“Seaweed is a healing food for the modern era”
- John Lewallen

Healthy living consciousness is on the rise in the recent years. Simple diet changes have been proven to lower the incidence of non-communicable diseases worldwide. Eating trends of natural food sources have been augmented to bring health and vitality and one such natural resource is seaweed.

In the vast ocean’s realm, several forms of life flourish with species of fishes, aquatic plants and animals which are rich sources of micro and macro nutrients. Among these, seaweeds are a fascinating and diverse group of organisms that are nutritionally valuable for humans.

Seaweeds are really not weeds but large marine algae classified under three important groups namely green, brown and red. Seaweeds include thousands of species from aquatic plants called “Phytoplankton” to huge floating and anchored plants in the ocean.

Worldwide there are about 900 species of green, 4000 red species and 1500 brown species of seaweeds. Red and green seaweeds are found mostly in subtropical and tropical waters, while brown seaweeds are more common in cooler, temperate waters (Reddy et al., 2006). Around 265 species of seaweed are being harvested commercially and of these, 145 species are used for food and 110 for phycocolloid production (Lindsey et al., 1999 and Worm et al., 2007).

According to the Food and Agriculture Organisation, between 1981 and 2000, the global production of aquatic plants rose from 3.2 million tons to nearly 10.1 million tons (wet weight). China holds the first rank in production followed by
North and South Korea, Japan, Philippines, Chile, Norway, Indonesia, United States of America and India.

In India, seaweeds grow abundantly along the coasts of Tamil Nadu, Gujarat, Lakshadweep and Andaman and Nicobar Islands. As Kaliaperumal (1997) states 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 Chemical Research Institute (CSMCRI) and Central Marine Fisheries Research Institute (CMFRI) have reported vast seaweed resources along the coastal belts of South India.

The consumption of seaweed enjoys a long history throughout the world. Seaweeds are the oldest plants on Earth and the healthiest food supplement. The global scenario of seaweed consumption dates back to 2700 BC in China and 100 BC in Europe. In general seaweeds were used for herbal medicine and food by the Greeks and Romans (Joh et al., 1994). Seaweeds have been harvested and consumed for centuries in Asian countries, especially Japan, China and Korea. Seaweeds or sea vegetables have been referred to as “nature’s medicine chest” because they contain high concentrations of many important nutrients (Jimenez, 2001).

Japan leads the world in production, consumption and export of seaweeds. Many varieties of seaweed are best known by their Japanese names, such as Aarame, Kombu and Wakame.

Japanese consumed seaweed as a vegetable, made into tea or as an ingredient in foods such as soups, noodles, salads, cakes, jellies and sauces. The mean intake of seaweeds in Japanese diet has been reported to be approximately 7 gram per person per day (Center for Food Safety and Applied Nutrition, 2003).
Dang (2004) reported that Vietnamese living in coastal areas have traditionally utilized seaweed species as food supplement, herbal medicine, sweetened jellies and also added in vegetable soups.

Burrows (1991) states that sea lettuce (Ulva lactuca) is a popular food in many places including Scandinavia, Great Britain, Ireland, China and Japan. They can be eaten raw in salads or cooked in soups and is high in protein, soluble dietary fibre, variety of vitamins and minerals.

Sohn and Kain (1989) reported that in the Republic of Korea, Wakame is enjoyed as an ingredient in soya bean and other soups, as well as in seaweed salads. In recent times there has been an overproduction of Wakame and this has led to increased marketing of new products, such as seaweed salad and precooked Wakame.

France was the first European country to establish a specific regulation concerning the use of seaweeds for human consumption as non–traditional food substances. In France twelve macroalgae (six brown algae, four red algae, two green algae) and two microalgae are authorized as vegetables and condiments (Burtin, 2003).

Consumption of seaweeds is not so popular despite its abundance in Indian coastal areas. In India, porridge made from Gracilaria species and Acanthophora species is consumed mainly in the coastal states of Kerala and TamilNadu. In India people consume seaweed indirectly in the form of phycocolloids added in chocolate, ice cream, jellies and as stabilisers in food products (Dhargalkar et al., 2005). Agar-agar, agarose and carrageenan are commercially valuable substances extracted from seaweeds.

The benefits of seaweeds are numerous and profound. Harvested in pure seawater, seaweeds can be considered as nature’s most complete and balanced nutrient food source (Wood House, 2003).
Seaweeds can help to build and sustain the broad nutritional balance of vitamins, minerals and vital nutrients on which optimum health and vitality depends.

A number of epidemiological researches have shown health benefits linked to seaweed consumption (JaneTeas, 1981, Hiqashi *et al.*, 1999, Funahashi *et al.*, 1999).

Ruperez (2002) stated that seaweeds contain a high concentration of minerals, vitamins, proteins and indigestible carbohydrates and a low content of lipids. They are also a good source of dietary fiber that differ chemically and physico-chemically from that of land plants and thus may include different physiological effects. No fewer than 92 different mineral elements have been found in seaweed including some elements, which we require only in trace amounts. Seaweeds contain as much as fifty times more minerals than land grown plants.

Seaweeds draw an extraordinary wealth of mineral elements from the sea that can account for up to 36 per cent of its dry mass. The mineral macronutrients include sodium, calcium, magnesium, potassium, chlorine, sulfur and phosphorus; the micronutrients include iodine, iron, zinc, copper, selenium, molybdenum, fluoride, manganese, boron, nickel and cobalt. Gram for gram, they are higher in vitamins and minerals than any other class of food. Seaweeds are best used in treating mineral deficiency diseases (Madhurjya, 2010).

Madhusudan *et al.* (2010) stated that seaweed has a large proportion of iodine compared to dietary minimum requirements and it is primarily known as a source of this nutrient. The highest iodine content is found in a brown algae dry kelp ranging from 1500-8000 parts per million and dry rockweed (Fucus) from 500-1000 parts per million.

Wong *et al.* (2000) reported that the quality of protein and lipids in seaweeds is extremely acceptable mainly due to the high content of essential amino acids and
the relative high levels of unsaturated fatty acids. Seaweed proteins contain all essential amino acids, the levels of which are comparable to those of the Food and Agricultural Organisation / World Health Organisation requirements.

Annian et al. (2008) found that Ulva reticulata had 50.24 per cent carbohydrate, 19.98 per cent protein and 1.7 per cent 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 dietary fiber content of seaweeds range from 33 to 75 per cent of dry weight and mainly consists of soluble polysaccharides that show important functional activities such as antioxidant, antimutagenic, anticoagulant and antitumour activity. Dhargalkar et al. (2009) noted that seaweeds are the best source of nondigestible fiber for increasing fecal bulk and decreasing bowel transit time.

Seaweeds are also found to contain high antioxidant and antimicrobial activity. The environment in which seaweeds grow is harsh as they are exposed to a combination of light and high oxygen concentrations. These factors can lead to the formation of free radicals and other strong oxidizing agents but seaweeds seldom suffer any serious photodynamic damage during metabolism. This fact implies that seaweed cells have some protective mechanisms and compounds (Matasukawa et al., 1997).

Santoso et al. (2004) noted that marine alga have been used as a novel food with potential nutritional benefits in food and pharmaceutical industry. Traditionally seaweed has been used in treating arthritis, constipation, nervous disorders, rheumatism, colds and skin irritation (Yaychuck, 2006). Ryan Drum (2005) reported that seaweeds improve lung function, prevents breast cancer and boosts heart health. It also helps in weight loss, reduce cholesterol and controls high blood pressure and thyroid disturbances.
Seaweed is a resource that continues to be used for various other contemporary purposes (Mitton, 2006). Some of the modern uses of seaweeds are in pharmaceuticals, thalassotherapy and homeopathy. Pharmaceutical companies utilize alginates for numerous types of dermatological problems. Seaweed solutions are also utilized as tonics for detoxification and nutritional supplementation in diseases such as rickets, tuberculosis and various states of debility. Homeopaths also prescribe seaweed and its derivatives for various ailments including obesity.

Recently, aquatic habitats have increasingly showcased to provide a rich source of natural bioactive compounds with hypcholesterolemic, anti-inflammatory, antiviral, antineoplastic, antimicrobial and hypertensive properties (Hanaa et al., 2008).

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. A study on rats has shown that simultaneous consumption of fish (fish oil) and brown seaweeds decreases the concentration of triacylglycerol in the serum and liver (Murata et al., 2002).

It is well documented that seaweeds such as green Laver and Sea Tangle may regulate hyperglycemia, hyperlipidemia (Park et al., 2007 and Park et al., 2009) and oxidative stress (Kwak, 2005). Furthermore, it is accepted that dietary fibers of edible seaweeds may regulate hyperglycemia and hyperlipidemia due to inhibited absorption of glucose and lipid in the intestine (Ginzberg et al., 2000).

Felix et al. (2010) reported that phenolic-rich extracts from four edible marine macroalgae commonly found in United Kingdom showed potential biological effects towards cultured colon cancer cells and anti-diabetic effects by inhibiting the action of digestive enzymes.
Based on epidemiological and biological data, consumption of seaweeds is 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 seaweed like Padina, Sargassum and Laminaria may have clinical value in the prevention of cancer metastasis (Zakir, 2006).

The well known fact that fishes are known dietary source of $n-3$ fatty acids, is supported by the fact that the $n-3$ fatty acids are obtained by them from the algae or plankton in their diet. The most widely available dietary source of eicosapentaenoic acid and decosahexaenoic acid from oily fish such as salmon, herring, mackerel, anchovies and sardines are due to the consumption of algae by them. Oils from the above fishes have a profile of around seven times as much $n-3$ as $n-6$ and regarded as hypolipidemic functional ingredient (Falk-Petersen et al., 1998).

Iron deficiency is one of the most prevalent nutritional deficiencies in the world and it affects 20-50 per cent of world population (Saloojee, 2001). According to WHO (2008) statistics, 60-70 per cent of Indian adolescent girls are suffering from anaemia. Possible ways to improve iron status may include food fortification, diet, antihelmithic treatment and supplementation (Kanani, 1997).

Apart from nutritional deficiencies, degenerative diseases like cancers are also on the rise. Among all the cancers oral cancer is the eleventh common cancer in the world (Napier, 2008). Oral cavity cancer accounts for approximately 1-5 per cent of all malignancies and is a significant worldwide health problem. India has the highest number of oral cancer in the world and it varies from 0.2 to 5.2 per cent (Neufeld et al., 2005).

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 Kanniyakumari in Tamil Nadu. They are available throughout the year and can be stored for long periods in dry form. Seaweeds do not absorb toxic amounts of any element. It provides hundreds of organic compounds and is toxin free.

There are extensive studies on nutritional value of fresh water algae like spirulina but seaweeds are yet to be popularized and promoted. Seaweeds added in small amounts are power houses of nutrition.

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 general objective: To

- select edible seaweeds, develop value added products and assess the therapeutic effect of the value added products.

**The specific objectives were to:**

- assess the microbial content, evaluate the toxicology, antioxidant activity and antimicrobial properties of the selected seaweeds
- develop value added products with seaweeds and study the *invitro* iron bioavailability and antioxidant activity of the value added seaweed products
- study the impact of value added seaweed products among selected anaemic adolescent girls and adult males with precancerous oral lesions.
The following hypothesis was framed for the study

Hypothesis

Seaweeds *Ulva reticulata* and *Ulva lactuca* have a therapeutic effect on anaemia and precancerous oral lesions among selected adolescent girls and adult male subjects respectively.