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Review Article

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Environmental Eco-Friendly Marine Resource Macro Algae (Seaweeds): An Omnipotent Source for Value Added Products and its Applications

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The consequent reduction of land resources by human activities such as pollution, over exploitation, industrialization, migration etc., has lead man to search for other alternative ways to meet the demands for well-being. When this has been the existing situation in most of the developing countries, kelp forest resources like seaweeds which are known for its potentially strong bioactive compounds can be the best fit to fulfill numerous requirements such as nutritious food, biofuels, biofertilizer and pharmaceuticals to cure different diseases and other industrial applications. From the history till date seaweed has been employed in various sectors like food, pharmaceuticals, agriculture, waste water treatment and so on. Malnutrition and poverty have become the major issue in many of the developing nations, hale and healthy life can be guaranteed by seaweed food products and also people can be self- employed. Besides many research works done regarding seaweeds this review provides a collective idea about the potentials and wide range applications of seaweed, a marine macroalgae.

Introduction

Seaweed which is a macroalgae seen in various form, color and occur along the coastal line in marine habitat and India as a peninsular nation has got wide distribution of seaweeds compared to other countries (Brian E. Lapointe *et al.*, 1981, Subba Rao, *et al.*, 2006). Several harvesting techniques and cultivation methods for red, brown and green algae were in practice depending upon the species and other environmental factors (Buschmann *et al.*, 1995; Westermeier *et al.*, 1991). The biochemical components of seaweed such as carbohydrates,proteins, vitamins, fat, mineral are numerous and their composition experiences seasonal variation. The various compounds such as sulfated polysaccharides, fucoxanthin,carrageeanans, agarans, terepenoids etc., and organic extracts such as methanolic, ethanolic and butanolic extracts of different seaweeds possess antioxidant, antiviral, antinflammatory, anticancer activity against various pathogens and diseases. With the increased domestic, industrial and vehicle uses seaweed compounds extracted and processed are being used as various biofuels. Moreover *Ulva* species has been used in the production of all the four biofuels like bioethanol, biodiesel, biobutanol, biogas while biomass of other macroalgal species such as *Sargassum, Padina, Dictyota, Ascophyllum, Laminaria, Saccharina* were also found to be used in the production of various fuels. On the other hand polysaccharides of seaweeds are used to produce agar a phycocolloid which has its application in the food industries in the form of stabilizer, thickening agent; other carbohydrates such as fucoidan, laminarin, carrageenan were also analysed to have varied applications in the food and drugs sector.

Seaweed extracts from *Laminaria, Undaria, Saccharina* species were known tobe employed in cancer treatment whereas other mineral rich extracts treats arthritis and hypothyroidism. Current world which approaches the trends of nanotechnology, silver and gold nanoparticles from potential seaweed species was found to have intense antimicrobial properties that aids effluent treatment. Apart from these seaweeds such as *Laminaria, Sargassum, Ulva* species were being used in treating waste water, *Ascophyllum* species as beauty enhancers, nutritious animal feed while their alkaline extractsas biofertiliser have provided good quality plants.

Morphology and Diversity

Algae have a great variety of forms, sizes and colors in which some are simple colonies with many cells; some are filamentous, tubular, meshed, membranous or saccate algae. Some are more delicate and complex, such as, Sargassum having structures similar to roots, stems and leaves of plants as well as differentiated air bladders which help the algae floating to water surface to be able to absorb more sunlight. Nevertheless, although algae may have different forms, their internal structures are composed of similar cells with simple differentiation instead of true roots, stems or leaves. Seaweeds are grouped into three based on colour: Green algae (Chlorophyta), brown algae (Phaeophyta), Red algae (Rhodophyta), Blue-green algae (Cyanophyta) which are being harvested and utilized for several purposes (Brian E. Lapointe *et al.*, 1981). The thallus (the algal body), lamina or blade (a flattened leaf-like structure), stipe (a stem-like structure), holdfast (a basal structure provides attachment to a surface) forms the parts of a seaweed which is shown in the figure 1.

Occurrence and Distribution

Seaweed is particularly available in abundant in three areas: the worm northern waters around the Kermadec and three king island, the cook straight kaikoura coast region in central New Zealand and the south in an area encompassing Fiordland,Stewart island and the Otagocoast. Also it was found that enumerable amount of varied species belonging to different genus are found along the Indian coast (Subba Rao, *et al.*, 2006).

The figure 2& 3 shows the different kinds of species distribution that includes Chlorophyta, Phaeophyta,Rhodophyta and Cyanophyta alongside countries of Indian ocean and areas of Indian coastal line (Vinod K. Dhargalkar., 2014) whereas figure 4 picturizes the seaweed strength along the coastal areas of other countries like china, Korea, Japan, USA, Ireland, Iceland, Scotland.

Cultivation and Harvesting

With the advent of various seaweed species cultivation of seaweed attracts more attention to put seaweed in varied uses. The physical, chemical and biological parameters should be investigated before cultivation. Apart from this, the general environmental factors that influence the cultivation and harvesting processes are location, water and land quality, fauna, climatic factor, marketing accessibility, farm management operations, industrial and domestic pollution. Depending upon the properties and natural environment of individual seaweed species or species in groups, the harvesting methods are selected. The seaweed culture methods that are in practice are off-bottom method, raft method, horizontal culture method, mixed culture method, long line method. It is noted that the major problem faced by the seaweed industry is the lack of efficient harvesting technique. Let us see the viable harvesting that has been used from the past. The culturing method varies between species to species and for instance the red algae are generally seen in deep waters and are much smaller in size compared to the brown algae. In addition, the harvesting of red algae is expensive and involves complexity and it was reviewed that two planting techniques were commonly used for red algal farming. One is the direct method that involves the direct burial of the thalli into the sandy bottom using different types of tools and the other is the Plastic Tube Method which consists of fastening bundles of thalli to plastic tubes filled with sand, which anchor the algae to the sea bottom (Buschmann, *et al.,* 1995).It was estimated from the experience gained from subtidal farms that hand-pulling of thalli has given more production rather than the use of tools (Westermeier *et al.,* 1991).Mechanized harvesting that uses power-driven barges equipped with reciprocating underwater mowers (cropping vessels) were used for cultivating Macrocystis that grows in large beds. Similar cropping equipments were used to harvest Ascophyllum species which grows at high tide.The predominant species *Porphyra yezoensis*, *Porphyra tenera* grow in the inner parts of estuaries and bays and can survive in high salt conditions whereas Porphyrapseado linearis grows in the deeper waters. The Concochelis–Spore culture technique was used to cultivate these Porphyra (nori) species(Suto, S., 1971).The rope cultivation and stone techniques were used in japan to cultivate the brown alga Undaria or "wakame". The "collector strings" that are hung in the water for the sporophytes of Undaria to grow and tanks were used for seedling. As an expansion of past technique, along with natural beds a new substrate of rocks exploded with dynamite was also used to grow Undaria (Tamura, T., 1966).Production of hybrid varieties of Undaria was also made possible by crossing closely related species . To harvest Laminaria that grows only on hard, rocky ocean bottoms, reciprocating cutters mounted on dredges or a system of continuous grapnels were used andthe development of techniques for cutting the normal 2-yr growth period to harvest down to 1yr was researched to increase the production (Hasegawa, 1971). It was reported that in Norwegain coastal area the sugar kelp *Saccharina latissima* was cultivated by integrating with salmon (Salmo salar) aquaculture and the growth was seemed to be good in late autumn and in spring (Aleksander Handa, Silje Forbord *et al.,* 2013).

Green algae may be found in marine or freshwater habitats, and some even thrive in moist soil. The green macro algae were cultivated in outdoor tanks and the biocrude was obtained through hydrothermal liquefaction in batch reactor. Also, the green algae were cultivated in ponds, open lagoons and in cages. It was reported that the Oedogonium species has given the maximum yield followed by Derbesia, Ulva species (Neveuxa *et al.,* 2014).

Biochemical Composition

The composition of seaweeds varies depending upon season, density and other environmental factors. Compared to vegetables, fruits, pulses and cereals, seaweed records the maximum content of carbohydrates, proteins, vitamins, minerals, fat, fibre, ash, moisture. Earlier work has revealed that the different species gathered from similar area, family, environmental factors showed greater variations with respect to their elemental composition (Murugaiyan *et al.,* 2012). Also it has been observed that red seaweed contains thirty times more potassium than bananas, 200 times more iron than beetroot, the Nori seaweed constitute twice the protein thanmeat and the Hijiki seaweed contains twice the amount of calcium compared to full-cream milk. Further,it was noted that 15,000 novel compounds were chemically determined and algae are considered to be the predominant source for novel biologically active compounds that is required for human nutrition (Ivanova *et al.,* 2013).While seasonal variations are of great concern, it was showed that the phaeophyta and rhodophyta recorded the maximum biomass during summer and cholorophyta was maximum during autumn season (Dadolahi-Sohrab *et al.,* 2012). The table 1shows the composition of some commercially important seaweeds.

Properties

It was reviewed that seaweeds are rich in bioactive compoundsthat promotes and some of the species to say are. Laminaria species, Fucus species, *Ascophyllum nodosum*, Chondruscrispus, Porphyra species, Ulva species, Sargassum species, Gracilaria species and Palmaria palmate (Susan *et al.,* 2010). Since chemical preservatives were proved to cause deleterious health hazards like cancer, asthma etc., seaweeds have been known to be the safe and promising replace as food additives that has antimicrobial, antioxidant properties(Kasi Pandima Devi *et al.,* 2008). Also it was identified that many secondary metabolites from the marine source with effective antibacterial, antifungal and antiviral activities which are being used as antibiotics and drugs to treat various infectious diseases (Abad *et al.,* 2011). Bioactive compounds of marine macro algae are known to have diverse mechanism of action against diseases. In addition to this, red, brown and green macro algae were detected to contain compounds with cytostatic, antiviral, antihelminthic, antifungal and antibacterial activities (Newman *et al.,* 2003).

Antioxidant Activity

Algae are antioxidant in nature because of their non-enzymatic antioxidant components likereducedglutathione(GSH),ascorbicacidal phatocopherol,betacarotenoids,flavonoids,hy droines,pycocyanin,proline,mannitol,myoino si-tol, phenolics and polyamines (Fu-Jin Wang *et al.,* 2011).The antioxidants can inhibit the intiation of the oxidative chain reaction and thus prevent cell damage caused by Reactive Oxygen Species(ROS) (Sung-Myung Kang *et al.,* 2011). The antioxidant molecules can destroy free radicals by donating hydrogen atoms or by electron donation. In most of the cases DPPH had been used as a free radical to evaluate reducing substances rather than nitric oxide, deoxyribose, hydrogen peroxide, ABTS. The DPPH radical scavenging activity was evaluated using an ESR(Electron Spin Resonance) spectrometer(H. Indu and R. Seenivasan., 2013).From the earlier works done it was reported that the extracts of species such as *Hijik fusiformis*, *Cladosiphon okamuranus*, *Undaria pinnatifida*, and *Sargassum fulvellum* were known to possess effective DPPH radical scavenging activity (Mise *et al.,* 2011, Yan *et al.,* 1999). Also Carotenoids have radical scavenging which helps to keep up health and in prevention of disease whereas Fucoxanthin has been reported to effectively scavenge chemically-generated free radicals like DPPH (Stahl and Sies., 2012). Based on quenching rate constants it was shown that the radical scavenging activity of fucoxanthin and its metabolite fucoxanthinol were higher than that of α-tocopherol and lower than β-carotene (K. Mikami and M. Hosokawa., 2013). Fucoxanthin (FX), an orange colored carotenoid belonging to non provitamin carotenoids which is also known as xanthophylls are present in edible brown seaweeds such as *Undaria pinnatifida*, Hijikia fusiformis, Laminaria japonica and Sargassum fulvellum possess significant antioxidant activity. Sulfated polysaccharides (SP) are the compounds found in the extracellular matrix of seaweeds that has got antioxidant property and the well-known sp. are carragenans, agarans, xylase, galactose, mannose, fucan, fucoidan (Nednaldo *et al.,* 2012). Based on the rheological behavior, the polysaccharide content and the methanol extract of red algae Gracillaria biridae and Gracilaria verrucosa were reported to possess antioxidant property (De almeida *et al.,* 2011, Bartolomeu *et al.,* 2012). Further it was noted that the water extract of Laminaria species had higher antioxidant activity than its ethanol extract(Ismail A Jr and Tan, 2002). Thus high levels of oxidative stress leads to many harmful diseases such as atherosclerosis, Parkinson's disease, Alzheimer's disease, acute myocardial infarction, chronic fatigue syndrome and fibromyalgia. FX was estimated as an effective tool to prevent and treat these diseases (Nicolantonio *et al.,* 2012).

Anticancer Activity

Cancer being a fatal disease has become a major health problem worldwide mainly because of bad food habits. The conventional chemotheraphy or radiotheraphy treatment to control tumors and reduce the risk of mortality rates has resulted in other ill-effects such as long term side effects, destruction of healthy tissues etc. Several types of carcinomas such as prostate cancer, leukemia, colon cancer, breast cancer, liver cancer, melanoma and lymphoma are in existence (Thamaraiselvan *et al.,* 2013). In a quest to cure and uproot cancer, seaweeds were identified as the best source that has antitumor properties. The seaweed compounds or extracts undergo several types of mechanisms against the cancer cells and some of them are apoptosis induction, inhibition of tumor invasion, hyaluronidase activity inhibition, anti-angiogenic activity. Regulation of mammary gland integrity (Suhaila *et al.,* 2012). Polysaccharides present in the cell wall of macroalgae contain immunomodulatory and anticancer effects and are most considered in the medical areas of study (Shilpi *et al.,* 2011). Sulfated polysaccharides from brown species viz., Sargassum, Laminaria, Ecklonia inhibited growth of Sarcoma-180 cells and acted as antitumor against L-1210 leukemia (Yamamoto *et al.,* 1974, 1981, 1984a). Further fucoidan or fucose containing sulfated polysaccharides (FCSP) and MAPK (mitogen activated protein kinase) along with FCSP in brown seaweeds found to enhance and augment macrophage mediated immune signaling molecules production and thereby induced apoptosis (Marcel *et al.*, 2011).Breast cancer ranks the second most common cancer in the world and is the major cause for mortality in women (Laura *et al.*, 2006). As a remedy for this, the methanol extract of Sargassum muticum activity against proliferation of breast cancer cell lines were evaluated for its apoptosis property (Farideh *et al.*, 2013). Also the combination of seaweed Porphyra dentate, β-sitosterol and campesterol was known to reduce the tumor size considerably (Ghislain *et al.*, 2014). Nextly the colorectal cancer which affects both men and women, their cancer cell lines proliferation could be inhibited by the extracts of Laminarian species and Ulva faciata by apoptosis induction mechanism (Ryu *et al.*, 2013, Hee-Kyoung *et al.*, 2012, 2013). Furthermore based on dosage the anti-tumor and anti-metastatic activities of fucoidan isolated from Fucus evanescens were studied. Alginates and palmitic acid from the species Sargasum vulgare (brown algae) and Amphiroa zonata (red algae) were also reported to possess antitumor property (Alekseyenko *et al.*, 2007, Harada *et al.*, 2002).

Antimicrobial Activity

Algal biomass has been analysed to have antimicrobial activity and it mainly depends upon the algal species taken and the extraction method followed. The antimicrobial compound extracted from a biological source is generally by means of attacking the cell wall and cell membrane of the target organism. Further it disrupts the electron transport chain, coagulates protein and nucleic acid synthesis (Gupta and Abu-Ghannam, 2011). Among seaweed species the ethyl acetate extracts of Sargassum species have strong antimicrobial activity against bacteria and fungi than the water extract and the activity is due to the presence of meroterepenoids (Horie *et al.*, 2008). The brown alga Stoechospermum marginatum was active against bacterial strainsKlebsiella and Vibrio cholerae whereas the green alga Cladophora prolifera was bacteriocidal against *Saccharomyces aureus* and *Vibrio cholera* (Muruleedhara *et al.*, 2003, Rodrigues *et al.*, 2004). It was found that the extracts of red algae *Gracilaria fisheri* inhibits the pathogen *Vibrio harveyi* which affects the Shrimp population (Kanjana *et al.*, 2011).Also the butanolic extracts of the seaweeds Ulva lactuca and Sargassum wightii exhibited considerable inhibition zone against the shrimp pathogen *Vibrio parahaemolyticus* (Immanuel *et al.*, 2004). The phlorotannins of Ascophllum nodosum was more active against the Escherichia coli strain than the condensed or terrestrial tannins (Wang *et al.*, 2009). The dichloromethane extracts of several seaweed has showed significant antibacterial action against fish pathogens such as *Asparagopsis armata, Falkenbergia rufolanosa* (Bansemir *et al.*, 2006).The dimethyl sulfoxide (DMSO) extracts of seaweed species and their antiprotozoal activity against Plasmodium species has been studied and the selectivity index was the parameter used to evaluate the activity (Catherine *et al.*, 2011). The same DMSO extract of *Sargassum longifolium* showed inhibitory activity against various bacterial strains whereas the acetic acid extract showed maximum inhibition against Proteus species and minimum activity against Streptocccus species (Ponnanikajamideen *et al.*, 2014). The antifungal activity against *Phythium phanidermatam* and *Colletotrichum capsici* was maximum in Ulva fasciata. Ultimately nanoparticles which is the most welcomed compound because of its size and viability was found to be extracted as silver nanoparticles from Ulva lactuca by agar well diffusion method and it was analysed for its antibacterial activity (Sivakumar and Thinakaran, 2013).

Antiviral Activity

Promising feature of seaweed is its antiviral potential by which many fatal diseases can be treated. AIDS is a fatal disease caused by Human Immunodeficiency Virus (HIV) which belongs to retro virus family and has no effective treatment till date. The antiviral activity of seaweeds depends on the dosage and time. Apart from other causes the Herpes Simplex Virus (HSV-1) and HSV-2 which causes infection in mouth,face and genital area was also identified as a major risk factor for Human immunodeficiency Virus(HIV) (Vo *et al.,* 2011, Celum 2004) and the antiviral activity against these virus has been conferred with SQDS (Sulfoquinovosyldiacyl glycerol) fractions extracted from *Sargassum vulgare* (Erwan *et al.,* 2013).Also the bioactive alginates from Sargassum species has antiviral property and it was studied that the extracts of this species acted against the viruses Human T cell Lymphotropic Virus Type1(HTLV1) and Human Immuno deficiency Virus Type1 (HIV-1) (Liu *et al.,* 2012, Romanos *et al.,* 2002, Mi-Jeong Ahn *et al.,* 2002). The fucoidan polysaccharide was against HIV and human cytomegalovirus (HCMV) while its derivative galactofuran extracted from the seaweed Adenocystis utricularis showed inhibitory action towards the retro viruses (HSV) 1 and 2 (Ponce *et al.,* 2003). Further the diterpenes isolated from the Dictyota species exerted antiviral action and galactofucan sulfate extract from *Undaria pinnatifida* worked against HSV-1, HSV-2 and HCMV (Human Cyto Megalovirus) (Siamopoulou *et al.,* 2004, Queiroz *et al.,* 2008). Considering plant viruses the seaweed polysaccharides such as fucans, laminarin, alginates, ulvans obtained from *Fucus vesiculosus, Laminaria digitatum, Lessonia* species, Ulva species respectively, when injected in to tobacco plants, protected against Tobacco Mosaic Virus(TMV) by inducing Jasmonic acid (JA) and Salicylic acid (SA) signaling pathways (Jeannette *et al.,* 2011).

Anti-inflammatory activity

In general inflammatory response is an auto defensive mechanism that is met with huge leukocyte production and the inflammatory reactions are generally due to the presence of ROS, nitric oxideand other factors which results in tissue damage(Yong-Fang *et al.,* 2001). Caulerpin an alkaloid extracted from Caulerpa racemosa was found to exhibit anti-inflammatory properties (De Souza *et al.,* 2009) and this compound act by suppressing the antigen, histamine secretion, lymphocyte and natural killer cell proliferation(Mohamed *et al.,* 2007). The sulfated polysaccharides play a major role in treating inflammation. Also it was demonstrated that the fucans of Fucus species, Laminarian species on injection into rats reduced the peritoneal inflammation by leukocyte inhibition (Cumashi *et al.,* 2007). The ulvan polysaccharides of Ulva rigida also exerted anti inflammation by reducing immune stimulation(Jiao *et al.,* 2011). The fucoxanthin from seaweeds was active against inflammation and allergic reactions by degranulating the mast cells which secretes histamine (Shota Sakai *et al.,* 2009). It is noted that the carrageeanan produced from Eucheuma or Chondrus or Hypnea species was used to analyse anti-inflammatory activity (Vipul *et al.,* 2014).

Applications of Seaweed

Macroalgal species are being used as a major viable source in various fields of applications. The carbohydrates content of seaweed has been the major area of interest in several fuel, food and medicinal industries. Many food additives like agar, carrageenan, laminarin, fucoidan extract from seaweed is found to be implemented in food industries. Since the nanoparticles has gathered interest among researchers in the current world, seaweed nanoparticles being a natural source has potent application in biomedical industries apart from several human uses seaweeds are used as feed for cattle and aquatic animals and as fertilizer for various food and cash crops the various species of seaweed and its targeted content of application has been discussed in the following sections.

Biofuels

As there is a tremendous increase in fuel consumption these days, mankind has been in pursuit of natural source for fuel recovery which ensures pollution free environment. And now scientists have found certain seaweeds can be the raw material to produce fuel. These macroalgal biomass must be pre-treated for most biofuel applications. The first step of pre-treatment is to remove foreign objects and debris such as stones,sand, snails, or other litter that may be caught in the biomass either manually or by washing in many cases, chopping or milling is then required to increase the surface area/volume ratio (Fionnuala *et al.*, 2013). Finally, the biomass should be dewatered to 20%–30% to increase shelf life and reduce transportation costs in situations where it must be stored for long periods or transported over long distances before further processing.

The principal energy process considered for seaweed is fermentation, either anaerobic digestion,to create biogas, or ethanol fermentation. Other thermochemical options for macroalgae utilizationinclude direct combustion, gasification, pyrolysis and liquefaction (Wei *et al.*, 2013). For better understanding about the production of biofuel from the algal biomass is made through the figure 5.

Bioethanol

Generally, bioethanol is produced from wood, grasses, and other inedible parts of plant but it is a tedious process to make sugar monomers. In order to overcome this, marine algae can be used as source for bioethanol production. Algae contain large quantities of carbohydrate biomass and high photon conversion efficiency for bioethanol production (Leilei Ge *et al.*, 2011, Hornl *et al.*, 2000). In addition, marine algae has buoyant property which can simplify the process of bioethanol production by neglecting the pre-treatment steps. It is noted that in japan they use 4.47 million sq.km for harvesting Sargassum horneri for bioethanol production. Ulvareticulata macroalgae which can grow quickly was said to possess the potential to produce bioethanol. It is reported that other species such as Padina japonica, *Sphacelaria rigidula, Dictyosphaeria cavernosa, Sargassum polyphyllum* have appreciable dry weight content (Okazaki *et al.*, 1986). Brown seaweed *Laminaria hyperborea* has high amount of soluble carbohydrate (Ayhan Demirbas and M. Fatih Demirbas.,2011). Bioethanol from algae was known to reduce greenhouse gas emission by 85% over reformulated gasoline (Lalitesh *et al.*, 2014).

Biodiesel

Since diesel price is on hike irrespective of the demand biodiesel which is a natural fuel can be made from oils available within the algae. It is significantly noted that the macroalgae contains oil within its cell and biodiesel obtained with this oil is engine compatible. There are different varieties of macroalgae which contain oil once grown, the oil is removed from the macroalgae using chemicals or by squeezing oil out of the cells using scientific equipment.

Then the oil is used as an ingredient in biodiesel. This oil is changed chemically from plant oil to biodiesel. The finished product can be used on its own as pure biodiesel but is normally mixed with ordinary diesel and used directly in cars. Biodiesel is an alternative biodegradable energy source which has less CO_2 and no emission (Rocio Maceiras *et al.*, 2011). Oil extraction from algae and transesterification process are the two major steps involved in biodiesel production and the brown seaweed *Ascophyllum nodosum* has high oil content compared to the species such as Sargassum, Codium, Ulva, Enteromorpha (Van der Wal *et al.*, 2013).

Biogas

For use in domestic and industrial gas fuel seaweed can be subjected to anaerobic digestion for the production of methane gas it was estimated that the methane yield from anaerobic digestion of seaweed was 0.12 N/CH_4/g (Thomas Potts *et al.*, 2012). *Saccharina latissima* is a brown seaweed rich in carbohydrate was anaerobically digested for biogas production. It was reported that two process parameters such as steam explosion and thermal pretreatment method for biomass degradation seemed to affect the biogas yield in general the brown algae are more easily degraded than the green algae, and the green are more easily degraded than the red (Fionnuala Murphy *et al.*, 2013). Anaerobic digestion has been the most efficient method for the production of biogas rather than fermentation and thermal treatment. The biogas yield from certain species viz *Saccorhiza polyschides, Ulva species*, *Laminaria digitata*, *Fucus serratus and Saccharina latissima* are discussed in the following table.3 (Adam Hughes *et al.*, 2012) despite the variations in the quantity and material ratios, the ratio between the methane produced and the input chemical oxygen demand was reported to be stable (Matsui and Koike., 2010).

Biobutanol

To note that the biobutanol has become a very competitive renewable biofuel for use in internal combustion engines and has been a boom to mankind. While comparing fuel properties it indicates that n-butanol is potent enough to remove the drawbacks brought by low-carbon alcohols or biodiesel. The applications of butanol as a biofuel are considered as three aspects, and they are as combustion experimentors in some well-defined burning reactors, as gasoline in spark ignition engine, as diesel fuel in compression ignition engine. From these demonstration that butanol is estimated effective as a second generation biofuel, from the viewpoints of combustion characteristics, engine performance, and exhaust emissions (Chao Jin *et al.*, 2011). Ulva lactuca was considered as the reserve species for acetone butanol ethanol (ABE) fermentation (Vivekanand *et al.*, 2012). The fermentation done with the bacterial strains such as Clostridium beijerinkii, Clostridium saccharoper butylacetonium and the algal carbohydrate resulted in the production of biobutanol. The yield and the concentration of biobutanol obtained from media were 0.29g butanol/g sugar and 4g/litre respectively (Vanegasa and Bartletta, 2013).

Polysaccharides of Seaweed

Seaweed polysaccharide is known for their varied functions and structures. They constitute natural sugars and sugar acids similar to land plants and in animals polysaccharides. As these polysaccharides contain hexose sugar, glucose, galactose and mannose, they have identical chemical formula, shape, properties and specific atomic orientation (Hill and Surrey, 2007).

Agar

Seaweed agar is the most ancient phycocolloid found in Japan and discovered by Minoya tarozaemon in 1658 and firsttime manufactured in monument (Christopher S. Lobban, Michael J. Wynne., 1981, 1981). Agar is the major component of the cell-wall of certain red algae,which are the members of families, Gelidiaceae, Gelidiellaceae and Gracilariceae (D. Chakraborty, 1945). Agar consists of a chain of 9-p galactopyranose units linked in 1,4 bonds with a sulphated galactose in order to increase the yield and gel strength of agar, an alkaline treatment was done with sodium hydroxide for nearly one hour at the rate of 2 to 3 % alkali solution of 20,000 1/tonne at 90°C (Vigneswara Rao *et al.,* 1965). Also the sun-bleached seaweed was washed well in water and soaked for 24 h and then ground to a pulp and rinsed again in water and then the pulp was then extracted with water under pressure for 2 h after bringing the pHto 6 by adding of acetic acid. The agar gel was subjected to freeze thawing and bleached with NaClO before drying in a current of hot air (Taratra *et al.,* 2010). It is insoluble in cold water but soluble in boiling water. When agar was cooled to 34-43°C it forms a firm gel and does not melt further below 85°C (K. Funaki and Y. Kojima., 1951). In food technology agar is used as gelling and thickening agent in the confectionary and bakery industries, as stabilizer in the preparation of cheese and for salad dressings. In fish and meat industry, agar is applied for canned products, as a protective coating to avoid shaking during transport of these products. The agarose polycolloid play a prominent role in the DNA research and gel electrophoresis further agar is widely used in pharmaceutical industry as laxatives as drug vehicle and as a medium for bacterial and fungal cultures and also used as an ion exchanger in the ion exchange resins (Rao and Thivy., 1960).

Alginate

Algin or alginic acid is a membrane mucilage and a major constituent of all alginates and the trade name is sodium alginate. Alginic acid is obtained from brown seaweed species such as Ecklonia, Macrocysiis, Undaria, Laminaria and Duruillea from temperate area andturbinaria,sargassum, cysto seira and harmophysa from the tropical areas. Alginic acid which is the major polysaccharide of the brown seaweeds consists of unbranched chains comprising of contiguous fl-l,4-linked d-mannuronic acid and blocks of contiguous e-l,4-linked e-guluronic acid (Arne Haug *et al.,* 1967). The proportions of D-mannuronic acid and l- guluronic acid varies between different species and from different parts of the same weed (A. Haug *et al.,* 1974). Alginates are found in both the intercellular region and the cell walls and it does biological functions structural and ion exchange type. Also it was extracted from the spices*Laminaria digitata* by alkaline extraction protocol(Peggy Vauchel *et al.,* 2008, Haug *et al.,* 1969).The molecular weight of alginate ranges generally between 500 and 1000kda (Moe *et al.,* 1995). As discussed earlier the alginate composition of different seaweed species are ascophylum nodosum (22–30%); *Laminaria digitata* fronds (25–44%); *Laminaria digitata* stipes (35–47%); laminaria hyperborea fronds (17–33%); laminaria hyperborean stipes (25–38%) (Rinaudo, 2007.). Alginate contents ranges between 17 and 45% are extracted in sargassum species (Fourest and Volesky, 1996). In industries the alginates are extracted from brown seaweed sargassum turbinarioidesby cutting the thallus with a knife near the rhizoid and the algae were washed and sun- dried at ambient temperature and stored in aerated bags (Taratra *et al.,* 2010). Japanese work on the brown seaweed has revealed that alginate is subjected to polymerization in the cytoplasm and then transported to the cell surface(Abe *et al.,* 1973). It has observed d-mannuronic acid precursor of polymannuronic acid that while separating from the brown seaweed, fueus gardneri in young tissue. They identified the presence of trace quantity of a gdp-guluronic acid (Lin and Hassid, 1966). Further on extracting epimerase from pelvetia canaliculata the convertion of polymannuronic acid into a mixed poly-d-mannuronic-l-guluronic polymer has been witnessed by tritium incorporation (Madgwick *et al.,* 1973). In beverages alginates acts as clarifying agents for making wines and liquor where as it acts as foam stabilizer in leger beer and malt beer(H. Ertesvåg and S. Valla, 1998.). Artificial casings are made with alginates as poses to ensure longer shelf life in sausage industries and it alginates are used in the form of gel for deep freezing of fish, meat and poultry products in western countries (Bernd H. A. Rehm. 2009).

Carrageenan

Macroalgal carrageenan is a sulphated polymer obtained from various red seaweeds and it differs from agar in its high sulphate and ash content.The major difference between the agars and carrageenan is that the former contains d- and l-galactose units whereas the latter consists entirely of the d-sugar (Hill and Surrey, 2007). They are commercially important hydrophilic colloids present in the matrix of red seaweeds (rhodophyta) and does structural function also they are considered as high sulfated galactans and as strong anionic polymers. Seaweed species Kappaphycus, Eucheuma Chondrus crispus, Gigarttna stellate, Iridaea, Hypnea species have high content of Carrageenan (Bixler and Porse., 2011). Carrageenan can be recovered to either by direct drying on steam-heated rolls or by precipitation of the carrageenan from solution by 2-propanol or other alcohols. It is to be noted that in the past alcohol precipitation method was used to recover carrageenan from irish moss (Bourgade, 1871).

Fucoidan

Fucoidan is a sulfated polysaccharide found mainly in various species of brown seaweed and fucoidan is used as dietary supplements(M. Tutor-Ale *et al.,* 2011). Fucoidan is a class of sulfated, fucose rich, polysaccharides found in the fibrillar cellwalls and intercellular spaces of brown seaweeds. Fucose-containing sulfated polysaccharides (fcsps) consist of a backbone of (1→3)- and (1→4)-linked α-l-fucopyranose residues, that may be organized in stretches of(1→3)-α-fucan or of alternating α(1→3)- and α(1→4)-bonded l-fucopyranose residues(M. Tutor-Ale *et al.,* 2011). Apart from fucose and sulfate groups fucoidans also contain galactose, xylose, mannose and other uronic acid (Tutor-Ale *et al.,* 2011). Fucoidan was extracted using dilute acetic acid from various species of laminaria and fucus. Fucoidans were reported to possess various biological such as anti-inflammatory, anticoagulant, antithrombotic (Trinchero *et al.,* 2009, Raghavendran *et al.,* 2011), antiviral including anti-HIV (Kusaykin *et al.,* 2008, Lee *et al.,* 2004), immunomodulatory (Raghavendran *et al.,* 2011), antioxidant (Wang *et al.,* 2010), and antitumor (Andriy *et al.,* 2010). Fucoidan from laminaria species were found to inhibit a variety of DNA and RNA enveloped viruses and also useful in elucidation of mammalian sperm and egg (Frank *et al.,* 1989). The "fucan" extracted from pelvetia canaliculata had a very strong affinity for magnesium which in turn can assist the contact of their fronds with seawater. It was also studied that Pelvetia canalieulata, since grows on the higher part of the shores have a high "fucan" content (Carlberg *et al.*, 1978).

Laminarin

Laminarin is a storage glucan found in brown algae and is used as a carbohydrate food reserve similar to diatoms (Anne Beattie *et al.*, 1961). Laminarin is β-glucan and itis known to induce anti-apoptotic and anti-tumoral activities (Rioux *et al.*, 2010). This is a water-soluble polysaccharide containing approximately 20-25 glucose units. It has two types of chains namely, g-chains terminated at the reducing end with glucose and m-chains terminated by mannitol (Percival, 1978). In addition the laminaran, from *Eisenia bicyclis*, may contain 1,6-1inked units in the chains, or the chains may be branched at C-6 (Bidwell, 1967). It was that the mannitol and laminarin are active metabolites which can be interconverted (Quatrano and Stevens, 1976). Also it was shown that laminarin isolated from the cytoplasm of developing zygotes of fucus species decreased during the first 7 hours of wall assembly while the content in cellulose in the wall increased laminarin structure and composition vary according to algae species (Chizhov *et al.*, 1998). Based on the degree of polymerization the molecular weight of laminaran has been found as 5000KDa approximately (Rioux *et al.*, 2007).

Pharmaceutical Application of Seaweed

Most inspired bioresource as far as pharmaceuticals is concerned is seaweed because of the high nutrient content. Seaweed has been used as food throughout Asia, Japan, China, Rome, etc., to treat various health disorders. The romans used seaweed in the treatment of wounds, burns, and rashes (Hocman G., 1989) whereasin Scotland physicians used dried seaweed stem to drain abdominal wall abscesses and they also inserted seaweed into the cervix to treat dysmenorrheal and seaweed was also employed intravaginally for vaginal atresia for which it was used urethrally and rectally for strictures (Abdussalam S., 1990, Johnson. N., 1990).Traditional chinese medicine includes use of the brown alga laminaria in the treatment of cancer. The ancient Egyptians used seaweed to treat breast cancer. Seaweeds are being extensively used in cardiovascular conditions as it can reduce cholestrol level**.** In general alginates from seaweeds has been used in wound dressings and as fillers in tablets, pills and as ointment base whereas seaweed carrageenan acts as good emulsifiers in mineral oil and drug preparations. *Saccharina japonica* and *Undaria pinnatifida* was analysed to contain fucoidan which can destruct cancer cells. Also complete wipe out of cancer cells by fucoidan treatment has been demonstrated in japan. It is noted that cancer mortality rates and breast cancer rates are considerably low in japan because of seaweed consumption (Jane Teas *et al.*, 2009, Carmen Aceves *et al.*, 2005). Seaweed extracts being a source of calcium, magnesium, selenium and other minerals has been evaluated to treat osteoarthritis (Frestedt *et al.*, 2009, Joy *et al.*, 2008). And it was reported that intake of seaweed powder 5g/day, 12g/day and 4-6g/day in diet controls cholesterol, hypertension, metabolic syndrome respectively (Yukio *et al.*, 2001, Krotkiewski *et al.*, 1991). Iodine rich seaweeds like asparagopsis tcudjirmis, sarconema species was reported to cure hypothyroidism(goitre). Also in the earlier research works seaweed extracts was known to stimulate B lymphocytes and macrophages that in turn modulates immune response (Liu *et al.,* 1997, Shan *et al.,* 1999).

Application of seaweed in other areas

On pursuing the trends of biotechnology and its advancements, seaweed a single macroalgal source with varied types, characteristics and multipotent properties was known to be be employed in various sectors as from animal feed to the latest emerging field nanotechnology.From the earlier literature works done the other areas of effective uses of seaweeds and their distinct types are summarised in the following sections.

Seaweed Nanoparticles

Increasing trend in nanotechnology has gathered interest among the researchersthereby algal nano particles are known as bio nano factories as they are highly stable, easy to handle and avoids cell maintenance. Added to this, metal nano particles from seaweed have excellent potential in biomedical applications(Song JY and Kim BS., 2009). Benign nanoparticle synthesis which is nontoxic has been an emerging trend in todays world(Shankar *et al.,* 2004). Ecofriendly gold nanoparticles synthesized from *Turbinaria conoides* was confirmed to be associated withcarboxylic, amine, and polyphenolic groups by fourier transform-infrared spectroscopy (Shanmugam *et al.*, 2013). Green seaweed *Caulerpa peltata*, red *Hypnea valencia*, brown *Sargassum myriocystum* seaweeds were used tosynthesizezinc oxide nanoparticles and they can be used in effluent treatment process to reduce microbes (Nagarajan and Kuppusamy, 2013). Silver nanoparticles from *Sargassum tenerrimum* along with the presence of phytochemicals as reducing agents wasfound to have excellent antimicrobial activity (Dhanalakshmi *et al.*, 2012). Further report identified that Fe_3O_4 nanoparticles obtained from *Sargassum muticum* which contain sulfated polysaccharides as the reducing agent was determined to have antimicrobial potential, stabilizing capacity and this on fabrication came out with other metal oxides (Mahnaz *et al.*, 2013).

Seaweed in Wastewater Treatment

The two major areas of waste water treatment in which seaweed has its prominent role to play are one is to treat sewage and agricultural wastes to exploit nitrogen- phosphorous wastes and the other is to remove toxic metals from industrial effluent and it was suggested to be a boon in coastal areas (Schramm *et al.,* 1991). Alginates extracted from the seaweed *Sargassum sinicola* was used to co-immobilize the microalgae *Chlorella sorokiniana* and the bacterium Azospirillum brasilense which promotes growth when employed in waste water treatment. Seaweeds were used in wastewater treatment because of its ability to absorb nutrients and heavy metal ions that are toxic. Also seaweeds were suggested as biological indicator of marine pollution like eutrophication on considering its capacity to take up ammonia in the nitrogen form and phosphorous. Despite varying concentration and type seaweeds such as *Sargassum, Laminaria, Ecklonia, Ulva* and *Enteromorpha* were identified as indicators of heavy metal pollution (Ryther *et al.,* 1975).

Seaweed as beauty promoters

Seaweeds possess potentials to stimulate blood circulation and revitalize, nourish and eliminate toxins of the skin. Seaweed bath is one such instance been practiced in Ireland with fucus serratus species promoted to treat rheumatism and arthritis. Also all the required nutrients, aminoacids and oils were found to be absorbed by the skin in seaweed bath. An Irish company has been established to produce seaweed powder from *Ascophyllum nodosum* for the cosmetic and algotheraphy and it was said to improve damaged hair by means of ionic interactions with the proteins of hair. Also seaweeds enzymes were found to heal dandruff and stimulate hair follicles for hair growth. Silicon from seaweeds were analysed to have anti- wrinkle effect on facial skin and other anticellulite preparations from seaweeds has been used in the form of creams and lotions for hip, thigh and neck (Pramanick *et al.*, 2013).

Table.1 Biochemical composition of some seaweed species

Species	Biochemical compound	Yield
*Gracillaria*species	vitamin A	865μg RE /100g
	vitamin C	28.5± 0.1mg/100g
	Fiber	(24.7±0.7)%wet wt
	Lipid	0.43-(3.3±0.2)%wet wt
	PUFA	2.43-51.77% w/w
	Protein	(6.9±0.1)%wet wt
	Minerals	153.3±2.64mg/100g
	Ash	(22.7 ±0.6)%
	Aminoacid	116.37mg/g
*Padina*species	Carbohydrate	50.9±0.52mg/g dry wt
	Lipid	58.38-184.0 mg/g dry wt
	Protein	17.1% d.wt
	Vit B6	115±0.577 μg/g
	Vit B2	75±1.732μg/g
	Vit B1	46±2.309μg/g
	Minerals	90.93±0.257 μg/g
	Trace elements	30-110 ppm
*Enteromorpha*species	Omega -3 FA	10.38%
	Omega -6FA	10.9g/100g
	Fiber	33.4%dry wt
	Protein	19.5%
	Carbohydrate	64.9%
	Ash	15.2%
	Lipid	0.3%
	Moisture	9g/kg
Ulva species	Carbohydrates	(17.8±2.3)-70.1% d.wt
	Protein	14.7%
	Minerals	247.54mg/100g d.wt
	Lipids	0.51-1.18 %
	SFA	65.40±1.65%
	Aminoacids	829.48±6.51mg/100g
	Fibre	51.3-62.2%d.wt
	Ash	25.9-62.2% d.wt
	Vitamin E	19.70 μg/g d.wt

Laminaria species	Carbohydrates	23.61%
	Protein	16±3.8g/100g
	Lipids	26.05±0.3g/10g
	Aminoacids	86.5±14.1g/100gN
	Fibre	36.0±5.7g/100g
	Ash	24.9-36.4%
	Minerals	1929.57mg/100g d.wt
	Vitamin E	34.38 µg/g d.wt
Porphyra species	Carbohydrates	45.1%
	Protein	47% d.wt
	Lipids	2.1±1.2g/100g
	Fibre	47.7±4.25g/100g
	Ash	20.59±0.16g/100g d.wt
	Minerals	106.07±3.44
Palmaria species	Protein	28.25% d.wt
	Minerals	1686.78mg/100gd.wt
	Fatty acids	25.53±2.37%
	Moisture	84%
	Ash	12-37%
Undaria species	Ash	39.26±0.24g/100g d.wt
	Minerals	9992.42±383mg/100g d.wt
	Fibre	35.3%
	Fatty acids	33.36±3.91g/100g d.wt
Sargassum species	Carbohydrate	29.37-47.04±0.7% d.wt
	Protein	11.52-16.59±0.86%
	Fattyacid	0.16±0.006-20.96%
	Fibre	77.40±16.14g/kg
	Ash	194.30±48.65g/kg
	Mineral	1901.74mg/100g d.wt
	Moisture	14.33±1g/kg
Fucus species	Carbohydrate	65.7±0.4%
	Lipid	1.4±0.1%
	Protein	7%
	Mineral	11736±127mg/100g d.wt
	Ash	0.11-22.71±3.1%
	Vitamin	820 µg/gd.wt
Hypnea species	Carbohydrate	13.69%
	Protein	28.63±0.39%
	Lipid	1.43%
	Fibre	47.0025%
	Ash	21.28%
	Moisture	11.18%
	Aminoacid	77.1g/100g

Gelidium species	Protein	11.55±1.02%
	Carbohydrate	41.87±2.21%
	Lipid	1.53±0.61%
	Fibre	24.74±1.05%
	Ash	17.57±0.74%
	Moisture	10.85±0.98%
*Turbinaria*species	Protein	14.68%
	Carbohydrate	18.46±0.685%
	Lipid	2.53±0.14%
	Moisture	83.79±0.32%
	Ash	21.37±0.60%
	Fibre	29.61±1.59% d.wt
Acanthopora species	Carbohydrate	23.54±0.10%
	Lipid	55.33±5.1g/mg
	Fattyacid	64%
	Ash	16.4±2.4g/mg
	Protein	24%
*Colponemia*species	Carbohydrate	32.1±1.75%
	Protein	9.2±1.78%
	Lipid	1.5±0.29%
	Moisture	11.5±0.20%
	Fatty acid	1.0%
	Ash	28.1±0.86%
Ascophyllum species	Carbohydrate	69.6±0.2%
	Protein	(3-15)% d.wt
	Lipid	1.2±0.1 %
	Oil	2.85 %
	Ash	22.5±0.1 %
	Vitamin C	81.75 µg/g d.wt.
	Vitamin E	3.63 µg/g d.wt
Dictyota species	Carbohydrate	10.63%
	Lipid	16.1-20.2 % d.wt
	Protein	9.8%
	Minerals	0.559±0.009 ppm
Caulerpa species	Carbohydrate	9.7±0.477 %
	Protein	24.55±0.84 %
	Lipid	0.9±0.38%
	Fiber	1.36 g/kg
	Ash	24.2 % d.wt

Jania species	Protein	2.53±0.15% wet wt
	Lipid	0.22±0.035% wet wt
	Moisture	40.13±1.54 % wet wt
	Ash	48.14±1.88 % wet wt
	Fatty acid	11.319 % wet wt

Table.2 Biogas yield from certain seaweed species [16]

Species Name	**Yield in ml g volatile solids(g_{VS}^{-1})**
Saccharinalatis sima	335
Saccorhiza polyschides	255
Laminaria digitata	246
Ulva sp.	191

Fig.1 General structure of a seaweed

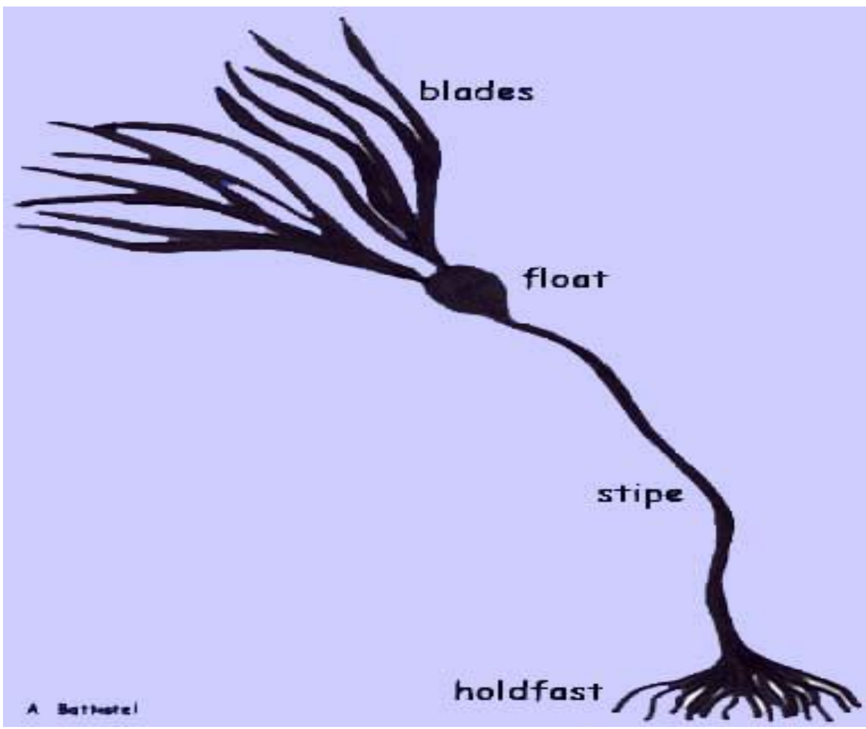


Fig.2 Distribution of species along Indian Ocean

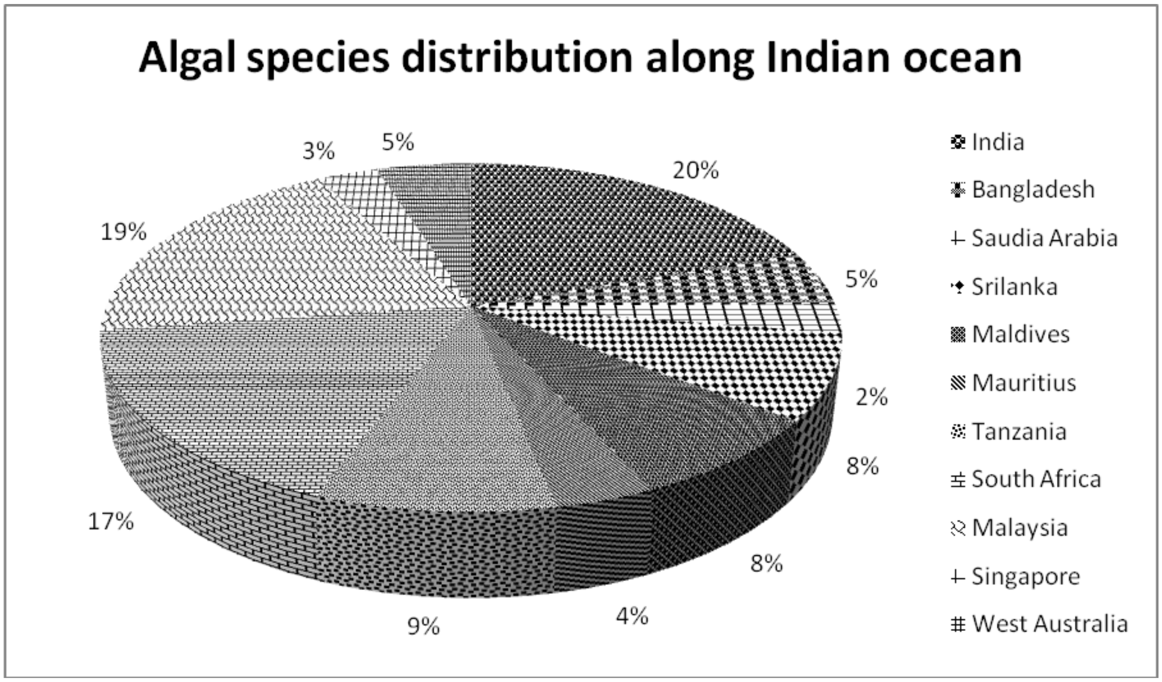


Fig.3 Graphical representation of species distribution

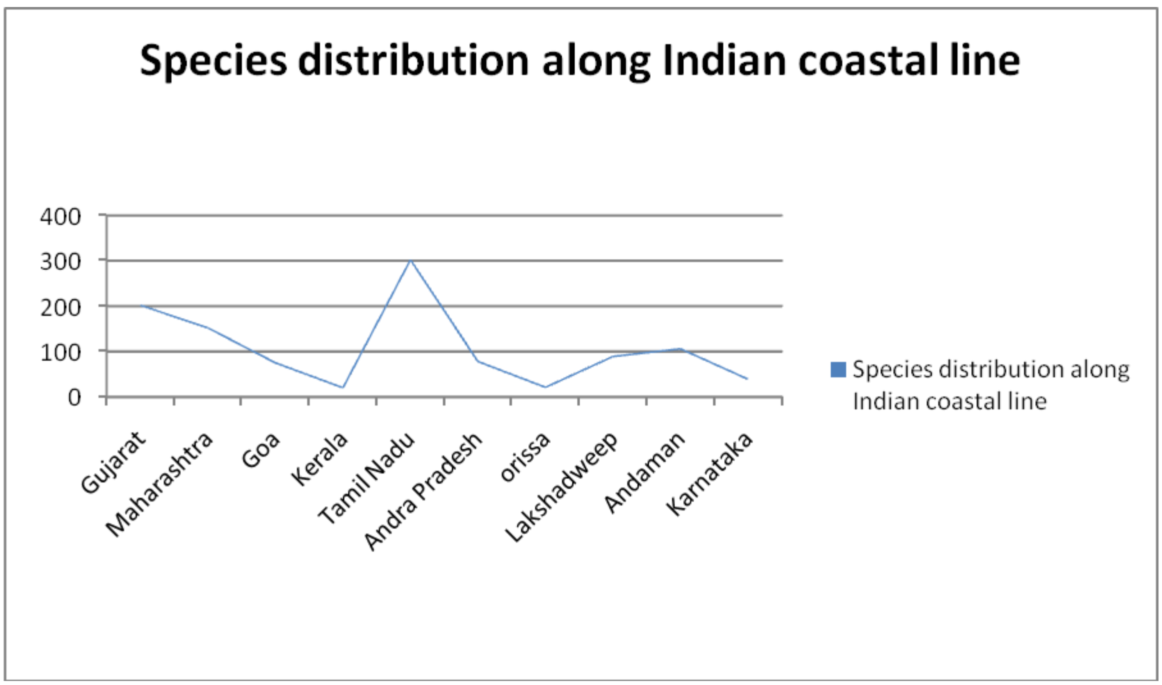


Fig.4 Macroalgal species weightage in other countries

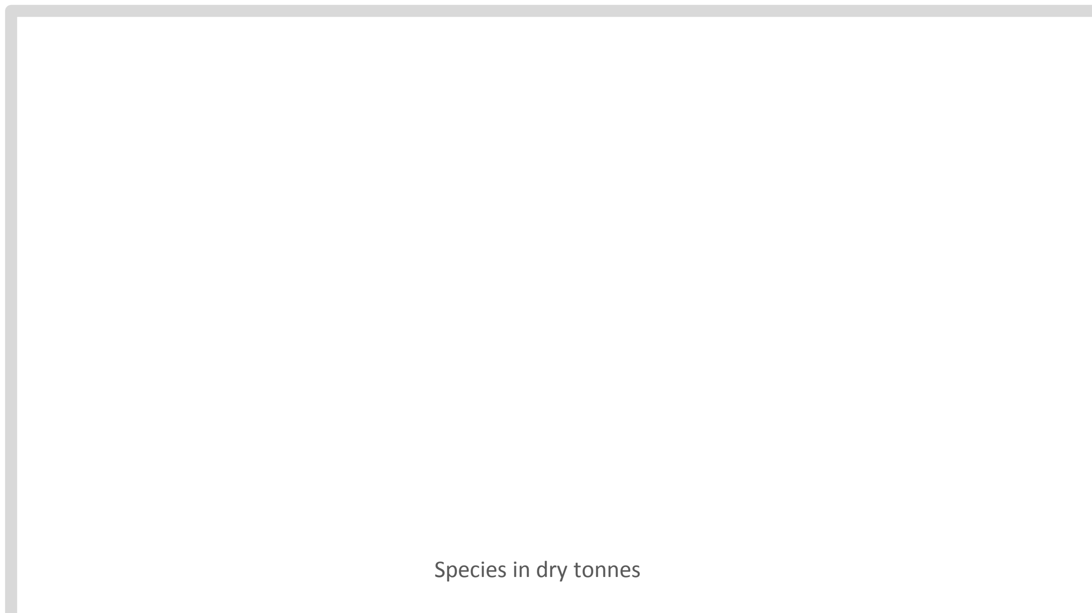
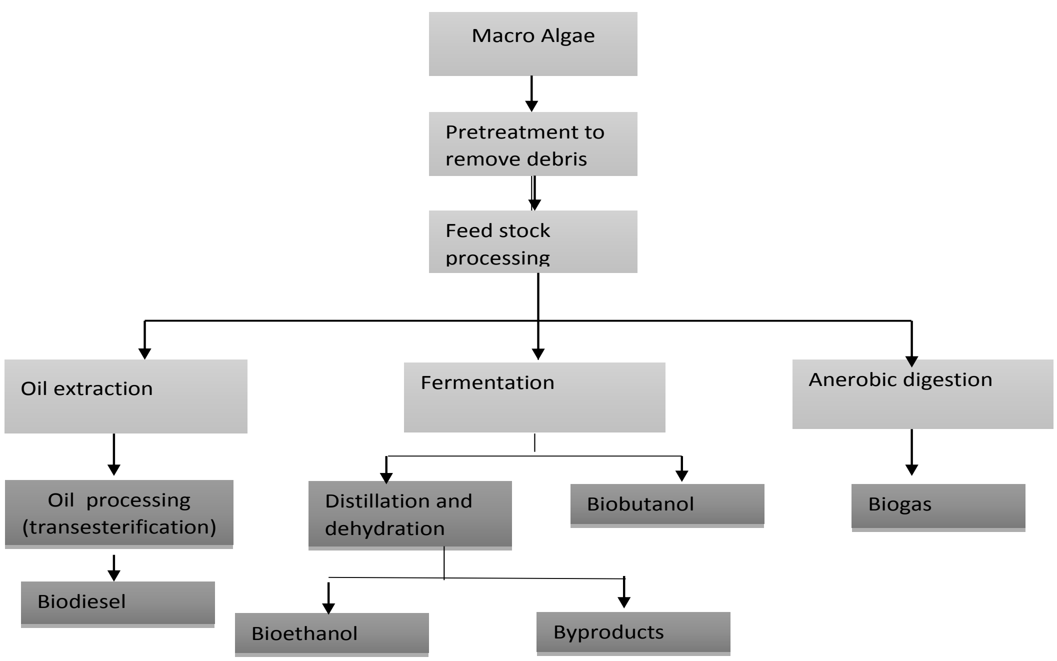


Fig.5 Flowchart showing various biofuel production from algal biomass



Seaweed as Animal Feed

Seaweed meal is rich in proteins and carbohydrates has been used as animal feed after getting the raw biomass cleaned, dried and milled. Also seaweeds were reported to be used as domestic animal feed in Norway, Iceland and France for years. Seaweed feed is considered to have 30 percent of the nutrition of the grains. It was being added to poultry diets in a ratio of 5-15 percent of the diet depending upon seaweed species and the targeted animal age. In addition feeding seaweed meal and sardine oil to chickens has resulted in the reduction of cholesterol level and increase in omega -3 fatty acid content. Seaweed extract from *Ascophyllum nodosum* on consumption by pigs was known to promote prebiotic activity as it has ascorbic acid, tocopherols, vitamin B, minerals and it was found to provide iodine for hogs, chickens, sheep and dairy cows (Jensen, 1972). The wet seaweed were being processed by passing through hammer mills with small screens to get fine particles followed by passing through drum dryer at 700-800^{o}C. It was reported that Ascophyllum which is a dark brown seaweed has high content of phenolic compounds whereas *Alaria esculenta* which is light brown seaweed was found to be more effective as animal feed than the latter. *Macrocystis pyrifera* and Sargassum species was evaluated as fodder supplements in goat and sheep diets. Also Sargassum species was fed to Nubian goats which replaced 25% flour feed (Casas-Valdez and Maina, 2006).

Seaweed as a Biofertilizer

Seaweeds have been used to nourish worn out soil around coastal areas. Use of seaweed fertilizer stimulated root volume, plant growth and even promoted fruit development thus resulted in the production of high quality agricultural products (Pramanick *et al.*, 2013). Further it was revealed that the use of seaweed fertilizer improved germination and disease resistant capacity in plants (Khan *et al.*, 2009). Water and alkaline extracts of *Ascophyllum nodosum* has given tomatoes of appreciable mass and also yielded good quality fruits. Seaweed extracts and fertilizers have given promising turnouts in agriculture for which it is a main stay in the catalogue of commonly preferred soil nourishers (Povolny, 1981).

Indian scenario

In the earlier works it has been reported that there are 271 genus and 1153 species of marine algae found along the Indian coast. It was estimated that the southern coast of India has got more than 200 species of seaweeds which stands a prominent source for agar and sodium alginate production in India. Also it was found that 75,373 tonnes of seaweeds the maximum mass are scattered along the Tamilnadu coastal line covering an area of 1863 sq km from Rameshwaram to Kanyakumari. It was reported that there are about 25 seaweed processing small scale industries of which 20 are agar producers however110-132 tonnes of dry agar are being produced annually based on the harvest of 880-1,100 tonnes (dry weight) in Tamilnadu and kerala. Seaweeds like Gracilaria, Gelidium, Kappaphycusare being cultivated on a large scale in India for the production of phycolloids (Ayhan Demirbas and Fatih Demirbas, 2011).Though India has got a longer coastal line and rich availability of seaweed resource the awareness in India about seaweed culture and its commercial applications is not fair enough. So the common people need more awareness about seaweeds to promote a better healthy future.

Economic Importance

From all the seaweed potentials studied earlier it is evident that the globalization of seaweed cultivation and seaweed derived products can improve the economic status of various countries all over the world. The European, Eastern and Southeast Asian countries are the major producers and consumersof seaweeds (Murty U.S and Banerjee A.K. 2012). According to FAO 2014 Chile tops the global natural seaweed producers and it was estimated as one of the first agar producers in the world (H.J. Bixler and H. Porse, 2011). Various seaweeds are being harvested for human consumption and industrially used in the production of a wide range of nutraceuticals. Patagonia is an outstanding place where all the seaweeds are harvested and commercialized as such biomass and bioproducts (Céline *et al.*, 2014). The red seaweeds are harvested for agar and carrageeanan industries whereas the brown species are utilized by alginates industries (Zaixso *et al.*, 2006). It is to be noted that rapid growth is seen in Japan and Korea is mainly because of seaweed production. The 2010 estimate has shown that the global seaweed production was 19 million tons and it accounts for US $5.7 billion. The increasing demand for seaweed based edible products puts its cultivation in a profiting trend.

In conclusion, seaweed thus serves as a sustainable feedstock and an ecofriendly resource for various purposes. Also many bioactive compounds and pharmacologically active substances have been isolated from macroalgae and put into use in various forms. Nowadays seaweeds are under threat in developing nations because of human settlements, natural barriers and lack of awareness regarding its potential use. Awareness about the importance of harvesting and commercialization of seaweeds and products should be effectively promoted in developing nations. The cultivators should be well trained to make them familiar with various harvesting techniques, the parameters and specificity involved in growing various classes of species for successful commercialization of seaweed farming. India, since it has got long coastal line with rich availability of seaweed species, if encouraged and promoted with financial aids by the government, malnutrition and poverty can be uprooted to the maximum extent.

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