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Importance of Marine Algae and Marine Derived Commercial Products

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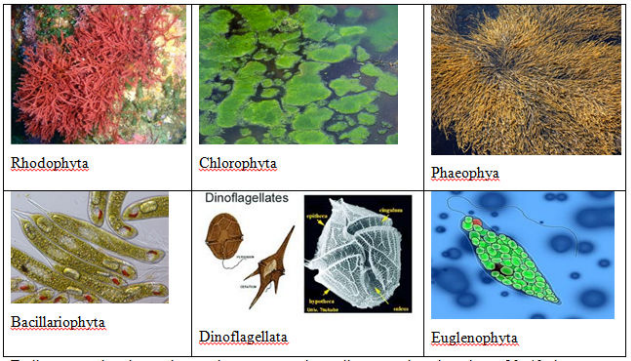
Introduction

Marine group of algae has large divisions and contains huge no of known and unknown genus. Each algae has its own advantage viz., pharmaceutical, antifungal, antibacterial, antiviral, human and animal feed. Microalgae are a huge group of photoautotrophic microorganisms, including species from different phyla such as Cyanophyta (bluegreen algae, cyanoprokaryotes, cyanobacteria), Chlorophyta (green algae), Rhodophyta (red algae), Cryptophyta, Haptophyta, Pyrrophyta, Streptophyta, Heterokontophyta. Microalgae displays a significant ecological plasticity, by the ability to adapt to changing extreme environmental conditions such as temperature, light, pH, salinity and moisture, which describes their worldwide distribution. Microalgae are a diverse group of photosynthetic microorganisms that convert carbon dioxide into valuable compounds including biologically active compounds such as biofuels, foods, feed and pharmaceuticals. Algae are considered as a sustainable source of biodiesel which have the ability to synthesize and accumulate significant quantities of lipids as they are sunlight driven oil factories (Chisti).

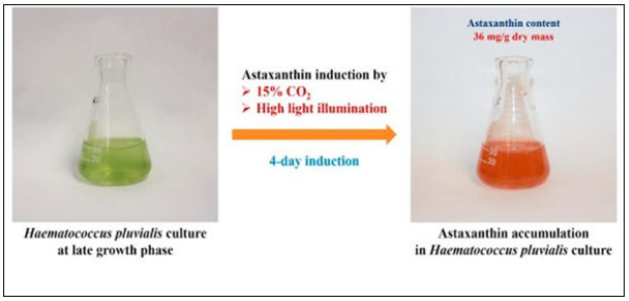


Earlier researches have shown that, compared to oil crops microalgae have 20–40 times more productivity whereas some of them can accumulate up to 80% of dry lipid biomass weight. Hence, microalgae have greater potential to be a major source for renewable energy production in terms of biofuel. Many algal strains are able to accumulate lipids when they are subjected to stress these strains have the potential to grow in mass culture (Rodolfi).

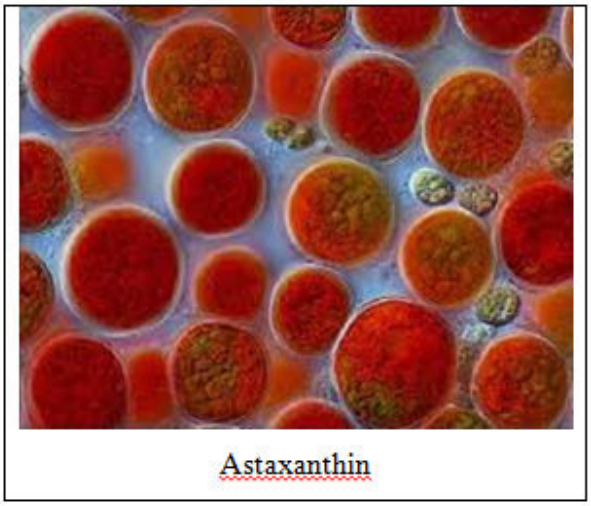
Keywords: Carotenoids; proteins and vitamins; Biofuel; carrageenan; agar agar; proteins and enzymes; sterols

Carotenoids

In photosynthetic organisms, including algae and plants, during the light phase of photosynthesis carotenoids act as accessory pigments in light harvesting and are also able to photoprotect the photosynthetic machinery from surplus light by scavenging reactive oxygen species with singlet oxygen and other free radicals. Almost all carotenoids are involved in quenching singlet oxygen and trapping peroxyl radicals.



The bioactivities of astaxanthin including UV-light protection and anti-inflammatory activity have been reported to effect human health conditions because of their stronger antioxidant activity (Guerin). The wide use of carotenoids as colorants has been found in natural foods including egg yolk, chicken, and fish. More than 750 carotenoids have been identified; still, only a few have been used commercially available such as astaxanthin, canthaxanthin, lutein, lycopene and β carotene are the most common.



As many other antioxidant compounds are present in algal cells, the main advantages of the using microalgae as a carrier of carotenoids is their positive impact on human health. Astaxanthin is synthesized by Chlorophyceae family namely Chlorella, Chlamydomonas, Dunaliella, and Haematococcus spp. Though, a few green microalgae such as Haematococcus sp. can accumulate xanthophylls in oil bodies outside the plastids in the cytoplasm (Lemoine and Schoefs). Formation of xanthophylls in algal cells can be influenced by nitrogen-limitation, temperature, oxidation, light intensity, metal ions and salts. β-carotene β-Carotene is a provitamin A carotenoid and therefore is able to be converted into retinol. Vitamin A has been revealed to reduce the risk of macular degeneration.

Proposed mechanisms of action for β-carotene in cancer prevention include inhibiting the growth of cancer, induction of differentiation by modulation of cell cycle regulatory proteins, modifications in insulin like growth factor-1, hindrance of oxidative DNA damage, and possible augmentation of carcinogen-metabolizing enzymes. Explicitly, β-carotene has been shown to condense cell growth and induce apoptosis in a variety of cancer cell lines, may be through caveolin-1 expression. Lycopene referred as a non-provitamin A carotenoid, lycopene possesses a variety of biological activities. These include antioxidant activity via singlet oxygen quenching and peroxyl radical scavenging, cancer prevention through inhibition of cancer growth, and induction of differentiation by modulation of cell cycle regulatory proteins. Additional reported properties of lycopene includes alterations in insulin like growth factor-1 or vascular endothet al growth factor levels, preventing the oxidative DNA damage, and possible development of carcinogen-metabolizing enzymes, reduced risk for some types of cancers, and some cardiovascular events.

Astaxanthin

Astaxanthin, another non-provitamin A carotenoid, has recently gained attention due to its antioxidant activity and is also traditionally used to pigment the flesh of salmon and trout through dietary supplementation. Astaxanthin scavenges free radicals, provides protection against cancer and an implicated role in inflammatory processes, ocular health, and diabetes. Latest studies on astaxanthin have shown its effectiveness against colon cancer cell proliferation, possibly through inhibition of the cell growth and increased apoptosis of human colon cancer cells.

β-Carotene

The value of the world wide carotenoid market was found to be nearly $1.2 billion in 2010 and is planned to reach over $1.4 billion by 2018. β-Carotene has the leading share of the market. Valued at $250 million in 2007, this part is expected to be worth $309 million by 2018. Red algae and cyanobacteria and show valuable fluorescent properties and accessory pigments. Some of the common phycobiliproteins include phycoerythrin (PE), phycocyanin (PC), and allophycocyanin (APC). These pigments are hetero-oligomers consisting of a grouping of subunits within producing cells (Cyanophyta) or chloroplasts (Rhodophyta) that are organized into complexes called “phycobilisomes”. Phycobiliproteins have been used as natural dyes; moreover, they are extensively being used as nutraceuticals or in other biotechnological applications.

Secondary Metabolites

The ecological function of secondary metabolites in microalgae or cyanobacteria is not well understood; however, several possible roles have been intended with recent researches carried out. For example, the brevetoxins responsible for neurotoxic shellfish poisoning (NSP) are generated by marine dinoflagellates which are considered to have an ecological role as a feeding deterrent. Swimmer’s itch caused by the molecule Lyngbyatoxin is thought to have an ecological role as a defense against grazing. Some secondary metabolites are said to play roles in sexual communication or symbiotic signals (Maschek and Baker). Secondary metabolites can be represented in all classes of molecules including isoprenoids, polyketides, peptides, and macromolecules such as nucleic acids, carbohydrates, proteins, and lipids. This level of chemical diversity associates with the huge number of environments inhabited by algae and cyanobacteria. Secondary metabolites signify unique adaptations to these diverse environments.

Filamentous cyanobacteria growing on a shallow tropical reef, and would expect unique chemical structures with exclusive biological properties to be produced. With more richness in chemical and biological diversity, the algae and cyanobacteria are gaining more value as commercial products. For example, the unique structures produced by algal species possess rich value as components in human food, cosmetics, and various pharmaceuticals.

Polyunsaturated fatty acids (PUFA)

It is very well known that, some of the ω-3 and ω-6 fatty acids are required for humans needs but cannot synthesize this is the reason why some PUFA are called essential fatty acids. The illness, smoking or alcohol intake can cause inability to synthesize some fatty acids. Essential fatty acids, particularly ω-3 and ω-6, are important for the reliability of tissues where they are incorporated. Linoleic acid is used as formulations for treatment of skin hyperplasias. Arachidonic acid can be obtained from linoleic acid. DHA and EPA showed an ability to reduce problems associated to cardiovascular strokes and arthritis, and also to lower hypertension. Furthermore, DHA and EPA play essential roles in lowering lipid content by reducing triglycerides, augmenting HDL levels and as anti-inflammatory agents. Although it is poorly synthesized, the breast milk contains high amount thus, newborns, fed with artificial milk, should be given ω-3 DHA as an additive.

Proteins and enzymes

Proteins are biopolymers of amino acids, are essential for human beings, as they cannot be obtained without feeding, because of some deficiency in synthesizing them in enough amount. In addition, besides nutritional benefits some proteins,

smaller peptides and amino acids have functions that contribute to a few health benefits. As microalgal species Arthrospira and Chlorella are rich in protein and amino acid they may be used as nutraceuticals or be included in functional foods to prevent tissue damage and diseases.

Vitamins

Marennine, a blue pigment responsible for greening of oysters, diatom Haslea (Navicula) ostrearia is particularly rich in vitamin E. Another microalgae named Porphyridium cruentum is rich in vitamins C, E (tocopherols) and provitamin A (β-carotene). In addition, Dunali ellasalina besides producing β-carotene (provitamin A), it also produces thiamine, pyridoxine, riboflavin, nicotinic acid, biotin and tocopherol.

Biofuel

The natural source of renewable energy such as microalgae, can be formed from natural resources such as sunlight, water and O2/CO2.The production of biodiesel and bioethanol from microalgae that have potential to replace fossil fuels being in an economic sustainable way and leading reduction of GHG emissions. Microalgae are considered to be an outstanding candidate for biomass production (nearly 77% of dry cell mass), photosynthesis process for lipid fabrication, and production of biofuel.

Biocontrol activity of algae

Approximately 30,000 freshwater and marine algal species have been studied and identified (Mata). They are able to produce a wide range of bioactive substances with antibacterial, antiviral, antifungal, immunostimulant and antiplasmodial activities (Borowitzka, Angulo-Preckler). Most of the isolated bioactive substances belong to groups of polyketides, amides, alkaloids, peptides, and fatty acids (Ghasemi, Feng). Research to identify bioactive compounds produced by microalgae has recently received considerable attention as a new source of novel antifouling substances. Marine dinoflagellates could produce diverse bioactive compounds, exemplified by okadaic acid, ciguatoxin, and maitotoxin (Yasumoto and Murata). The genus Amphidinium was also a rich source of bioactive compounds which showed certain biological activity, such as anti-fungal, anti-tumor, and hemolytic properties (Gopal). For marine dinoflagellate Amphidiniumcarterae, the toxic and red-tide microalgae, numerous efforts had been made to isolate pharmaceuticals and other biologically active compounds. However, the reports about its antifouling potential have not been found by now. So the present study was undertaken to explore the antifouling potential of Amphidiniumcarterae carterae at low temperature of 35. Secondly, the concentrate was purified by a C18 solid-phase extraction (SPE) column and eluted with 10 mL MeOH. Then, the methanol eluent was dried by nitrogen blowing, solubilized in 20 mLCHCl3, and partitioned with NaOH (0.1 mol L−1) three times. The aqueous partition is equivalent to a saponification, as described in lipidic extraction procedures, and the non polar compounds were discarded (Bursali). Thirdly, the aqueous phases were combined, acidized by H2SO4 (1.0 mol L−1) and extracted three times withCHCl3/MeOH (2:1). Finally, the organic phases were combined, concentrated under vacuum at the low temperature of 30, and dried by nitrogen blowing (the organic extract C). The organic extract C contained lipophilic compounds that were moderately polar and saponifiable.

Fatty Acids

Fatty acid with two or more methylene interrupted double bonds is good for normal cell function, and now has been entered in different areas like biomedical and nutraceutical. As a result of understanding the biological use of fatty acid it is most commonly used in western society against obesity and cardiovascular problem. Moreover PUFAs play an important role in cellular and tissue metabolism, PUFAs is stand for polyunsaturated fatty acids, it also play an important role in the regulation of membrane fluidity, oxygen and electron transport, as well as thermal adaptation (Funk, 2011). In addition, people show more attention towards healthy food in their busy life style (Napier, 1999).

In particular, people show increasing interest towards PUFAs family, namely EPA (5, 8, 11, 14, 17- eicosapentaenoic acid). EPA is a fatty acid of 20 carbon chain with having five double bonds located at the carboxy terminus or with the last double bond located at the third carbon from methyl terminus. EPA is normally esterified to form a complex lipid molecule inside the cell and play an important role in higher plants and animals as a precursor of a group of eicosanoids, hormone like substance such as prostaglandins, thromboxanes are crucial in regulating developmental and regulating physiology. Fish oil is seems to be conventional source of EPA. EPA is passed up by food chain via consumption by omnivores fish and then by carnivores fish and then finally by human (Wen and Chen). The biosynthesis of fatty acid occur in two steps, first step is the de novo synthesis of oleic acid from acetate followed by converting to linolenic acid and α-linolenic acid. The stepwise saturation and elongation form a ω-3 PUFA. Fish oil is a conventional source of EPA but fish do not synthesize EPA de novo, they derived this compound from the marine microorganisms they consumed, thus EPA passed through the food chain and ultimately reach to the human being. EPA from the marine fish oil is refined for pharmaceuticals, this oil having a very complex fatty acid varying with chain length and unsaturation degrees (Gill and Valivety). EPA has been found in wide variety of marine algae class but only some of them have the potential to demonstrated industrial production, mainly due to the fact that majority of marine algae have low specific growth rates and low cell densities when grow in autotrophic condition (Wen and Chen).

Sterols

Some species of microalgae have been used for promoting growth of juveniles, especially oysters for their content in sterols. Cholesterol is rarely being found in phytoplankton species such as Chaetoceros and Skeletonema that were reported to produce up to 27.7 and 2.0 µg sterols/g dry weight cholesterol being the major sterol. Other microalgae, such as

Thalassiosira and Pavlova also show high amounts of sterols. Pavlova lutheri contains other uncommon sterols such as brassicasterol, campesterol, stigmasterol and sitosterol apart from cholesterol. Its is well familiar that high levels of cholestrol and cholesterol lowering of plant sterols are of high risk for heart and coronary diseases.

Sterols are the major nutritional component found in seaweed, they are the most important chemical constituent of microalgae. Mainly sterols are present in plant, animal and fungi, with the most famous animal sterol known as “cholesterol”. Cholesterol is vital to cellular function and affects the fluidity of animal cell membrane. Cholesterol is a precursor to fat soluble vitamins and steroid hormones. Various species of seaweeds have different sterols, like green seaweeds contain 28 is of ucocholesterol, cholesterol, 24 methylene cholesterol and β-sitosterol while brown seaweeds contain fucosterol, cholesterol and brassicasterol. Red seaweeds contain sterols like desmosterol, cholesterol, sitosterol, fucosterol and chalinasterol (Sanchez). Brown seaweeds (Laminaria and Undaria) contain 83% - 97% of fucosterol in total sterol content (662 - 2320 µg/g dry weight) and desmosterol of red seaweeds (Palmaria and Porphyra) contain 87% - 93% of total sterol content (87 - 337 µg/g dry weight). However red seaweeds of C. crispus has cholesterol as major sterol. It is reported that plant sterol like β-sitosterol and fucosterol leads to the decrease in the concentration of cholesterol in the serum experimentation in animals and human (Whittaker).

Polysaccharide

Marine algae contain huge amount of polysaccharides mainly cell wall structure and also myco polysaccharides and storage polysaccharides (Kumar). Polysaccharides are the polymer of simple chain monosaccharide or simple sugar that is linked together by glycosidic bond. They have many applications like they are use in food, beverages, stabilizers, emulsifiers, thickeners, feed. The green seaweed species contain high content of polysaccharide like Ulva contain 65% of dry weight. The other seaweeds species contain high amount polysaccharide are Ascophyllum, Porphyra and Palmaria. Mainly the seaweeds contain polysaccharide concentration in the range from 4% - 76%. According to the nutritional perspective, seaweeds are low lipid content and having high carbohydrate most of this is dietary fibers even though they are not taken up by the human body.

However dietary fibers are good for human bodye. The polysaccharide cell wall mainly consists of cellulose, hemicelluloses, and neutral polysaccharides. The content of cellulose and hemicellulose of seaweeds species of interest is 2% - 10% and 9% of dry weight. Chlorophyceae or green algae contain sulphated galactans, sulphuric acid polysaccharide whereas the Pheophyceae also known brown algae contain alginic acid, fucoidan or sulphated fucose, laminarian or β-1, 3 glucan. Sargassan and Rhodophyceaeor red algae contain carrageenans, amylopectin like sugar also known as floridean starch, water soluble sulphated galactan, as well as porhyran as mucopolysaccharide that is present in the intracellular spaces (Kumar).

Agar

Agar is a mixture of polysaccharide mainly composed of agarose and agro pectin, which having structure and function properties as similar as carrageenan. Agar is the sulphated polysaccharides mainly extracted from Phaeophyceae, it is also extracted from red seaweeds such as Gelidium sp. and Gracilaria sp. The use of this compound is mainly in commercial and scientific areas because of its gelling emulsify and viscosity property. Agar is a generic name of seaweeds galactans containing α (1-4)-3, 6-anhydro-L-galactose and β9 (1-3)-D-galactose residues with having esterification of sulphatein small amount which is up to 6% (w/w) (Hemmingson). The low quality agar is used in food products like candies, fruit juice, frozen foods, bakery icing, meringues and desert gels. Agar also has an industrial application include paper coating, adhesives, textile printing dyeing, impressions, casting. The medium quality agar is used in biological culture media as the gel substrate. They are also important and used in the field of medical and pharmaceutical as a bulking agents, anticoagulant agent, laxatives, capsules and tablets. The high quality of agar or highly purified agar (agarose) is used in intermolecular biology for separation techniques like electrophoresis, immune diffusion and gel chromatography. Agar-agar is used for cooking & as a food source in Japan. It is known for the manufacturing of capsules for industrial application & also used as medium for cell culture. Agar structural and functional property is same as carrageenan.

Agar affects the absorption of ultraviolet rays (Murata, M. and Nakazoe), it can decrease the blood glucose level and also exerts an anti-aggregation effect on red blood cell. Agar-oligosaccharide has also been shown that it suppresses the production of a pro-inflammatory cytokine and also suppresses the enzyme associated with production of nitric oxide. Agar type polysaccharide which is extracted from cold water extraction of another Gracilaria species shows anti-tumor activity. If agar is hydrosylates then it result to form agaro-oligosaccharides with activity against glycosidase and antioxidant ability (Fernandez). The agar quality and its content is totally depend upon the physiochemical property as well as closely related to environmental parameters, growth and reproductive cycle. Although agar is also used in commercial level outside the hydrocolloid industry, the recently used this in medicinal, pharmaceutical areas for the treatment against the cancer cell, since it can be induce the apoptosis of these cell in vitro (Chen).

Alginate

Alginate is first discovered by British pharmacist, ECC Stanford in 1880, its first industrial production began in California in 1929.

Alginate is a common name for a family of linear polysaccharide containing 1, 4 linked β-D-mannuronic and α-L-guluronic acid residues which is arrange in a non-regular block wise order (Andrade). Alginate is produced from brown algae and it mainly used in food and pharmaceutical industry, because of its ability to chelate metal ion and to form high viscous solution. It is also used in the textile industry the sizing cotton yarn and also used as a gelling agent. Alginate is available in both forms that is acid and salt, the acid form of alginate is a linear polyuronic acid and it is called asalginic acid, whereas the salt form is an important cell wall component of brown seaweeds, consisting of 40% - 47% dry weight of algal biomas. It has been reported that alginate is play an important role as a dietary fiber in human and animal both. It is used for decrease the concentration of cholesterol, exerts hypertension effect, can prevent absorption of toxic chemical substance (Kim and Lee). This dietary fiber is not present in any land plant, they help protect against the potential carcinogen, and they protect the surface membranes of the stomach and intestine, and they also clear the digestive system. They also have a property to absorb substance such as cholesterol and then eliminated from intestine (Burtin) and they result in hypocholesterolemic and hypolipidimic responses (Panlasigui).

Alginate


Alginate producing algae

Carrageenan

It is the generic name for the family of natural water soluble sulphated galactans, having alternative backbone consisting of α (1-4)-3, 6-anhydro-D-galactose and β (1-3)-D-galactose (Goncalves). Carrageenan is widely used then agar as emulsifiers and stabilizer in numerous foods especially milk based product. κ- and ι-carrageenan are very importantly used in milk products like chocolate, pudding, deserts gels, ice creams, jellies, jams, evaporated milk, because of its thick and suspension property. Carrageenan commercially divided into five of the following λ-carrageenan, ι-carrageenan, κ-carrageenan, μ-carrageenan, ν-carrageenan. In sulphate level large difference that is 20% (w/w) in κ-carrageenan and 40% (w/w) in λ-carrageenan is due to the difference in the seaweeds species and their extraction condition. The μ-carrageenan and ν-carrageenan biologically are the precursor of κ-and ι-carrageenan, can be transfer into sulfotransferase and sulfohydrolase (Van de Velde). Carrageenan can also be used as a potential pharmaceutical as anti-tumor, anti-viral, anti-coagulant and immunomodulation activity (Zhou). Carrageenan can dissolve in water because of the biomolecules group that composed of linear polysaccharide chain with sulphate half esters attached to the sugar unit. Other medical use of carrageenans are asan anti-coagulant in blood products and also for the treatment of bowel problems, constipation and dysentery. They also used for making internal poultices to control stomach ulcers. New research from biocide properties shows that carrageenan gel from Chondrus crispus may block the transmission of HIV virus as well as other STD viruses such as gonorrhoea, genital warts and the herpes simplex viruses (HSV) (Luescher -Mattli).

Antiviral Activity

It has been reported that some sulphated polysaccharide from red algae show antiviral activity against viruses that are responsible for human infection. Most notable are Aghardhiellatenera and Nothogeniafastigiate (Kolender). It was tested that galactan sulphate (from Aghardhiellatenera) and xylomannan sulphate (from Nothogeniafastigiata) show antiviral activity against the most infectious viruses like human immune deficiency virus or HIV, herpes simplex viruses types 1, 2, respiratory syncytial virus or RSV. The polysaccharide present in these seaweeds are active during the first stage of RNA replication, when it adsorbs onto the surface of the cells. The most important requirement of antiviral polysaccharide is that it has to be very low cytotoxic effect towards the mammalian cell and most of the seaweeds fulfill this requirement especially Aghardhiellatenera and Nothogenia fastigiata. Carrageenan is a potential that show invitro antiviral activity. There are many types of carrageenan like μ-carrageenan, λ-carrageenan, κ-carrageenan and ι-carrageenan.

It was also reported that some carrageenan also show potent antiviral activity against different strain HSV 1 and 2. Carragaurd is a carrageenan based on microbicide, is an undergoing phase 3 trials, it is used for blocking of HIV and other sexually transmitted disease. A sulphated polysaccharide from Schizymeni apacifica inhibits the HIV reverse transcriptase in vitro, which is a later stage in HIV replication (Nakashima), they don't have any effect or minimal effect on DNA and RNA polymerase activity. Some high molecular weight galactan sulphate also known agaroids from Gracilaria corticata show antiviral property against HSV type 1 and 2, this is because of the inhibition of initial virus attachment to the host cell (Wu). Fucoidan has potent antiviral activity against HSV type 1 and 2, human cytomegalovirus (Malhotra) and HIV. Fucoidan show antiviral property by inhibiting the binding of viral particle to host cell (Baba, 1988). It also has the property to inhibit the binding of sperm to the zona pellucid (Oehninger).

Antibiotic Activity

Macro algae have many compounds that show antibiotic activity. The interesting list of compounds present in macro algae are halogenated compound such as halogenated alkanes, haloforms, alkenes, alcohol, aldehyde, hydroquinone and ketone (Lincoln). Compounds such as sterols, heterocyclic and phenolic compounds show antibiotic property. Many of these compounds show antiseptics as well as cleansing property, but their antibiotic activity in vivo is often only achieved at toxic concentration (Lincoln). A halogenated furanone also known as fimbrolide which is a promising antibacterial agent, belong to class of lactones from Delis eapulchara. It has been exam in edas effective result on bacterial anti-fouling (Kjelleberg and

Steinberg) and also used as treatment for chronic Pseudomonas aeruginosa infection. Pseudomonas aeruginosa infection mainly cause by the production of mucoid alginate and formation of biofilm in the lungs of patients suffering from cystic fibrosis (Hoiby). Bacterial inhibition mainly occur by inhibiting the furanone on the quorum sensing mechanism by functioning as intracellular signal antagonist, as a result disruption of intra and inter cellular cell-cell communication occur (Rasmussen). This effect mainly occur in gram negative bacteria. Compounds like sterols heterocyclic and phenolic compounds sometimes shows antibiotic property. These properties may be developed into antiseptics and cleansing agent but the antibiotic property in vivo is only achieved at toxic concentration.

Anti-Cancer Activity

Fucoidans obtained from brown algae Eclonia cava, Sargassum hornery and Costaria costalla, widely spread in the sea of the South Korea, play an inhibitory role in colony formation in human melanoma and colon cancer cells. Hence these fucoidans may be effective anti tumour agents (Ermakova). Hydrolyzed fucoidan from sporophyll of Unda riapinnnatifida were used to determine the molecular weight and hydrolysis condition on cancer cell growth. Native fucoidan showed anti-cancer effect. A test showed that anti-cancer activity of fucoidan could besignificantly enhanced by lowering the molecular weight, only when they are depolymerized by mild condition (Yang).

Conclusion

Algae has multifunctional compounds viz., carotenoids, astaxanthin, β carotene, secondary metabolites, PUFA, proteins and enzymes, vitamins, biofuel, biocontrol activity of algae, fatty acids, polysaccharide, agar, alginate, carrageenan, antiviral activity, antibiotic activity and anticancer activity. All the compounds are very essential for human health and well being. Hence for the sustainability of algae availability and its growth we have to preserve the marine ecosystem.

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