CHAPTER - I

1.0. INTRODUCTION

Marine macroalagae are plant like organisms that generally live attached to rock or other hard substrata in coastal areas, are called seaweeds (Hardy and Guiry, 2006). “Seaweeds” are the common name for countless species of marine plants and algae that grow in the ocean as well as in rivers, lakes and other water bodies. Some seaweeds are microscopic such as the phytoplanktons that live suspended in the water column and provide the base for most marine food chains. Some are enormous like the giant kelp that grow in abundant “forests” and tower like under water redwoods from their roots at the bottom of the sea. Seaweeds are multicellular and macrothallic. They are photosynthetic and must be firmly attached to a stratum to stay in the photic zone where they can receive sufficient sunlight (Yang, 2002; Smith, 2004). Seaweeds are also called the benthic marine algae which just mean attached algae that live in the sea (Rindi, 2004).

The classification of seaweeds into divisions is based on various properties such as pigmentation, chemical nature of photosynthetic storage product, the organization of photosynthetic membranes and other morphological features. Traditionally, they belong to four different groups, empirically distinguished since the mid-nineteenth century on the basis of color: blue-green algae (phylum: Cyanophyta, up to 1500 species), red algae (phylum: Rhodophyta, about 6000 species), brown algae (phylum: Ochrophyta, classes: Phaeophyceae,

about 1750 species), and green algae (phylum: Chlorophyta, classes: Bryopsidophyceae, Chlorophyceae, Dasycladophyceae, Prasinophyceae, and Ulvophyceae, about 1200 species). However, each of these groups has microscopics, if not unicellular, representatives (Thahira Banu, 2010). All seaweeds at some stage in their life cycles are unicellular, as spores or zygotes, and may be temporarily planktonic. The blue-green algae are widespread on temperate rocky and sandy shores and have occasionally been acknowledged in seaweeds floras. Seaweeds are found growing throughout the world oceans and seas (Bold and Wyne, 1985; Hurd *et al.*, 2014; Guiry, 2012).

There are about 20,000 species of seaweeds classified in three divisions according to pigment and storage contents in their thallus. Seaweeds form an integral part of marine coastal ecosystems. They include the macroscopic, multicellular marine algae that commonly inhabit the coastal regions of the world. It has also been estimated that, there are about 9,000 species of macro algae broadly classified into three main groups based on their pigmentation (for example, Phaeophyta, Rhodophyta and Chlorophyta or the brown, red and green algae respectively). Brown seaweeds are the second most abundant group comprising about 2,000 species which reach their maximum biomass levels on the rocky shores of the temperate zones.

Among the 20,000 species of seaweeds in the world, India possesses 434 species of red seaweeds, 194 species of brown seaweeds and 216 species of green seaweeds. Distribution of seaweeds species in India are Gujarat 202; Maharashtra 152; Goa 75; Karnataka 39; Kerala 20; Lakshadweep 89; Tamil Nadu 302;

Andhra Pradesh 78; Orissa 1; West Bengal 6 and Andaman & Nicobar Islands 34. India presently harvests only about 22,000 tones of macroalgae annually compared to a potential harvest of 8,70,000 tones, a mere 2.5 percent (National Academy of Agricultural Sciences India, Dec 2003).

Seaweeds are highly adaptable and grow on every coastline throughout the world. Algae are the first photosynthetic cellular plants from which all subsequent groups of plants have been evolved. They are very diverse group of organisms that range from single celled to multicellular forms, show a low level of thallus differentiation and lack elementary conducting tissues of more advanced plants. Macro algae attain visible sizes and are organized in filamentous or parenchymatous thalli. Larger algae that have a very complex differentiated thallus are named seaweeds and when they are attached by a holdfast with upright stems and fronds as tall as trees are known as *kelps* (e.g., *Macrocystis* reaches 65 m. height).

In India, seaweeds grow abundantly along the coasts of Tamil Nadu, Gujarat, Lakshadweep and Andaman & Nicobar Islands. Kaliaperumal and Kalimuthu (1997) states that rich seaweed beds are found around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Kerala, Gulf of Mannar in Tamil Nadu and Chilka in Orissa. Approximately 700 species of marine algae are found in the Indian coast. Surveys carried out by the Central Salt and Marine Chemicals Research Institute (CSMCRI) and Central Marine Fisheries Research Institute (CMFRI) have reported vast seaweeds resources along the coastal belts of South India.

The seaweeds flora of India is highly diversified and comprises mostly of tropical species, but boreal, temperate and subtropical elements have also been reported. In all, 271 genera and 1153 species of marine algae, including forms and varieties have been enumerated till date from the Indian waters. Many of the rocky beaches, mudflats, estuaries, coral reefs and lagoons along the Indian coast provide ideal habitats for the growth of seaweeds. The coast is characterized by mixed tides and generally with narrow intertidal regions (Anon, 2005).

Edible seaweeds are algae that can be eaten and used in the preparation of food. It contains high amounts of fibre and complete protein (Wong and Cheung, 2000). They may belong to one of several groups of multicellular algae: the red algae, green algae and brown algae. Seaweeds are used extensively as food in coastal cuisines around the world. Seaweeds have been a part of diets in China, Japan and Korea since prehistoric times (Bird, 2011). Seaweeds are consumed in many traditional European societies in Iceland, Western Norway, the Atlantic coast of France, northern and western Ireland, Wales and some coastal parts of South West England, as well as Nova Scotia and Newfoundland. The Māori people of NewZealand traditionally used a few species of red and green seaweeds (Morrison, 2014).

Edible seaweeds have historically been consumed by coastal populations across the globe. Today, seaweeds are still part of the habitual diet in many Asian countries. Seaweeds consumption also appears to be growing in popularity in Western cultures, due to the influx of Asian cuisine as well as notional health benefits associated with consumption. Isolates of seaweeds (particularly viscous

polysaccharides) are used in an increasing number of food applications in order to improve product acceptability and extend shelf life.

Seaweeds are harvested or cultivated for the extraction of alginate, agar, carrageenan and gelatinous substances collectively known as hydrocolloids or phycocolloids. Hydrocolloids have attained commercial significance, especially in food production as food additives (Romero Gonzalez *et al.,* 2001).

The photosynthetic mechanisms of edible seaweeds are similar to that of land based plants. They are generally more efficient in converting solar energy into biomass, mainly because of their simple cellular structure and being submerged in an aqueous environment with access to water, Carbondioxide and other nutrients.

Macro algae are considered as the food supplement for 21st century, because they contain proteins, lipids, polysaccharides, minerals, vitamins and enzymes. Marine algae are similar to oats in protein and carbohydrate values. The green and red algae appear higher in crude protein far tested about 2 to 4 percentages. All algae contain high content of carbohydrates (sugar and starches) in polysaccharide biochemical structure which is a natural nontoxic colloidal substance that has been used as mucilaginous material referred to as gel. The nutrients composition of seaweeds varies and is affected by species, geographic area, season and temperature of water. These sea vegetables are of nutritional interest as they are low calorie food, but rich in vitamins, minerals and dietary fibres.

Seaweeds, which have traditionally been used by the Western Food industry for their polysaccharide extractives Alginates, Carrageenan and Agar also contain compounds with potential nutritional benefits. Seaweeds have recently been approved in France for human consumption (as vegetables and condiments), thus opening new opportunities for the food industry (Gorcia Closas, 2006). After human food consumption, the next most valuable commercial use of seaweeds are as raw material for extraction of phycocolloids (Agar, Alginate and Carrageenan), which are used in several industries (National Academy of Agricultural Sciences India, Dec 2003). Edible seaweed polysaccharides are extensively used as thickening agents in sweet and savory sauces and condiments. A number of applications of seaweeds polysaccharides are also utilized in order to stabilize food products against degradation, staling and heating or cooling/freezing.

In recent years, seaweeds have served as important sources of bioactive natural substances with various biological activities and potential health benefits (Pangestuti and Kim, 2011). Marine food, due to its phenomenal biodiversity is a treasure house of novel healthy food ingredients. Edible seaweeds are present in most people´s daily diet, either directly as raw or processed food or indirectly through by-products used in food and pharmaceutical industry such as gelling, stabilizing and thickening agents or as a source of colours, flavours and textures added to food products (Sartal *et al.*, 2012).

Edible seaweeds are consumed as food in various forms as salad, soups, pickle, sauce, pasta and jellies. The alginates are used as thickening agents in

sauces, syrups and toppings for ice creams. In pie fillings, it reduces moisture retention by the pastry and in cake mixes, it thickens the batter and aids in moisture retention and in canned meat and vegetables, it gives both temporary or delayed thickening agents and biologically active compounds (Kadam and Prabhasankar, 2010).

The coastal population of Tamil Nadu uses *Gracilaria edulis* for preparing gruel (porridge), this is the only known use of algae as food in India. *Gracilaria edulis* is also used in Tamil Nadu as manure for coconut plantations (Silas and Kalimuthu, 1987). Agar is used in the preparation of jellies, dairy products (yoghurt), confectioneries (jelly/ marshmallow type), bakery products (including pie fillings and icings) and canned meats. Agar is widely used in India in vegetarian foods and dishes such as Faluda and Blancmange. The growing interest in tissue culture as a standard method for the propagation of orchids and other ornamental plants, vegetables, fruits and other agricultural products has increased the demand for Agar-Agar as a culture media.

Edible seaweeds can help to build and sustain the broad nutritional balance of vitamins, minerals and vital nutrients on which optimum health and vitality depends. Seaweeds offer a wide range of therapeutic possibilities both internally and externally. Eating unprocessed dried seaweeds can yield many healing benefits. Many physical ailments in humans can be regularly resolved with the simple addition of seaweeds to their respective diets (Dhargalkar, 2014). Based on epidemiological and biological data, consumption of seaweeds are considered as an important factor contributing to the relatively low breast

cancer rates reported in Japan. Fucans and sulfated polysaccharides extracted from brown seaweeds have been shown to have inhibitory effect on cell growth in various experimental models. These findings raise the possibility that brown seaweeds like *Padina*, *Sargassum* and *Laminaria* may have clinical value in the prevention of cancer metastasis (Zakir, 2006).

From a nutritional point of view, edible seaweeds are low calorie foods with a high concentration of minerals, vitamins and proteins and a low content of lipids which are in the range of 2.3 – 4.6 percent based on semi dry sample weight (Dawczynski *et al*., 2007).

In general, red and brown species of seaweeds demonstrate large differences in their protein content. Dawczynski *et al.* (2007) reported that the protein content of seaweed products varied widely from 26.6 ± 6.3 percent in red algae, to 12.9 ± 6.2 percent in brown algae varieties. Seaweed proteins from red algae in particular, contain all essential amino acids, the levels of which are sufficient to meet dietary requirements.

Shanmugam and Palpandi (2010) found that *Ulva reticulata* had 50.24 percent carbohydrate, 19.98 percent protein and 1.7 percent lipid contents in dry sample. The analysis of fatty acids revealed the presence of myristic acid, palmitic acid, heptadecaenoic acid, oleic acid and linoleic acid.

The quality of protein and lipid in edible seaweeds are most acceptable for consumption compared to other vegetables mainly due to their high content in essential amino acids and relatively high level of unsaturated fatty acids. They have more than 54 trace elements, required for human body's physiological

functions in quantities greatly exceeding vegetables and other land plants. However, compared to land plants, the chemical composition of seaweeds has been poorly investigated (Wong and Cheung, 2000).

Phytochemical compounds isolated from edible seaweeds could benefit health. Certainly there has been great interest from the pharmaceutical industry in the high throughput analysis of macroalgal compounds for the development of novel drugs (Aneiros and Garateix, 2004).

Seaweeds have recently received significant attention for their potential as natural antioxidants. Antioxidant activity of marine algae may arise from carotenoids, tocopherols and polyphenols (Kumar *et al*., 2009). These compounds directly or indirectly contribute to inhibition or suppression of free radical generation (Hung and Wang, 2004). Investigation on dimethyl sulphoniopropionate (DMSP) has recently revealed that their compound from marine algae could serve as an effective antioxidant (Athukorala *et al*., 2006). It provides blood thinning, anti-inflammatory and antioxidant polysaccharides, which keeps the blood thin and easier for the heart to push through the blood vessels, prevents clots from forming, prevents free radical damage to the blood vessels and keeps plaques from clogging the blood vessels that feed the body.

Stimulating overall health and well being, sea vegetables are known to boost the immune system, increase energy and endurance, relieve nervous tension, detoxify the body, balance the endocrine system, promote circulation, clarity of thought and lower cholesterol and fat in the blood. Since sea vegetables are so concentrated in life sustaining minerals, they make the perfect

complementary addition to meals and recipes. Seaweeds present a wide variety of interesting bioactive molecules.

Edible seaweeds are consumed extensively by Indonesians, Japanese and Koreans who have understood the nutritional properties. Valuable health benefits of these seaweeds are yet to be exploited by Indians. It is reported that seaweeds like *Ulva lactuca, Ulva reticulata, Enteromorpha intestinalis, Acanthophora spicefera, Gracilaria edulis, Padina tetrastomatica* and *Sargassum wightii* are highly concentrated in the coastal belt of Gulf of Mannar, Rameswaram to Kanyakumari in Tamil Nadu. They are available throughout the year and can be stored for long periods in dry form. Seaweeds do not absorb toxic substances of any element. It provides hundreds of organic compounds and is toxin free. There are extensive studies on nutritional value of fresh water micro algae like "Spirulina" but seaweeds are yet to be popularized and promoted. Seaweeds added in small amounts are power houses of Nutrition.

Gracilaria species is one of the most widely cultivated genera, and is widely cultured extensively for subsistence farming and agar extraction, and is an important component of many traditional foods. *Gracilaria* species contribute to 70 percent of the world's agar and is used in genetic engineering trials to take up nutritional properties of other seaweeds (Phang *et al*., 2007). Brown algae namely *Padina gymnospora and Padina tetrastomatica* are abundant local species with the potential for integration with abalone culture as a feed source (Troell *et al*., 2006).

Red algae have been consumed by humans for atleast 2800 years their full agronomic and biotechnological potential have yet to be realized. 344 species are considered to be of economic value, but only species of *Porphyra, Gelidium, Euchuema and Gracileria* have been cultivated to significant amounts (Shah and Huffman, 2003).

The food industry is currently directing new product development towards the area of functional food ingredients due to consumers demand for healthier foods. The interest in developing these foods is thriving, driven largely by the market potential for foods that can improve the health and well being of consumers (Charalampopulous *et al*., 2002). According to a widely accepted definition, a Functional food is any modified food that may provide a health benefit beyond the nutrients it contains (FDA, 2004). These healthy foods include products with reduced fat, sugar or salt, fortified with vitamins, minerals, phytochemicals and containing probiotics (Manzi *et al*., 2007). These products are often marketed as promoting health or reducing the risk of disease. There is therefore a potential niche in the market for development of functional foods from seaweeds in order to capatilise on their rich phytochemical and dietary fibre levels. Edible seaweeds could be a good source of dietary fiber in the diet. Soluble and insoluble dietary fibers were recognized to have different physiological response (Wel *et al*., 2001).

The supplementation of seaweeds in foods could also increase consumption amongst the non-seaweeds consuming population (Gupta and Abu-Ghannam, 2011). Most of the edible seaweeds are not very tasty fresh, but dried

powder or flaked form sea vegetables are often best. The ease of drying sea vegetables in full sunlight and their long term stability when kept completely dry permits is safe. Coastal dwellers in tropical climates such as Indonesia and Malaysia have also eaten fresh seaweeds, especially as salad components.

Edible seaweeds not only possess nutrient potentials but also nutraceutical potentials like antioxidant, antimutagenic, anticoagulant, anticancerous and antibacterial activity. Hence, seaweeds can be considered as futuristically promising plants forming one of the important marine living resources of high nutritional value and nutraceutical potentials.

Recipe books promoting the use of 'sea vegetables' or 'marine vegetables' in home cooking are becoming more popular. The Department of Home Science, Thassim Beevi Abdul Kader College for women, Kilakarai published a receipe book under the UGC Innovative scheme and introduced a P. G. Diploma in seaweed farming and processing for food in 2004 – 2005 (Sumayaa, 2007). The consumer health and nutrition become more influential in the food industry, the use of seaweeds as an ingredient is on the rise and product development involving salads and wraps appears to be slowly evolving. As dried seaweeds are high in dietary fibre, along with a range of other potentially bioactive components, this addition has the potential to enhance the nutritional quality of a product. Habitual consumption of seaweeds may offer a nutritionally rich addition to the diet (Yang *et al.,* 2010).

Research conducted in western and other Asian countries reveal that consumption of sea vegetables has prevented the onset and incidence of

cardiovascular disease, obesity, cancer, osteoarthritis and diabetes mellitus. In south India the Mandapam coast of Gulf of Mannar region harbors luxuriant growth of seaweeds (CSMCRI, 2005). Edible seaweeds produced in tones, possess high nutritional value is being poorly consumed as food by the people in these areas as well as in the other part of India. Exploiting natural food resources is an easy and quick solution to prevent the rising prevalence of lifestyle and nutritional disorders. In the modern and stressful unhealthy lifestyle seaweeds are promising as natural resource in terms of availability and nutrient density. Hence keeping these facts in mind, the study was carried out with the following objectives:

The objectives of the present study to:

- Select edible seaweeds, identified to toxicological studies to determine the suitability of human consumption.
- To assess the nutrients and microbial load in the selected seaweed samples.
- Incorporation of selected edible seaweeds in South Indian indigenous recipes as value addition and
- Sensory evaluation of the indigenous Indian recipes incorporated with the selected edible seaweeds.

The following hypothesis was framed for the study:

- To ensure the selected edible seaweeds identified under study for the suitability for human consumption.
- To bringout the value addition through selected edible seaweeds to improve the quality of indigenous south Indian recipes commonly used by the local population.