Chapter 1

INTRODUCTION

1.1 Introduction

Life on the earth originated in the sea and until about 450 million years ago, the only plants on earth were marine algae. The next 400 million years witnessed the evolution of the land flora including bryophytes, pteridophytes, gymnosperms and angiosperms. During the evolutionary process, most of these plants lost their ability to live in seawater and throughout the modern bryophytes, pteridophytes and gymnosperms, there is not a single marine species. In the angiosperms, there is only one small group of seagrasses, which can be described truly marine. Thus, the sea still remains, as it was in the pre-Devonian times, the province of algae, and today about 90% of all the species of marine plants belong to one or other groups of algae (Dring, 1982).

Algae are defined as the photosynthetic nonvascular plants that contain chlorophyll-a and accessory pigments and have simple reproductive structures (Dawes, 1981). They differ from the higher plants in that they do not possess true roots, stems or leaves. However, some of the larger species possess attachment organs called holdfasts that have appearance of roots and there may also be a stem-like portion called a stipe, which flattens out into a broad leaf-like portion called lamina. Some species consists simply of a flat
plate of tissue while in others, the plant body, or thallus, is composed of a narrow, compressed or tubular axis with similar branches arising from it. Smaller species are mainly filamentous (Chapman and Chapman, 1980). Algae vary in size from microscopic unicellular forms (phytoplankton) to the giant benthic macrophytes (e.g., macrocystis), which are attached to solid substrata such as rocks or boulders (Dawes, 1981). The phytoplankton dominates the water column, while the rocky shores are abundantly covered almost exclusively with macroalgae. Muddy and sandy areas have fewer macroalgae because most species cannot anchor there.

Algae are located at the base of the food chain for marine organisms. Since the oceans occupy about 71% of the earth’s surface area, the role of algae in supporting aquatic life is essential. All marine organisms ultimately depend on algae for their existence. In addition to directly and indirectly supplying organic molecules for different organisms, algae produce oxygen as a by-product of photosynthesis. They may supply about 30 - 50% of the net global oxygen. Algae function as chemical modulators in marine ecosystems and also provide habitats for many marine organisms such as snails, limpets, seaurchins etc. (Anon, 2000).

The marine macroalgae, commonly known as seaweeds, constitute an important renewable marine resource with several commercial applications. Most of these macroalgae belong to the three traditional divisions of algae – chlorophyta (green algae), rhodophyta (red algae) and phaeophyta (brown algae). These groups of algae find wide applications in food, pharmaceutical and various other industries. The uses of these algae as food, fodder and fertilizer have been well known in many countries for centuries. The marine macroalgae are often called ‘sea vegetables’ since they contain sufficient amounts of diverse macro as well as micronutrients of human
food value. They contain substantial amounts of proteins, carbohydrates, lipids, vitamins, amino acids, fatty acids, trace elements and minerals. The trace metal content of macroalgae is higher than that of terrestrial plants. They also contain substances of stimulatory and antibiotic nature. Marine macroalgae are the only source of the hydrocolloids such as agars, carrageenans and alginates, which are extensively used in various industries as gelling, thickening and stabilizing agents. Attempts are being made for screening pharmaceutically active compounds from marine macroalgae. With the energy crisis, they are also being evaluated as sources of methane fuel (Chapman and Chapman, 1980).

**Macroalgae as Food**

Marine macroalgae have been consumed by humans both in raw and in cooked form for centuries. There are historical references to such uses as early as 600 – 800 B.C. and they were undoubtedly used in prehistoric times. Today, as processed and unprocessed food, algae have a commercial value of several billion dollars annually. Approximately 500 species are eaten by humans and some 160 are commercially important (Anon, 2000). In addition to the use of algal extracts in prepared foods, algae are eaten directly in many parts of the world. They are eaten as staple items of diet in Japan, China, Korea and many other Asian countries. The principal users of algae as food are the Japanese who have been using algae in everyday cookery since eighth century. At present, algae account for about 10% of Japanese diet (Ninawe, 2003). People from Hawaiian Islands, Scandinavian and a few other European countries use marine macroalgae and their products as food additives and supplements. In western countries, algae are largely regarded as health food and there has been an upsurge interest in
algae as food. In India, marine algae such as *Gracilaria* have been used by some coastal populations for making gruel (Chennubhotla et al., 1987). Some of the edible marine algae occurring along the Indian coast are species of *Ulva, Enteromorpha, Chaetomorpha, Caulerpa, Codium, Gracilaria, Grateloupia, Centroceras, Laurencia, Hypnea, Acanthophora, Dictyota, Padina, Porphyra* and *Sargassum*.

The food value of marine macroalgae lies in their richness of various macro and micro-nutrients including proteins, carbohydrates, lipids, amino acids, fatty acids, vitamins and trace minerals especially iodine. The pattern of free and combined amino acids of many algae are more or less similar to that of vegetables. Some of the algal species contain a high amount of the basic amino acid arginine that in general is abundant in animal protein. The lipid contents of algae are low in general, but contain higher percentage of unsaturated fatty acids, which are more than 10% of the total fatty acid content. Eicosapentanoic acid (EPA) constitutes about 50% of these unsaturated fatty acids. These fatty acids have gained prominence in recent years due to their effectiveness in preventing arteriosclerosis, cancer, coronary heart disease, ageing etc. It has also been reported that derivatives of EPA are beneficial to the human body because they act as local hormones and helps in human metabolism. Like vegetables, marine macroalgae contain all types of vitamins, antioxidants and ascorbic acid. They are rich in group-B vitamins particularly B₁₂ than their vegetable counterpart. Vitamin A content of many algae amounts to half of the same spinach contents. Marine algae are rich sources of iodine, which serves as a precursor of thyroxine. They are also rich in essential trace elements (Chapman and Chapman, 1980; Chennubhotla *et al.*, 1987; Anon, 2000; Ninawe, 2003).
Introduction

Macroalgae as Fodder

Marine macroalgae constitute one of the best renewable resources for livestock feed. The importance of algae as fodder has been recognised since a long time. Historical accounts from 46–43 B.C. report such uses of algae (Waaland, 1981). As animal feed, algae are used to supplement protein intake. They are also valued as a source of trace minerals and vitamins (Metting et al., 1990). In number of countries, animals are regularly fed upon fresh algae or are given a prepared algal meal. Algae are utilised in many countries as feed for cattle, pigs and poultry. They are also used as feed for fish and other aquaculture species. It has been found that the milk produced by the cows that feed on algal meals is richer in fat content than that produced by cows fed on conventional fodder. Likewise, hens fed with algal meals produce eggs rich in iodine (Chapman and Chapman, 1980).

Macroalgae as Fertilizer

The application of marine macroalgae as agricultural fertilizer is a common and widespread practice in coastal areas throughout the world. In India, it is used for coconut plantations especially in coastal areas of Kerala and Tamil Nadu (Chennubhotla et al., 1987). It has been found that algal fertilizer is superior to the conventional organic fertilizer. Its effects on plants include higher yields, increased nutrient uptake, changes in plant tissue composition, increased resistance to frost, fungal diseases and insect attack, longer shelf life of fruits, and better seed germination (Metting et al., 1990).

Marine algae contain all major and minor plant nutrients and trace elements. These can be readily absorbed by plants and this helps in controlling many deficiency diseases in plants and enhancing crop yield. Algae
also contain a wide range of amino acids and vitamins, which might be utilised by plants. It has been suggested that many of the crop responses to algal fertilizer are primarily due to the presence of growth substances such as cytokinins, auxin and gibberellin. Algal fertilizer also function as a soil conditioner. It improves aeration and aggregates stability. The carbohydrates and other organic matter present in algae alter the nature of the soil and improve its moisture retaining capacity. The high amount of organic nitrogen present in marine algae helps in maintaining a high level of available nitrogen in the soil (Chennubhotla et al., 1987).

**Macroalgae in Medicines**

Marine macroalgae have been used as medicines or drug sources for a great many years, stretching back to the era of folk medicines. The Chinese, Koreans and Japanese recognized the pharmaceutical values of many types of marine algae for centuries. Algae have been extensively used in the traditional medicines of maritime nations for treatment of goitre, cancer, hypertension, cough and other diseases. They are used as vermifuges and in the treatment of many viral diseases (Chapman and Chapman, 1980). Most of the marine algae contain sterols and related compounds, which are antagonistic to cholesterol in mammalian systems and could reduce elevated blood pressure. The vitamin and mineral contents of algae are potentially important in the prevention of dietary insufficiency diseases. Algal extracts such as agars and alginates are widely used for medical and dental purposes. In dentistry, they are used as intra – oral impression materials. Agar is used as a laxative and as an anticoagulant for blood. It is useful in the preparation of food prescribed for diabetic patients and promotion of tissue growth. The phycocolloid carrageenan is used in the treatment of peptic ulcer in humans.
Introduction

The ability of carrageenan to form metal salts indicate an important use as non-toxic chelating agent in the treatment of heavy metal poisoning. Many bioactive compounds and polysaccharides of marine algae have been identified for use in medicines. Sulphated polysaccharides from macroalgae have been reported to inhibit the activities of viruses especially the herpes and HIV. These carbohydrates have shown to strengthen the immune system of human and animals. Algae also possess active principles that control and prevent various microbial infections (Ninawe, 2003).

The numerous food and medicinal values of marine macroalgae suggest that they can function as a unique therapeutic super food for human beings and they are being considered as the ‘medical food of 21st century’.

Industrial Applications of Macroalgae

Marine macroalgae constitute the basis for a multimillion-dollar industry, in which billions of dollars worth agar, carrageenan, alginates and other valuable minerals and chemicals are extracted annually. Many of these products are extensively used in industries such as food, confectionery, dairy, pharmaceuticals, textiles, paper etc. all over the world. The phyco­colloids such as agar, carrageenan and alginates are used as thickening, gelling, emulsifying and stabilizing agents in various industries. Agar extracted from red algae is used as a solidifying agent in bacteriological culture media. It is also used in processing canned meat, fish and poultry. It is used for stabilizing bakery icings and clarifying wines, juices and vinegar. Agar is used as a stiffening agent in a number of food products. It is used in the manufacture of various pharmaceutical preparations, photographic film coatings and paints. Alginates obtained from brown algae are extensively used in food, pharmaceutical, cosmetic, textile, paper, dairy, paint and
various other industries. Carrageenans isolated from red algae are used in dairy products, imitation creams, puddings, syrups and canned foods (Chennubhotla et al., 1987).

Other Applications

The potential role of microscopic algae in sewage treatment has long been recognised. However, there is as yet no cheap and efficient means of harvesting such algae on a commercial scale (Dring, 1982). Consequently, macroalgae, which are much easier to harvest are now being considered for this purpose. Algae are also used to recover heavy metal ions from industrial effluents or process waters (Greene and Bedell, 1990).

Marine macroalgae have frequently been used as indicators of trace metal pollution in coastal waters. They concentrate metal ions from seawater and the variations in the concentrations of metals in algal thalli often are taken to reflect the metal concentrations in the surrounding seawater. Algae accumulate only those metals that are biologically available (Lobban and Harrison, 1997).

One of the major new uses of marine macroalgae is their use as a biomass source for the production of fuels such as methane and alcohol by bacterial fermentation, thus providing a renewable replacement for the dwindling supplies of natural fuels from fossil sources (Dring, 1982). They are also being considered for the photobiological production of hydrogen, which is recognised as an ideal energy carrier that does not contribute to environmental pollution or global warming (Melis, 2002).
1.2 The Status of Marine Macroalgae in India

India, with a long coastline of about 7500 km including those of Island territories, possesses great potential of marine algal resources. The littoral and sublittoral rocky areas of Indian coast support a good growth of different marine algae including agarophytes (agar producing algae), alginophytes (algin producing algae), carrageenophytes (carrageenan producing algae) and edible algae. Out of about 20,000 marine algal species distributed throughout the world, 844 species have been reported from Indian coast (Oza and Zaidi, 2001). This includes 434 species of red, 216 species of green and 191 species of brown algae. Of these, 18 species of red algae are agarophytes, 13 species are carrageenophytes and 54 species of brown algae are potential alginophytes. The estimated total standing stock of marine algae on Indian coasts is about 70,000 - 80,000 tonnes wet weight (Zaidi et al., 1999). Among the maritime states of India, Tamil Nadu on the southeast coast occupies the prime position in algal availability (22,000 tonnes wet weight). The richest resources are found in the area from Mandapam to Kanyakumari. Gujarat on the west coast of India has an algal resource of about 20,000 tonnes wet weight. The important places of algal interest on this coast are Okha, Dwaraka, Adatra and Veraval. The island territories like Andaman and Nicobar Islands in the Bay of Bengal and Lakshadweep group of Islands in the Arabian Sea have been found to harbour a variety of marine algae in good quantities. Fairly rich algal beds are present along the coasts of Maharashtra, Karnataka, Kerala, Goa and Andhra Pradesh. Along the coast of Kerala, approximately 1000 tonnes of marine algae are produced annually and the important places of algal interest on this coast are Kovalam, Vizhinjam, Varkala and Kannur.
Chapter 1

Although India has a good wealth of naturally occurring marine algae, they are exploited commercially only for the manufacture of phycocolloids such as agar and alginates. The algal industry in India produces about 60 tonnes of agar and 500 tonnes of alginates annually. The annual demand of raw materials is 2000 tonnes of agarophytes and 13,000 tonnes of alginophytes. Since the indigenous production of phycocolloids is unable to meet the increasing demand, India imports about 10 – 12 tonnes of agar, 35 tonnes of alginates and 140 tonnes of carrageenan annually costing foreign exchange of about Rs. 10 crores (Zaidi et al., 1999). The cultivation of commercially important marine algae is being attempted in India to meet the increasing demand of raw materials for algae based industries.

The use of marine macroalgae as an alternate staple food or food-supplement has not caught any appreciable level in India. However, as the alarming growth of population has resulted in an increased demand for non-conventional food sources, marine macroalgae, which form an annually renewable resource, are becoming increasingly important. In India, where the coastal area is very long and where more than half the population is vegetarians, marine algae have a great potential as human food. The utilization of algae as food and food supplements could help in meeting the food and nutritional security and health measures of Indian population.

In this context, many studies have been done on the nutritional and biochemical aspects of Indian marine macroalgae. However, most of these studies are confined to a few coastal regions like Gujarat, Maharashtra, Goa and Tamil Nadu. In Kerala, most of the studies are confined to the southern coastal region. No detailed biochemical investigation has been carried out so far on the marine algae from central and northern coast of Kerala. Hence, the present study has been undertaken to investigate the biochemical
composition of marine macroalgae from two localities of Kerala coast – one from central and the other from northern Kerala coast.

1.3 Area of the Present Study

Kerala, situated on the southwest part of India, lies between north latitudes $5^\circ 15'$ and $12^\circ 85'$ and east longitudes $74^\circ 55'$ and $77^\circ 05'$ and covers 38.864 sq. km. It has a coastline of about 580 km, which is about 8% of the total coast length of India. The coasts north of Kozhikkode and south of Kollam are mainly rocky, while the central part is mainly sandy. Sea erosion on the coastal tract is a frequent feature of Kerala where groins and seawalls have been constructed as a protective measure. The tides are semidiurnal type and the mean tidal ranges vary from 0.9 m in the south to 1.8 m in the north. The coastline is very low and coastal areas are flooded by storm tides in many sections during the southwest monsoon season. The climate is typical of tropical features. The annual rainfall is high ranging from 200 – 300 cm, most of which falls during the southwest monsoon season. During the northeast monsoon season, rainfall is negligible. Based on the temperature and rainfall, the seasons of the year are designated (Menon and Rajan, 1989) as:

i. Wet summer monsoon season (southwest monsoon) – June to September

ii. Retreating monsoon season (withdrawal of southwest monsoon) – October to November

iii. Dry winter monsoon season (northwest monsoon) – December to February

iv. Hot season (Transitional period between NW monsoon and SW monsoon) – March to May
Ettikkulam along the northern coast and Narakkal along the central coast of Kerala were the sites chosen for the present study. The former is a rocky beach while the latter, a sandy beach. Algal samples were collected during the period August 1999 – April 2001.

1.4 Scope and Objectives of the Present Study

In the context of use of marine macroalgae as an ideal health food for humans, information on their biochemical composition is of immense value since the nutritive value of algae comes from various biochemical constituents such as proteins, carbohydrates, lipids, amino acids, vitamins, trace elements, iodine etc. Also, knowledge of the mineral constituents of marine algae is important in their use as livestock feed and fertilizer. Information on the toxic heavy metal content of marine algae is of utmost importance from the point of view of using them as food and fodder. The trace metal composition of marine algae also provides information on the pollution status of coastal environments. Likewise, an assessment of the available natural resources of agarophytes for their agar content and its quality is necessary in view of the increasing demand of raw materials for agar industry in recent years. Since marine algae exhibit specieswise, classwise, seasonal and geographical variations in their biochemical composition, a thorough biochemical investigation is essential for the proper utilisation of natural beds of marine algal resources and for the cultivation of economically and nutritionally important species of marine algae.
The objectives of the present study can be summarized as:

- Evaluation of the nutritional values of some selected species of marine macroalgae from central and northern Kerala coast by identifying their biochemical compositions.
- Determination of the interspecies, interclass, spatial and temporal variations in the biochemical compositions and nutritional values of macroalgae.
- Screening of macroalgae for their wide variety of amino acids.
- Estimation of the trace mineral content of marine algae including toxic metals.
- Qualitative and quantitative evaluation of agar extracted from agarophytes.

**References**


