa Rao *et. al*. (1979 b) have conducted experiments on production of fuel gas for domestic use, utilizing *Sargassum* as raw material. Digester design and operating parameters are given. According to them a mixutre of about six micro-organisms mostly derived from marine environments were used in digesters. Addition of indole acetic acid stimulated anaerobic digesters. Salinity of the liquid above 20% was stated to be detrimental to production of fuel gas.

Medicinal Uses of Seaweeds

Seaweeds were considered to be of medicinal value in the Orient as early as 3000 B. C. The Chinese and Japanese used them in the treatment of goitre and other glandular diseases. Although the Romans believed seaweeds to be useless, they also used them to heal wounds, burns, scurvy and rashes. The British used *Porphyra* to prevent scurvy during long voyages.

Various red algae (particularly *Coralline officinalis, C. rubens and Alsidium helimintho-corton*) were employed as vermifuges in ancient times. Dulse is reported to be a laxative and also used to reduce fever. Several red algae (including *Chondrus crispus, Gracilaria, Gelidium* and *Pterocladia*) have been used to treat various stomach and intestinal disorders. The algae apparently absorb enough water and its water content helps relieving constipation and other associated discomforts. The stipes of *Laminaria cloustoni* have been used to aid in child birth by distending the uterus during labour. A number of species of marine algae have been found to have anticoagulant and antibiotic properties. Carrageenan may be useful in ulcer therapy and the alginates are found to prolong the "rate of activity" of certain drugs (Mathieson, 1969). Species of *Sargassum* were used for cooling and blood cleaning effect. *Hypnea musciformis* was employed as vermifuge or worm expelling agent and *Centroceras clavulatum* as cathartic agent. The iodine rich seaweeds such as *Asparagopsis taxiformis* and *Sarconema* can be used for controlling goitre disease caused by the enlargement of thyroid gland (Umamaheswara Rao, 1970).

Though the importance of different seaweed products in pharmacology is known, the development of antimicrobial, antifungal and antiviral substances from seaweeds is still in an initial stage of research and development. Extracts from *Chondrus crispus* and *Gelidium cartilagineum* have been found to be active against influenza B and mumps virus, (Garber *et. al.*, 1958). Henriquez *et al.* (1979) assayed 33 species of Chilean marine algae for their antibacterial activity against *Sarcina lutea* ATCC 001, *Staphylococcus aureus* ATCC 65388 and *Bacillus subtilis* ATCC 6633. Some degree of antibacterial activity was found to be present in 17 of these 33 extracts. Caccamese *et. al.* (1980) tested the lipid extracts of more than 20 algae from eastern Sicily for antimicrobial activity against tobacco mosaic virus Some of them mainly belonging to Dictyotales were found to be active. Caccamese *et. al.* (1981) tested lipid extracts of 13 algae from Eastern Sicily for antimicrobial activity against *Bacillus subtilis* and *Phoma tracheiphila* and for antiviral activity against tobacco mosaic virus. *Zanardine prototypus* and *Cystoseira balearica* exhibited the best antimicrobial and antiviral activity among the species tested. Blunden *et. al.* (1981) examined the extracts of British marine algae for anti-influenza virus activity based on nhibition of influenza neuraminidese. The antibacterial and antifungal activity of Indian seaweed extracts (Sreenivasa Rao *et. al.*, 1979 c; Sresnivasa Rao and Shelat, 1979 and Sreenivasa Rao and Parekh, 1981) and also the effect of seaweed extracts on *Mycrobacterium tuberculosis* (Sreenivasa Rao *et. al.*, 1979 d) have been studied. Antibiotic substance isolated from *Enteromorpha* effected complete inhibition of growth of the tubercle bacilli in the cultures. Naqvi *et. al.*, (1981) examined the extracts of 25 seaweeds from Indian coast for antiviral, antibacterial, antifungal, antiprotozoal, antifertility activities and a wide range of pharmacological activities. Significant biological activity was obtained in 13 species of seaweeds, the most promising activity being 100% antifertility (anti-implantation) activity observed in 3 species namely *Padina tetrastromatica, Gelidiella acerosa* and *Acanthophora spicifera*.

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