CHAPTER - II

REVIEW OF LITERATURE

The review of literature pertaining to the study **"An analytical study on the selected edible seaweeds and their efficacy test for human consumption"** is present under the following headings:

Edible seaweeds – An overview

Consumption of edible seaweeds in global scenario

Toxicological studies of edible seaweeds

Nutritional importance of edible seaweeds

Therapeutic value of edible seaweeds

Edible seaweeds – An overview

Edible seaweeds have salted flavor, somewhat mildly spicy and they can be eaten and used in the preparation of food. They typically contain high amounts of fiber, trace minerals and contrary to land based plant foods, they contain complete proteins. Some of the important edible seaweeds genera found along the Indian coast are *Porphyra, Rhodymenia, Hypnea, Gracilaria, Gigartina, Gelidium, Grateloupia, Laurentia, Iridaea, Phyllophora, Sargassum, Dictyota, Stoechospermum, Dictyopteris, Padina, Turbinaria, Ulva, Enteromorpha, Monostroma, Caulerpa* and *Chaetomorpha etc.* (Jaspars and Folmer, 2013).

Seaweeds are extensively used as food by coastal people all over the world. Red algae like *porphyra* and *nori* are used in soups and salads. *Irish* moss is another red algae used in producing various food additives along with *Kappaphycus*. Alginate, agar and carrageenan gelatinous substances collectively known as hydrocolloids or phycocolloids. Hydrocolloids have attained commercial significance especially in food production. Most of the carrageenan is extracted from *Kappaphycus alvarezii* and *Eucheuma denticultum*. Carrageenan was a family of linear sulphated polysaccharide extracted from red seaweeds. The name is derived from a type of seaweeds that is abundant along the *Irish* coast line (Buck *et al.*, 2006).

Hong and Hien (2004) reported that Vietnamese living in coastal areas have traditionally utilized seaweeds species as food supplement, herbal medicine, sweetened jellies and also added in vegetable soups. Burrows (1991) stated 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. Sea lettuce *Ulva* species have a long tradition of human use in Scotland, low income families who resides near tidal areas may rely exclusively on ocean resources, they eat seaweeds as part of their regular diet (Ostraff, 2006).

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 seaweeds salads. In recent times there has been an over production of *Wakame* and this has led to increased marketing of new products, such as seaweeds salad and pre-cooked *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 macro algae (six brown algae, four red algae, two green algae) and two microalgae are authorized as vegetables and condiments (Burtin, 2003).

Edible seaweeds consumption has gained a measure of acceptance in some Westernized cultures such as Hawaii, California and Brazil, where there are large Japanese communities who have had a tangible influence on the local dietary practices (Yamori *et al.,* 2001).

Marine edible seaweeds have recently become a widely consumed food in Western countries, either directly as raw or cooked products or indirectly being part of many food products as ice cream, mayonnaise, cheese and chocolates prepared due to the thickening properties of agar, alginates and carrageenans that are polysaccharides extracted of algae (Ruperez, 2002). In the West, seaweed alginate from brown algae and agar or carrageenan from red algae are typically used industrially (Cofrades *et al.,* 2010).

Edible seaweeds serve as food stuff in the Asian diet for centuries as it contains carotenoids, dietary fibers, proteins, essential fatty acids, vitamins and minerals. Approximately one million metric tons of wet seaweeds are harvested and extracted to produce the three hydrocolloids like agar, carrageenan and alginate (Nussinovitch, 1997).

In Malaysia, Sabah is the main seaweeds producer and most of the total production comes from Semporna, which is located on the East coast of Sabah (Sade *et al.,* 2006). According to (Matanjun *et al.,* 2009) the chemical composition of edible seaweeds from some regions of the world has been well documented, but no reports are available on the nutritive value of the tropical seaweeds from North Borneo and the data from her publication only focus on *Eucheuma cottonii, Caulerpa lentillifera, Sargassum polycystum, Kappaphycus alvarezii, Eucheuma denticulatum, Gracilaria changii, Gracilaria edulis, Caulerpa lentillifera* and *Sargassum polycystum* (Matanjun *et al.,* 2009; Matanjun *et al.,* 2011). The reports on chemical composition of Semporna, Sabah edible Seaweeds are still lacking and the proximate compositions depend on species specific differences, growth environments, geographical locations and harvesting season (Ortiz *et al.,* 2006; Renaud and Luong-Van, 2007; Marsham *et al.,* 2007; Chakraborty and Santra, 2008; Matanjun *et al.,* 2009; Venugopal, 2011).

Alginate is extracted from brown seaweeds. Agar and carrageenan are extracted from red seaweeds namely *Gracilaria Gelidium, Kappaphycus alvarezii* and *Eucheuma denticulatum*. These are used as thickening agents and they improve the texture of foods. Alginates are the basis of many slimming diet foods, particularly biscuits, alginic acid which swells in the stomach and fills it, so that the dieter no longer feels hungry. The body cannot assimilate the alginic acid, so no calories are absorbed (Bhaskar *et al.,* 2006).

Major seaweeds used for alginates include *Ascophyllum nodosum*, *Laminaria* sp., *Macrocystis* sp., *Sargassum* sp., *Durvillea* sp. and *Ecklonia* sp., These two latter seaweeds are commonly found in waters in southern Australia. During the 1960's *Durvillea* sp., *and Ecklonia* sp., were harvested and used in Tasmania for alginate processing. Alginate produced by brown seaweeds, especially in the form of sodium and calcium alginate, is widely used in the food and pharmaceutical industries due to their ability to chelate metal ions and to form highly viscous solutions.

Consumption of edible seaweeds in global scenario

Edible seaweeds are traditionally consumed in Asia as sea vegetables, while in western countries they have been used as sources of gelling or thickening agents. With reference to nutrients, seaweeds are considered as low calorie food, exhibiting high concentration of minerals such as magnesium, calcium, phosphorous, potassium, iodine, vitamins, proteins and carbohydrates but with low lipid content. The earliest record of use of seaweeds dates back to 2700 BC in the compilation on 'Chinese Herbs' by Emperor Shen Nung reports show that, seaweeds have been a part of the Japanese diet since 300 BC. Seaweeds are mainly consumed in the oriental countries like Japan, China, Korea and more recently in USA and Europe. The Republic of Korea has the highest per capita consumption of seaweeds in the world (National academy of agricultural sciences India, Dec 2003). Since ancient times in Asia seaweeds have been consumed in great quantities as food but in the western world seaweeds species have been used mainly as food additives. However, there has been an increasing interest in edible seaweeds in Europe and Latin America (Aguilera Morales *et al.*, 2005).

The consumption of seaweeds as food has strong roots in Asian countries such as China, Japan and the Republic of Korea, but demand for seaweeds as food has now also spread to North America, South America and Europe. China is by far the largest seaweeds producer followed by the Republic of Korea and Japan but seaweeds today produced in all continents. Red and brown seaweeds also used to produce hydrocolloids; alginate, agar and carrageenan, which are used as thickening and gelling agents. Today, approximately 1 million tones of wet seaweeds harvested and extracted to produce about 55,000 tones of hydrocolloids (McHugh, 2003).

Japan leads the world in production, consumption and export of seaweeds. Many varieties of seaweeds are best known by their Japanese names, such as *Aarame, Kombu* and *Wakame.* The Japanese have been consuming seaweeds for more than 10,000 years. Japanese consumed seaweeds as a vegetable, made into tea or as an ingredient in foods such as soups, noodles, salads, cakes, jellies and sauces. The daily seaweeds consumption per person in Japan has remained relatively consistent over the last 40 years. Seaweeds consumption frequency differs from person to person in Japan, resulting in a constantly fluctuating iodine intake. Seaweeds are served in approximately 21 percentage of Japanese meals (Yashinaga *et al.*, 2001) with 20-38 percentage of the Japanese male and female population aged 40-79 years consuming seaweeds more than five times per week, 29-35 percentage three to four times per week, 25-35 percentage one to two times per week, 6-13 percentage one to two times per month, and 1-2 percentage rarely consuming seaweeds (Iso *et al.,* 2005). A food frequency questionnaire on the Japanese *Kombu* association website indicates that *kelp* (assuming *kombu)* is consumed at a rate of: 27.5 percentage once per week, 25.5 percentage once per month, 18 percentage three or four times per week and 15.9 percentage once every few months, with only 6.1 percentage of survey respondents stating they consume *kelp* nearly every day (Nihon Konbu Kyoukai, 2010).

The consumption of edible seaweeds are widespread among peoples of the south pacific islands. In Fiji, edible seaweeds form an important part of the diet. There is considerable evidence to suggest that the native Fijians have a long tradition in the collection and consumption of seaweeds and that this is in common with consumption of seaweeds by coastal peoples throughout Melanesia (Robin South, 1993). The populations in countries like New Zealand, Canada, Ireland, Norway, Iceland and Scotland have been consuming seaweeds since ancient times. Some Government and commercial organizations in France have been introduced three promoting seaweeds for restaurant and domestic use with some success. Fresh and dried seaweeds are utilized as human food (Erhart, 2001).

The consumption of edible seaweeds directly (fresh or dried) may not appeal to the Indian people because they are adverse to the tastes, smells and textures. However, they can be eaten in small quantity mixed with strongly flavored spices such as fried onions, raw garlic, chili powder, curry, vinegar and other ingredients to make them more palatable. There are several ways Indians add seaweeds to their diet. The variety of dishes can be prepared with different seaweeds, from desserts such as jellies, jams, breads, pizzas, pasta, casseroles etc. Dry or fresh seaweeds can be tucked into sandwich or make seaweeds chips by drizzling in oil. By simply eating unprocessed dried seaweeds one can yield many healing benefits. Fresh seaweeds can be cut in to strips and toss into soups and salads.

Consumption of seaweeds are 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 Tamil Nadu. In India people consume seaweeds indirectly in the form of phycocolloids added in chocolate, ice cream, jellies and as stabilisers in food products (Dhargalkar and Pereira, 2005). Agar-agar, agarose and carrageenan are commercially valuable substances extracted from seaweeds.

Treatment of vegetables for consumption exposes the phytochemicals to detrimental factors that may lead to alterations in concentrations and health related quality (Volden *et al.*, 2009). In reality, only a small amount of fruits and vegetables are consumed in their raw state, as most of them need to be processed for safety, quality and economic reasons. The evaluation of the influence of food processing is a key factor while establishing technological conditions that enable to preserve or improve original activity and bioavailability of naturally occurring antioxidants. In the development of new food products from seaweeds it will be important to ensure that the processing conditions utilized do not adversely affect the contents of bioactive compounds, in order to produce functional food products with nutraceutical properties (Kusznierewicz *et al.,* 2008).

Edible seaweeds have been used as human food from time immemorial. Use of seaweeds as staple diet has been extensive in the far Eastern countries as compared to other parts of the globe (Anonymous, 2002). Seaweeds are eaten for their value, flavours, colours and textures and are typically combined with other types of food. Apart from China and Japan the other seaweeds consuming countries are Korea, Philippines, Malaysia, Chile, Indonesia, Norway, Nambia, Sweden, Iceland, Ireland, Hawai, England, Wales, Germany, France, Canada, Russia, USA as well as many Island in the South Pacific, but they are not very commonly used in India for food purpose. It is believed that seaweeds play a key role in the production of protein, vitamins and minerals for human nutrition (Anonymous, 2002). Currently, human consumption of green algae (5%), brown algae (66.5%) and red algae (33%) is high in Asia, mainly Japan, China and Korea (Dawes, 1998; Mannivannan *et al.,* 2009).

Toxicological studies of edible seaweeds

The study of the adverse effects of chemicals on living organisms is called Toxicology (from the Greek word toxicos and logos) (Schrage, 2006). It is the study of symptoms, mechanisms, treatment and detection of poisoning, especially the poisoning effects on people. Irhimeh *et al.,* (2007) investigated the toxicity of seaweed extract in both human and animal. Human clinical studies using 3g daily *Undaria* seaweed extract with 75 percent fucoidan content indicated no clinical toxicity.

Karez *et al.,* (2003) revealed that, the trace metal concentration like Zn, Cd, Pb, Cr and Cu were determined in some benthic algae due to increasing industrial activities it was accumulated in algae. The bio-concentration factor for Zn was examined in algae, among that *Padina gymnospora* showed higher accumulation than others and also it has very high affinity for cellular binding.

Frank Riget *et al.,* (1997) studied that, the variability of elements like Cd, Fe, Co,Ce, Sr and Se levels in three seaweeds species, *Fucus vesiculosue, F. disticheus* and *Ascophyllum nodosum* from different samples sites in west Greenland for three years period. The variability of element concentration showed a complicated pattern and the element levels varied from place to place but it was low compared to other areas in Europe and North America. Caliceti *et al.,* (2005) found that, the concentration of heavy metals (Fe, Zn, Cu, Cd, Ni, Pb, Cr, As) in seven seaweeds.

Seaweeds samples were collected in four sampling sites of Venice. Metals were extracted using hot concentrated acids in microwave digestion rotor and analysed by AAS. High contamination levels especially for lead were detected in *Ulva* and lesser extent in *Gracilaria* the least contaminated genera with all metals except Arsenic were *porphyra* and *Undaria.* Karez *et al.,* (1996) studied that the accumulation of heavy metals in seaweeds species at Brazil, for their study they use six seaweeds species which were cultivated in laboratory for biomointoring purpose. Denise Phaneuf *et al.,* (2002) studied the contamination of marine algae in St. Lawrence River estuary and also evaluated the risks to human health from the consumption of these algae. The most frequently collected species of algae were *Fucus vesiculocus, Asophyllum nodosum, Laminaria longicrusis, Palmaria palmata* and *Ulva lactuca.* These samples were analysed for metals (As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn) iodine and organochlorines. The results suggested that the concentration of metals were not very high. Hg and organochlorines were too low to detect. All species had very high iodine content especially in *Laminaria* spp. For regular consumption of *U. lactuca* and *P. palmata* it is most preferable to choose the species with low iodine concentration. Qari and Siddiqui (2010) depicted that, the heavy metal concentration in red seaweeds from different coastal areas of Karachi in Arabian Sea. They stated that high variability of metals concentration in the following trends Mg>Fe>Mn, Zn>Cu.

Almela Concepcion *et al.,* (2006) examined that 112 samples of seaweeds preparation sold in Spain. The concentration ranges found were total As (0.031–149), inorganic As (<0.014–117), Pb (<0.050–12.1) and Cd (<0.003–3.55). All the samples were tested *Hizikia fusiforme* exceeded the inorganic arsenic limit established in some countries and considerable number of species exceeded the Cd limit set by international regulations. Martin Rose *et al.,* (2005) evaluated that, the arsenic levels in five varieties of seaweeds in various place. Total and inorganic arsenic were analysed both before and after cooking preparation. The arsenic remaining in water used for soaking also measured. *Hijiki* (brown seaweed) which having more inorganic arsenic compared to the other seaweeds it ranges that 67 – 96 mg/kg. Since consumption of *Hijiki* could significantly increase dietary exposure to inorganic arsenic, the Food Safety Association, UK issued advice to avoid eating these seaweeds. Marine algal toxins are responsible for an array of human illness associated with consumption of seafood and in some cases, respiratory exposure to aerosolized toxins. Approximately 20 percent of all food borne disease out breaks in the US results from the consumption of sea foods with half of these resulting from naturally occurring algal toxins (Ahmed, 1991).

Fahprathanchai Prannapus *et al*., (2006) evaluated the sub chronic toxicity for 60 days testing on *Cladophora glomerata* and *Microspora floccose* in albino rats. They depicted that 0.5 g/kg and 1.0 g/kg of body weight does not cause any toxicological signs in the treatment groups. The albino rats showed neither abnormal signs nor deaths during the study period.

Nutritional importance of edible seaweeds

The role of nutrition in human health is progressively gaining more attention over the last few years. Food is not only beneficial due to the presence of essential nutrients, but also due to the occurrence of other bioactive compounds which have been found to be important for health promotion and disease prevention. These beneficial effects can be attributed to the complex mixture of phytochemicals which possess antioxidant, antimicrobial, anticancer and antiviral activity. The compounds responsible for these activities include phenolic compounds, sulphated polysaccharides and organic acids and seaweeds are a rich source of such phytochemicals (Liu, 2003; Podsedek, 2007; Apostolidis *et al*., 2008).

Seaweeds are a source of biologically active phytochemicals, which include carotenoids, phycobilins, fatty acids, polysaccharides, vitamins, sterols, tocopherol and phycocyanins. Many of these compounds have been recognised to possess biological activity and hence beneficial for use in human and animal healthcare.

Seaweeds satisfy the nutritional requirements in humans and are catalogued as "health food", since they are rich in soluble dietary fibre (higher content in fibre than some fruits), proteins containing all essential amino acids, minerals, vitamins, antioxidants, polyunsaturated fatty acids (with low caloric value) and are also a source of bioactive compounds .

Protein

The protein content data in macro algae from tropical and subtropical coastal environments show low protein concentrations (Wong and Cheung, 2002). The protein content present in the different group of seaweeds from vedalai coast was studied. The result revealed that protein content was maximum in *Gracilaria acerosa* and minimum in *D. dichotoma* (Manivannan *et al*., 2009).

The protein level of *Ulva* species were in the range of 15 to 20 percent of dry weight (Arasaki, 1997). Green algae belonging to the genus *Ulva* contain 18 to 26 percent proteins (Nisizawa *et al.*, 2002). In Europe, *Ulva* species was already used for soups or salad preparations. Venture Uan (2006) estimated that, the nutritive value of *U. lactuca* as a food for goats and suggested that *U. lactuca* can be considered as medium quality forage for goats with high protein content.

The nutritional qualities of two edible green seaweeds *Caulerpa lentillifera* and *Ulva reticulata* were studied with a view to their utilization in human nutrition (Pattama Ratan arporn and Anong Chirapart, 2006). Protein and ash contents were the two most abundant components in these seaweeds. *Caulerpa lentillifera* and *Ulva reticulata* contained 12.49 percent, 21.06 percent protein and 24.21 percent, 17.58 percent ash based on dry weight, respectively. Both seaweeds contained high amounts of minerals and balanced amino acid profiles. Both seaweeds showed their potential of being healthy food for human diet or as source of ingredient with high nutritional values.

In the coastal area of Pakistan (Rashida Quasim, 1991) conducted a study to evaluate the seaweeds proteins on the basis of amino acid composition. Almost all amino acids except cysteine, methionine and histidine were found. The higher concentrations of acidic amino acids were found in species of Rhodophyaceae and Chlorophyaceae than in Pheophyaceae. The free amino acid fractions of seaweeds were mainly composed of alanine, amino butyric acid, taurine, ornithine, citrulline and hydroxyproline levels of these differ according to the seaweeds species (Ortiz *et al.*, 2006).

Structure and biological properties of proteins extracted from seaweeds are not as widely documented as of polysaccharides. Usually the content of proteins in seaweeds are less than five percentage. The lowest content of proteins have brown seaweeds. Most species of algae contain all of the essential amino acids (Aguilera Morales, 2005). Very important bioactive proteins that can be extracted from macro algae are lectins, which bind with carbohydrates and participate in many biological processes like intercellular communication. They have also antibacterial, antiviral or anti-inflammatory activities (Cunningham and Joshi, 2010).

Wong and Cheung (2000) reported that, the quality of protein and lipids in seaweeds are extremely acceptable mainly due to the high content of essential amino acids composition, antioxidant activity and therapeutic use of selected seaweeds and the relative high levels of unsaturated fatty acids. Seaweeds proteins contain all essential amino acids, the levels of which are comparable to those of the Food and Agricultural Organization (FAO) / World Health Organization (WHO) requirements. Wong and Cheung, (2001) studied the nutritional values of seaweeds protein concentrates isolated from red and green seaweeds species and reported that the red species showed significantly higher protein extractability, protein digestibility and essential amino acids than the green species. The protein content of brown seaweeds are generally low when compared to red and green seaweeds. With respect to the high protein level and amino acid composition, the red seaweeds appear to be an interesting potential source of food protein. Certain species of green algae like *Ulva* species have high levels of arginine or glycine. The free amino acid fractions of seaweeds are composed of alanine, aminobutyric acid, taurine, ornithine, citrulline and hydroxyproline. Levels of these compounds differ according to the species. All the species of seaweeds contain histidine, which is necessary for children and taurine which has pharmacological activity (Hong *et al.*, 2007).

Higher protein contents are recorded in green and red edible seaweeds (on average 10-30 percent of the dry weight). In some red edible seaweeds such as *Palmaria* palmate, *Nori* protein composition upto 35 and 47 percent of the dry matter respectively (Lahaye *et al.*, 1993).

Larsen (2011) suggested that, amino acid content of seaweeds are similar to those of vegetables but they are more complete comparable to those found in eggs almost all seaweeds contain the essential amino acids. Fleurence *et al.*, (2000) stated that, the red and brown algae are rich in fatty acids such as eicosapentaenoic acids and arachidonic acid.

Lipids

Edible seaweeds has very little fat, ranging from 1-5 percent of dry matter although seaweeds lipids have a higher proportion of essential fatty acids than land plants (Dharmananda, 2002). Seaweeds has very little fat ranging from 1-5 percent of dry matter, green algae whose fatty acid make up is closer to higher plants and have a much higher oleic and alpha linoleic acid content (Renaud *et al.*, 2002).

Wong *et al.*, (2001) found that seaweeds species *Undaria pinnatifida* and *Hijikia fusiforme* to be rich sources of omega-3 fatty acids. Lipids represent only 1-5 percent algal dry matters and should interesting polyunsaturated fatty acids composition particularly with omega 3 and omega 6 fatty acids, which play a role in the prevention of cardiovascular diseases (Reneud *et al.*, 2002). Drum (2003) reported that, most sea vegetables are excellent sources of the known vitamins A, B especially B_{12}, C,D,E and K as well as essential fatty acids. Folic acid, which is particularly important during pregnancy, lowers the risk of heart disease and allows us to metabolize carbohydrates (Shep, 2001). Le tutour (2000) reveled that, lipids extracts of some edible seaweed showed antioxidant activity and a synergistic effect with tocopherol.

Holdt and Kraan (2011) revealed that the red and brown algae are particularly rich in fatty acid with 20 carbon atoms. Phospholipids and glycolipids are the main classes of lipids found in edible seaweeds. When the decrease of environmental temperature occurs, seaweeds can accumulate Poly-Unsaturated Fatty Acids (PUFAs). The species that live in cold regions contain more PUFAs than species living in higher temperatures (Holdt and Kraan, 2011). Long chain PUFAs (LC-PUFAs) are of particular interest, because they are very important for human health maintains and they are synthesized only by plants (Pulz and Gross, 2004). These lipids consist of atleast 20 carbon atoms with atleast two double bonds. When the first double bond is located in the third carbon atom, the lipid molecule is referred as omega-3 (n-*3* LC-PUFA). The research (Aguilera Morales *et al.,* 2005) showed that n-*3* LC-PUFA constituted 10.38 percentage of total fatty acids found in *Enteromorpha* species.

2.4.3 Polysaccharides

Polysaccharides are a class of macromolecules which are increasingly gaining attention in the biochemical and medical areas due to their immuno modulatory and anticancer effects. These are present primarily in the cell walls and the composition varies according to season, age, species and geographic location. In addition to acting as a food reserve, they also provide strength and flexibility to the plant to withstand wave action and maintain ionic equilibrium in the cell. The regularity of their structures also promotes interaction with external ions and inter-chain hydrogen bonding (e.g., gelation). Brown seaweeds are known to produce different polysaccharides, like alginates, fucoidans, and laminarans. Laminarans and fucoidans are the main water soluble polysaccharides of brown algae whereas high molecular mass alginic acids are alkali soluble polysaccharides.

Seaweeds are valued for their high contents of polysaccharides (including agar, alginates and carageenans). The major components of seaweeds polysaccharides are galactose, mannose and glucose. Thus seaweeds contain a significant amount of soluble polysaccharides which have potential function as dietary fibre (Venugopal, 2011).

Edible seaweeds contain large amount of polysaccharides notably cell wall structural polysaccharides that are extracted by the hydrocolloid industries alginate from brown seaweeds. Carrageenans and agar from red seaweeds and other minor polysaccharides are found in the cell wall of *Fucoidans* in brown seaweeds and *Ulva* in green seaweeds (Lahaye and Jegou, 1993). Edible seaweeds contain various bioactive compounds with potential health benefits and their use as functional ingredients opens up new prospects for food processing and meat product formulations. Seaweeds basically contain high proportions of polysaccharides along with various other potentially beneficial compounds such as good-quality protein and essential fatty acids, particularly long-chain n-3 polyunsaturated fatty acids (PUFAs). Alginates are the most abundant ionic polysaccharides present in brown seaweeds (Fernandez- Martin *et al.*, 2009).

Researchers from France reported one particular polysaccharide in *Ulva* species as Ulvan. Ulvan is a sulphated polysaccharide that has been shown to kill cancerous colon cells and also aids in digestion. Recent findings suggested that sea lettuce was boiled and then drunk as a juice to kill intestinal worms. Seaweeds polysaccharides have been used within the food industry in a wide number of important applications aimed at improving the sensory properties and shelf-life of food products (Gupta and Abu-Ghannam, 2011).

2.4.3.1 Dietary fibre

Dietary fibre is the major component of seaweeds, the term “dietary fibre” was first used in 1953, in place of “crude fibre”, to refer to the non-digestible residue in foods (Potty, 1996). Dietary fibre in seaweeds are mainly composed of four families of polysaccharides; laminarans, alginates, fucans and cellulose. Laminarans are reserve polysaccharides found in brown algae and are composed of (1, 3)-β-D-glucose with some (1, 6)-linkages in which some of the reducing ends are replaced with mannitol. The major matrix component of brown seaweeds are gelling polyuronide, alginate, consisting of alternating sequences of β-(1,4)-D-mannuronic acid, its C5 epimer α- (1,4)-L-guluronic acid and 20–30 units of uronic acids (Jimenez Escrig and Sanchez-Muniz, 2000). Fucans are polysaccharides which can be classified into three major groups; fucoidans, xylofucoglycuronans and glycorunogalactofucans (Jiménez-Escrig & Sanchez-Muniz, 2000). Cellulose constitutes cell walls of brown algae and the cell walls of red algae are composed of sulphated galactans (carrageenans and agar), xylans, mannans and cellulose (Lahaye and Jegou, 1993). Green seaweeds contain starch, 42 cellulose, xylans, mannans and ionic polysaccharides which contain sulphate groups and uronic acids. (Lahaye and Jegou, 1993) reported that rhamnose, xylose, galactose and arabinose are also found in green algae.

Several researchers have suggested that sulfated polysaccharides from marine algae serve as free-radical scavengers and antioxidants and thus can play an important role in preventing the free-radical-induced oxidative damage related to alcohol (Hui Wang *et al.*, 2008). Seaweed polysaccharides also used to treat arthritis as they are active in promoting and aiding the healing process of the body. The recent application of polysaccharide for the immobilization of biological catalyst in the industrial processes is one of the greatest prospects in modern biotechnology (Draget *et al.*, 2005).

Consumption of seaweeds can increase the intake of dietary fibre and lower the occurrence of some chronic diseases such as diabetes, obesity, heart diseases and cancer which are associated with low fibre diets of the Western countries (Southgate *et al.*, 1990). Dietary fibre can be divided into soluble and insoluble fractions. The viscosity of soluble fibre is responsible for slower digestion and absorption of nutrients, and lower levels of blood cholesterol and glucose. Insoluble dietary fibre is characterized by its ability to increase fecal bulk and decrease intestinal transit time (Baghurst *et al.*, 1996; Potty, 1996). Seaweeds are rich in fibre (33–50 g/100 g db), particularly soluble fractions (50 – 85 percent of total dietary fibre content), therefore they can be exploited in order to enrich the fibre contents of foods which are generally low in this component (Jimenez Escrig and Goni, 1999; Jiménez-Escrig and Sánchez-Muniz, 2000; Rupérez and Saura-Calixto, 2001).

Dietary fibre from different algal sources is known for the capacity to lower serum cholesterol levels (Jiménez Escrig and Sánchez-Muniz, 2000; Ginzberg *et al*., 2003) and has the potential to be used as natural antioxidants by the food industry (Jiménez Escrig *et al.,* 2001; Rupérez *et al*., 2002).

Wel *et al.,* (2001) reported that, the insoluble dietary fibers were recognized to have different physiological response. Seaweeds have high fiber content, making up 32 percent to 50 percent of dry matter. The soluble fiber fraction accounts for 51 to 56 percent of total fibers in green (ulvans) and red algae (agars, carrageenans and xylans) and for 67 to 87 percent in brown algae (laminaria, fucus, and others). Soluble fibers are generally associated with cholesterol-lowering and hypoglycemic effects. Buck *et al*., (2006**)** revealed that, dietary fiber content in seaweed range from 33 percent to 75 percent of dry weight and mainly consist of suitable polysaccharides (range from 17 percent to 59 percent) seaweeds constitute a source of dietary fiber that differ chemically and physiochemical from those of land plants and thus way induce different physiological effects.

Accordingly, the fiber content of seaweeds varieties is higher than those found in most fruits and vegetables. The human consumption of algal fiber has been proven to be health-promoting and its benefits are well documented in the scientific literature. The consumption of this dietary fiber has been related to the following health-promoting effects: (1) promotes the growth and protection of the beneficial intestinal flora, (2) reduces the overall glycemic response, (3) greatly increases stool volume and (4) reduces the risk of colon cancer. In addition to the presence of some of the components which have potential benefits for the human body, the presence of dietary fibers provides some technological advantages for the use of marine algae as ingredients in food products such as meat products. The presence of these prebiotics can also be used to support the growth of lactic acid bacteria using seaweeds broth as a sole source of nutrition (Gupta *et al.*, 2010) and subsequently probiotics that can benefit human health. Thus, seaweeds have the potential to be used as a functional food ingredient or as a nutraceutical. The capacity of the fiber to absorb and retain water helps in the utilization of seaweeds as texturing and bulking agents, particularly in the making of low calorie foods. At the same time, the high concentration of mineral elements in seaweeds can help to reduce the amount of added sodium chloride in meat processing.

The dietary fiber content of seaweeds range from 33 to 75 percent of dry weight and mainly consists of soluble polysaccharides that show important functional activities such as antioxidant, anti-mutagenic, anticoagulant and anti-tumour activity. Dhargalkar and Verlecar (2009) noted that seaweeds are the best source of non-digestible fiber for increasing fecal bulk and decreasing bowel transit time.

Polyphenols

Polyphenols are produced by seaweeds (Mihova *et al.,* 1996). Polyphenols are strong antioxidants (Gumul *et al.*, 2011). Seaweeds produce these compounds to protect them from external conditions such as stress and herbivores (Li *et al.,* 2011). Polyphenols can donate hydrogen to free radicals and produce non reactive radicals (Gupta and Abu Ghannam, 2011). Seaweeds extracts contain appreciable amounts of polyphenols, but their content is strongly dependent on the extraction method. *Ascophyllum* sp., has significantly more polyphenols than other seaweeds, while *Ulva* sp., has the lowest content of these compounds (Keyrouz *et al.*, 2011).

Edible seaweeds contain appreciable amounts of polyphenols (Rodriguez *et al.,* 2011), which are effective antioxidants and may have particular biological activities. Polyphenols from edible seaweeds have also been suggested to influence responses relevant to diabetes through modulation of glucose-induced oxidative stress, as well as through inhibition of starch-digestive enzymes (Kim Woo Jung *et al.*, 2010) thus which possess anti-diabetic activity. Polyphenol rich extracts and isolated phlorotannin components have been shown to inhibit proliferation of cancer cells and to influence anti-inflammatory responses. Seaweeds have traditionally been used as food and folk medicine for curing helminthes infections, gout and eczema, particularly by coastal people in several countries (Duarte *et al.,* 2004). Compounds with cytostatic, antiviral, antihelmintic, antifungal, and antibacterial activities have been detected in green, brown and red algae. There are numerous reports concerning the inhibiting activities from macroalgae against human pathogens, fungi and yeasts.

Algal polyphenols also called phlorotannin that differs from terrestrial plants, polyphenols the highest content are found in seaweeds where phlorotannin range from 5 to 15 percent of the dry weight. It plays an essential role in preventing disease linked to oxidative stress (Nakamura *et al.*, 2000). Phlorotannins are the group of tannin compounds, which belong to the polyphenolic substances. Although tannins are widespread among both terrestrial and marine plants, phlorotannins, example eckol or dieckol, have been found only in brown seaweeds (Antonisamy and Raj, 2011). The phlorotannins are polyphenols formed by polymerization of phloroglucinol through the acetate malonate pathway (Li *et al.,* 2011). These polymers have many biological activities in organisms. Phlorotannins also have strong antimicrobial activities. They can attack microbiological proteins, which can result in inhibition of bacteria (Gupta and Abu Ghannam, 2011).

Minerals

Sea vegetables are an excellent source of most minerals especially potassium, iron, calcium, magnesium, sulphur, nitrogen, zinc, iodine, chromium and folate (Erhart, 2001). Seaweed has such a large proportion of iodine compared to dietary minimum requirements, that it is primarily known as a source of this nutrient. The highest iodine content is found in brown algae, with dry kelp ranging from 1500-8000 ppm (parts per million) and dry rockweed (*Fucus*) from 500-1000 ppm. In most instances, red and green algae have lower contents, about 100-300 ppm in dried seaweeds, but remain high in comparison to any land plants. Daily adult requirements, currently recommended at 150 µg/day, could be covered by very small quantities of seaweeds. Just one gram of dried brown algae provides from 500-8,000 µg of iodine and even the green and red algae. Sea vegetables contain high amounts of calcium and phosphorus and are extremely high in magnesium, iron, iodine and sodium. Quarter cup of *Hijiki* contains over half the calcium found in a cup of milk and more iron than in an egg, its important concern for vegetarians instead of eating animal based products.

Algae are a rich source of minerals. Researchers examined the mineral content in concentrates from seaweeds harvested from Japanese beaches. The highest concentrations of potassium (2.71 g/L), magnesium (0.19 g/L) and calcium (0.16 g/L) ions were detected in extract from *Sargassum wightii*. *Codium fragile* was shown to be a rich source of sodium ions (1.21 g/L). *Kappaphycus alvarezii* contains high levels of magnesium and calcium ions. Their concentrations in extracts were 581.20 mg/L and 460.11 mg/L, respectively (Nwosu *et al.*, 2011; Kumar *et al.*, 2011; Aslam *et al.*, 2010; Kuda and Ikemori, 2009; Rathore *et al.*, 2009).

Seaweeds draw an extraordinary wealth of mineral elements from the sea that can account for up to 36 percent 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. Seaweeds are best used in treating mineral deficiency diseases (Banu and Mageshwari, 2015).

The amount of iodine in sea plants exceeds that found in land plants and to help nourish the thyroid gland maintain good thyroxin level. Seaweeds are especially rich in calcium and iodine. One gram of dried seaweeds provides 70 mg of calcium compared to a daily requirement of about 1000 mg. It also supplies zinc for collagen strength and healthy skin chromium (essential for glucose utilization) copper, silver tin, phosphorous, brown and other trace minerals necessary for health (Irene yaychuk, 2006).

Cousens (2001) revealed that, the minerals in edible seaweeds are in colloidal form meaning they retain their molecular identity which remaining in liquid suspension. Colloids are very small in size and are easily absorbed by the body's cells.

Minerals such as iron and copper are present in seaweeds at higher levels than in many well-known terrestrial sources of minerals, such as meats and spinach. For example, there is more iron in an 8 g serving of dry *Palmaria palmata* (Dulse/Dillisk) than in 100 g of raw sirloin steak (6.4 mg versus 1.6 mg, respectively) (McCance *et al.,* 1993).

The folic acid abundant in sea vegetables plays a number of very important protective roles. Adequate level of folic acid in the diet is needed to prevent certain birth defects (Shep, 2001). Folic acid in seaweeds helps to remove homocysteine which otherwise increase the risk of coronary heart disease (Matelijan, 2006).

Vitamins

Seaweeds grow in the oceans, where they absorb a range of minerals and other nutrients. They are also fairly simple food making easy for human body to break down and release the healthful substances providing variety of vitamins and minerals. From a nutritional point of view, seaweeds have low calorie food, rich in some health promoting molecules and materials such as dietary fiber, Omega-3 fatty acids, essential amino acids, vitamins A, B, C, D and E, riboflavin, niacin, pantothenic acid and folic acid. All seaweeds appear to be nutritious, although, each type differs in nutrient contents.

Seaweeds contain several vitamins. Red and brown algae are rich in carotenes (provitamin A) and are used in fact, as a source of natural mixed carotenes for dietary supplements. The vitamin content ranged from 20-170 ppm. The vitamin C in red and brown algae is also notable, with contents ranging from 500-3000 ppm. Other vitamins are also present, including B12, which is not found in most land plants (Hong *et al.*, 2007) evaluated the vitamin C content of nine species of seaweeds including *Ulva lactuca* and *Kappaphycus alvarezii*. He stated that *Ulva lactuca* contained high amount of vitamin C among all the species, it was 145.6μg/g of fresh weight and *Kappaphycus* contain 82.76μg/g of fresh weight. Seaweeds have been the richest sources of vitamins like vitamin A, B, and E. Some seaweeds can supply adequate amounts of bioavailable vitamin B12 (Naidu *et al.*, 1993).

Edible seaweeds have all the vitamins. The main ones are provitamin A in the form of beta and alpha carotene found in red and brown algae with contents of 2 to 17 mg/100 gm dry. Vitamin C in red and brown algae with contents ranging from 50 to 300 mg /100 gm dry weight (Crasima *et al*., 1985).

Brown edible seaweeds are particularly rich in carotenoids, especially in fucokanthin, beta carotene and violaxanthis. The main carotenoids in the red algae are the beta carotene and alpha carotene and their dihydroxylated derivatives, zeaxanthin and lutein. The carotenoid composition of the green algae similar to that of higher plants (Chew *et al*., 2008).

Chlorophyll which is contained in algae is very importance algae are the highest known source of chlorophyll that is vital for rapid assimilation of amino acids. Eating high chlorophyll food helps production of vitamin E in the body. Vitamin E in edible seaweeds are important role in anti oxidant and helps to protect against cancers and cardio vascular disease, as it is also an anticoagulant (Padula, 2000). The brown edible seaweeds contain higher levels of vitamin E than green and red seaweed among the brown algae the highest levels observed in the fucaceae. Ascophyllum and focus species which contain between 200 and 600 mg of tocopherols /kg of dry matter (Padula, 2000).

Reusser (1994) reported that, sea vegetable are good source of natural vitamin D also essential for calcium absorption, bone health and muscle function. Solibami (1985) suggested that, vitamin K in seaweeds plays an important part in inhibiting the formation of prostoglantins and thromboxane. Edible seaweeds are rich in vitamins especially B-12 which is particularly recommended in the treatment of ageing, chronic fatigue syndrome and anaemia (Watanabe *et al.*, 1999).

2.5 Therapeutic value of edible seaweeds

Edible seaweeds are rich in bioactive compounds, antioxidants, soluble dietary fibers, proteins, minerals, vitamins, photochemical and polyunsaturated fatty acids. Although previously the seaweeds were only used as gelling and thickening agents in the food or pharmaceutical industries, recent researches have revealed their potential as complementary medicine. The red, brown and green seaweeds have been shown to have therapeutic properties for health and diseases such as anticancer, anti-obesity, anti-diabetic, anti-hypertensive, anti-hyperlipidemic, antioxidant, anticoagulant, anti-inflammatory, immune-modulatory, anti-estrogenic, thyroid stimulating, neuro-protective, antiviral, antifungal, antibacterial and tissue healing properties. Active compounds include sulphated polysaccharides, phlorotannins, carotenoids (e.g. fucoxanthin), minerals, peptides and sulfolipids, with proven benefits against degenerative metabolic diseases.

Epidemiological evidence suggests regular seaweeds consumption may protect against a range of diseases of modernity. The addition of seaweeds and seaweeds isolates to foods has already shown potential to enhance satiety and reduce the postprandial absorption rates of glucose and lipids in acute human feeding studies, highlighting their potential use in the development of anti-obesity foods. As seaweeds and seaweeds isolates have the potential to both benefit health and improve food acceptability, it offers exciting potential as ingredients in the development of new food products.

Seaweed phycocolloids like alginates has great therapeutic value as a heavy metal detoxifying agent. When added to the diet as a component of brown edible seaweed, alginate powder or sodium alginate, it can bind heavy metals present in food stream and carry them out with the stool, since alginate is generally not digestible (Aderhold *et al.*, 1996).

Sea vegetables are powerful healers they have and inflammatory, antiviral antimicrobial, antifungal and anticancer activity. The traditional benefits of sea plants, especially their algin, the element thought to be responsible for sea plants success in treating obesity, asthma and atherosclerosis. Epidemiological studies have shown a strong and consistent protective effect of vegetable consumption against the risk of several age related diseases such as cancer, cardiovascular disease, cataract and mascular degeneration (Heim *et al.*, 2002; Hunter and Fletcher, 2002; Cheung *et al.*, 2003; Zhang and Hamauzu, 2004). Fucoxanthin is the main carotenoids from brown seaweeds. This carotenoids have beneficial effects in cancer chemo prevention by acting either as an antioxidant or as a pro-oxidant (Matsuno, 2001).

Researchers have observed the effect of polysaccharides in biological systems as anti-coagulant, anti-tumour and anti-inflammatory agents and, which has led to the search for new compounds in the last few decades. Generally, the biological activity of polysaccharides from marine algae is related to the molecular size, type of sugar, sulfate content, type of linkage and molecular geometry which are known to have a role in their activities (Zhu *et al.*, 2005). Besides their well attested anti-coagulant and anti-thrombotic activity, they act on the inflammation and immune systems, have anti-proliferative and anti-adhesive effect on cells, protect cells from viral infection, and can interfere with mechanisms involved in fertilization.

Recently, aquatic habitats have increasingly showcased to provide a rich source of natural bioactive compounds with hypocholesterolemic, anti inflammatory, antiviral, antineoplastic, antimicrobial and hypertensive properties (Hanaa *et al.,* 2008). It is well documented that seaweeds may regulate hyperglycemia, hyperlipidemia (Park *et al.,* 2007) 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).

Nwosu *et al.,* (2011) reported that, phenolic-rich extracts from four edible marine macroalgae showed potential biological effects towards cultured colon cancer cells and anti-diabetic effects by inhibiting the action of digestive enzymes. The role of seaweed as a prebiotic catalyst for stimulating protective effects in phytoestrogen and estrogen metabolism is intriguing (Teas *et al*., 2009).

Al-Massarani (2014) reported *Laurencia* is an important marine red algal genus comprising of approximately 130 taxonomically accepted species. Compounds isolated from *Laurencia* species display a variety of biological activities, *viz.*, antiviral, antibacterial, antifouling, antifungal, antioxidant, antifeedant, antimalarial, antihelmintic, antiasthmatic and cytotoxic activities. Sesquiterpenoids with, various classes and skeletons, are the main constituents of this genus.

Santoso *et al.*, (2004) noted that the macro marine algae 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. 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. Some of the modern uses of seaweeds are in pharmaceuticals 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.

Lopez Lopez (2009) studied the influence of the addition of edible seaweeds *Himanthalia elongata*, *U. pinnatifida* and *Porphyra umbilicalis* collected from the Atlantic coast, on fatty acid composition, amino acid profile, and protein score, mineral content and antioxidant capacity in low salt meat emulsion model systems. Meat systems made with added seaweeds had lower sodium contents than control samples. The inclusion of *H. elongata* increased the sulfur amino acid score by 20 percentage. The added seaweeds supplied the meat samples with soluble polyphenolic compounds, which increased the anti-oxidant capacity of the systems.

Mendes *et al.,* (2010) revealed that edible brown seaweed have antitumor activity and inhibit colon cancer, brain and other tumors, sarcoma by boosting the immune system. Population studies shows that people with a regular intake of sea vegetable shows the longevity of the people of Okinawa was believed to be due to their regular consumption of sea vegetables. Seaweeds improve the health of the hair. It has been said that the thick, black, lustrous hair of the Japanese is partly due to their regular diet of brown seaweeds such as *arame* (Sho, 2001).

Seaweeds contain good amount of lignans, plant compounds with cancer protective properties (Mateljar, 2006). Sea vegetables contain powerful antioxidant and anticancer properties, to arrest the proliferation of cancer cells (Cousens, 2001). In Japan the low rate of breast cancer may be treated to the fact that the Japanese eat a great deal of seaweeds. In fact seaweed has killed cancer cells in lab experiments. 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).

Bioactive compounds from seaweeds have shown antimicrobial action against a number of Gram-positive and negative bacteria (Han *et al.,* 2005; Kim *et al.,* 2008; Gupta and Abu – Ghannam, 2010). The compounds responsible for antimicrobial activity of seaweeds are terpenes, phenolic or lipophillic in nature.

Phlorotannins extracted from brown seaweeds have been reported to have antibacterial activities against Gram-positive and negative bacteria (Nagayama *et al.,* 2002; Sandsdalen *et al.,* 2003). A compound isolated from brown seaweed, *Fucus vesiculosis*, exhibited bactericidal activity against both Gram-positive and the Gram-negative bacteria (Sandsdalen *et al.*, 2003) while compounds from red algae, *Rhodomela confervoides* has also exhibited bactericidal activity against Gram-positive and the Gram-negative bacteria (Han *et al.,* 2005). These findings suggest a potential use of seaweed extracts as natural preservatives in the food industry or as antibacterial drugs.

Several marine natural products with anti-inflammatory and analgesic properties have found use in studying their role in arachidonic acid metabolism and calcium mobilization in inflammation. Many agents that mediate inflammation and proliferation and $Ca^{2}+$ mobilization. Consequently, compounds which inhibit a phospholipase and $Ca^{2}+$ mobilization are anti-inflammatory, and thereby exert analgesic activity also (Mayer *et al.*, 1998).

The polar fraction of *Sargassum wightii* proved to be an anti-inflammatory agent (Dar *et al*., 2007). Similarly, *Galaxaura maringata* inhibited the inflammation produced by croton oil induced edema in mouse (Rozas and Freitas, 2007).

Marine plants such as *Cladophora sp., Codium sp., Hypnea sp.* (Paya *et al.,* 1993) and *Chlorella sigmatophora* (Guzman *et al.,* 2001) have also been reported for their anti-inflammatory properties. Buckle *et al.* (1980) isolated 6-n tridecylsalicylic acid from *Caulocystis cephalornithos*, and found to be an active anti-inflammatory agent in both acute and chronic animal models of inflammation and is chemically similar to salicylic acid but less ulcerogenic-a common side effect of salicylic acid.

Cholesterol has acquired an unsavory reputation for many years due to the strong correlation between the level of blood total cholesterol (TC) and the incidence of coronary heart disease (CHD). The use of three main classes of cholesterol-lowering medications including HMG-CoA reductase inhibitors, anion-exchange resins, and fibrates, a nutritionally balanced diet that reduces saturated fat and cholesterol intake has traditionally been the first goal of dietary therapy in lowering plasma TC. In recent years, Nutraceuticals and Functional foods from nature have attracted much interest as possible alternative therapies for lowering plasma TC (Chen *et al.,* 2008). One such is seaweeds which are rich in high soluble dietary fibres which have high cholesterol lowering property thereby reducing the risk of CHD (Castro *et al*., 2005).

Recently, it has been reported that functional sulphated polysaccharides from red microalga *Porphyridium sp.* as potent hypocholesterolemic agents which improve total serum cholesterol, serum triglycerides, hepatic cholesterol levels, HDL/LDL rations and increased fecal excretion of neutral sterols and bile acids in experimental animals (Devi *et al.,* 2009). Similarly, brown kelp, *Undaria pinnatifida* rich in fucoxanthin content has been reported to be a potent cholesterol lowering agent via upregulation of fat burning protein that accumulates in fat tissue around the internal organs and adipose tissue (Nakagami *et al.,* 2005). Likewise, sulphated polysaccharide extract of *Sargassum* *polycystum* has been reported to possess antilidemic property in the acetaminophen induced hyperlipidemia in experimental animal (Raghavendran *et al*., 2005). Hence, seaweeds a potent natural resource could be considered as hypolipidemic agents.

Marine species have also been reported for the anti-ulcer activity. The commonly available marine species namely *Padina boegersenii, Hypnea valentiae, Acanthophora spicifera, Gracilaria folifera and Gracilaria vercucosa* in the Gulf of Mannar region have been reported to exhibit anti-ulcer activity as evidenced in the pylorus ligation and ethanol induced ulcer models (Vasantha Kumar *et al.,* 2010). Carrageenan is a sulphated galactan polymer obtained from various red seaweeds belonging to the families Gigartinaceae, Solieriaceae and Hypneaceae are being used for ulcer therapy (Kaliaperumal, 2003).

Similiarly, the brown seaweed *Sargassum polycystum* administered rats have been reported to maintain the levels of glycoproteins and gastric juice content upon the HCI-Ethanol induced gastric mucosal injury in rats (Raghavendran *et al*., 2004). *Cladophora glomerate* and *Nostochopsis lobatus* the two endemic species of Thailand have been showed to exhibit potent anti-ulcer property in the stress induced ulcer model in rats (Peerapornpisal *et al.,* 2006). Recently, fucoidan has been reported for its anti-ulcer property which could be due to its suppression of cytokine mediated oxidative damage in gastric mucosa upon aspirin induction (Choi *et al.,* 2010).

Sea vegetables especially kelp are nature’s richest source of iodine, which as a component of the thyroid hormones thyroxin and triodothyronin. Glands add iodine to the amino acid tyrosine create hormone secretion (Mateljan, 2006). The brown seaweeds have traditionally been used for treating thyroid goiter.

Seaweeds contain Diiodotyrosin (DIT) which is precursor to essential thyroid hormones thyroxine (T4) and triodothyronine (T3) (Chandini *et al.*, 2008). Sea vegetable traditionally been used in Asia to treat heart disease hypertension cancer and thyroid problems. Seaweeds plays an important role in inhibiting the formation of prostaglandins and thromboxane. Seaweeds have been promoted for weight loss, boosting the immune system. Decreasing blood sugar and cholesterol increasing gastro intestinal tract function. Seaweeds are also widely used to maintain healthy skin and used to assist in weight loss, removes toxins and heavy metals (Michael *et al.,* 2000; Erhart, 2001).

Sea vegetable are a very good source of magnesium which has also been shown to reduce high blood pressure and prevent heart attack (Shep, 2001). The folic acid so abundant in sea vegetables plays a number of other very important protective roles. Folic acid in seaweeds helps to remove homocysteine, while otherwise increase the risk of cardio vascular disease (Malerjan, 2006).

Patricia Burtin (2001) suggested that, the calcium content may be as high as 7% of the dry weight in macroalgae an upto 25 to 34 percent in the chalky seaweed lithotamme. Seaweeds consumption may thus be useful in the case of expectant mothers, adolescents and elderly that all composed to a risk of calcium deficiency. Seaweeds contain trace elements such as chromium which affects the way insulin behaves in the body and zinc which helps with healing.

Acanthophora spicifera, Ulva and *Enteromorpha* are highly sulfated at the C-2 position of β-D-galactose units, with some of the residues being 4,6-pyruvylated, are recognized to possess a number of biological activities including anticoagulant, antiviral, and immune inflammatory activities that might find relevance in nutraceutical/functional food, cosmetic/cosmeceutical and pharmaceutical applications. This traditional food source has been found to maintain good health by providing nutritional benefits and thus helping to treat disease (Dhargalkar and Pereira, 2005).

Gokulakrishnan *et al.*, (2015) reported the proximate composition of the seaweeds *viz.*, *Cheatomorpha aerea*, *Enteromorpha intestinalis*, *Enteromorpha compressa*, *Dictyota dichotoma* and *Gracilaria corticata* were investigated by determination of protein, carbohydrates, lipid, moisture and ash content. The total protein was recorded upper most in *E. intestinalis* and bare minimum in *E. compressa*. The maximum carbohydrates recorded in *E. compressa* and minimum in *C. aerea*. The lipid content was acquired upper limit in *C. aerea* and least in *G. corticata*. The proximate composition of five different seaweeds species exhibited high nutritional value for human consumption.

Previous research would suggest that incorporatin of whole seaweeds into foods is generally acceptable to the consumer. Seaweeds or seaweeds isolate enrichment may not only benefit the nutritional value of a food product, but may also benfit the product in terms of imrpvng the shelf life and in some cases actually improving the sensorial properties. While chemical analyais wuld sugest a number of nutrional benefits of seaweeds consumption, there is a need for a more evidence relating dietary intake to health.

Based on these reviews, I have identified ten edible indigenous seaweeds from the Gulf of Mannar region which is close to my native place where I live and shall explore the possibility to top the “Untapped Potential of indigenous edible seaweeds available in the bioreserve area of the Mandapam region in the Gulf of Mannar coast for human consumption to carry out the study on “An analytical study on the selected edible seaweeds and their efficacy test for human consumption”.