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Bioactive Compounds and Properties of Seaweeds—A Review

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Abstract

In last three decades the discovery of metabolite and biological activities from macroalgae has been increased significantly. Many sophisticated modern research tools are available for making of chemical compound but there are still many natural bioactive compounds in the womb of nature which is a mystery, scientist are still working to find out more biologically active compounds. Bioactive substances from seaweeds currently receive the more attention from the pharmaceutical companies for the drug development as well as the researchers. Seaweeds are taking majority of attention from scientists because of its phenomenon bioactive compounds and its properties like anti-viral, anti-tumor, anti-inflammatory and anti-lipedimic and may more properties. This current review described mainly substances like metabolite, properties, and types of seaweeds. Emphasis is given to main metabolite and properties of seaweeds.

Keywords

Seaweeds, Metabolites, Bioactive Compounds, Anti-Viral, Anti-Tumor, Macro Algae

Subject Areas: **Biotechnology, Marine Biology**

1. Introduction

Seaweed is a term encompassing for macroscopic, multicellular or benthic marine algae. They attached to the bottom in relatively shallow coastal waters. They grow in the deep sea areas of depth up to 180 meter and also in estuaries and in black water on the solid substrates such as rocks, dead corals, pebbles, shells and other plant material. They are abundantly found in solid substrates and commonly presenting onto depth 30 - 40 meter. In India about 620 species have been reported with a potential of 77,000 tons (wet weight) per annum. The brown seaweeds contribute 0.2%, red seaweeds 27.0% and others contribute 72.8%. About 206 algae are reported from

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the mangrove environment. Seaweed may be categorized into one of multi cell algae, they may be *Chlorophyceae* (green algae), *Pheophyceae* (brown algae), and *Rhodophyceae* (red algae) [1]. Seaweeds have been used for a variety of purposes like food, medicinal, herbalism and other uses. Even though the therapeutic property of seaweeds are well known from many centuries, but the scientific research on therapeutic property on seaweeds began during 1970s. Scientist is successful in isolating chemical compounds from brown seaweeds that show anticancer and antitumor activity [2].

Seaweeds are the source of producing chemical compounds like agar-agar, carrageenan and alginates. These chemical compounds also known as phytochemical and are mainly use for human consumption, animal feed, manure (in many countries) etc. These phytochemical are also extensively used in food, textiles, dairy, paper industry and confectionary. Seaweeds extracts are also a very important component of mast biostimulate product found in market nowadays and it is best known for their richness in polysaccharide, minerals and certain vitamin [3]. There are many benefits of seaweeds extract known from thousands of years but only in modern time their bioactive ingredients are recognized, they contain bioactive substance like polysaccharide, lipids and polyphenols, with anti-bacterial, anti-fungal and anti-viral properties [4]. These properties make seaweeds more potential as a supplement in functional food or for the extraction of compound. Physiologically active substance in marine algae are classified into two types based on difference in their mechanisms: 1) non-absorbed high molecular wt. materials like dietary fibers and 2) low molecular wt. material, which are absorbed and affect the maintenance of human homeostasis [5]. Seaweeds extract are rich in natural plant growth hormone and beneficial trace element. In seaweed extract high level of natural plant growth hormone is present like auxin, cytokines and gibberellins. The best seaweeds extract come from the brown seaweeds *Ascophyllum nodosum*, harvested from mineral rich water like Norway and Nova Scotia. This seaweed extract grows in tidal zone and are subjected to tolerate floods, temperature, drought, salt stress extreme levels of solar radiation and ultraviolet rays [6].

2. Bioactive Compounds

2.1. 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 [7] [8]. 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 [9]. In addition people show more attention towards healthy food in their busy life style [10]. In particular, people show increasing interest towards PUFAs family, namely EPA (Δ5, 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 [11]. 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 and leucotriens that 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 [12]. 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 [7]. 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 [12].

2.2. Sterols

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, it also act as secondary messenger in developmental signaling. 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 [13] [14]. 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 [14].

2.3. Carotenoids

Carotenoids are nature’s most abundant pigments and found in higher plants, all algae, and photosynthetic bacteria. They represent photosynthetic pigment in red, orange or yellow wavelength. Carotenoids are natural pigments derived from five carbon isoprene units that are polymerized enzymatically to form regular highly conjugated 40-carbon structures with up to 15 conjugated double bonds. Carbon skeleton one end or both end undergo cyclization to form a ring of β-ionone end groups, which additionally may be substituted by oxo, hydroxy or epoxy groups at different position to form the different xanthophyll [15]. At least 600 different carotenoids play an important biological functions in bacteria, algae, plants and animals are reported [16]. Carotenoids are play an important role as an essential constituent photosynthetic apparatus, in the reaction center of photo systems where they act as 1) accessory pigment for light harvesting processing during photosynthesis 2) structural stabilizers for protein assembly in photo systems 3) inhibitor for photo or free radical oxidation by excess light exposure [17]. Some carotenoids also consider as vitamin that are classified accordingly to their biological and chemical activity and each vitamin may refer to as a vitamer compound. Vitamer compound are interconverted in the body whereas vitamins have diverse biochemical function in body like hormone, anti-oxidants, mediators of cell signaling and regulators of cell and tissue growth [3]. Carotenoids (tetraterpenes, carotenes) are hydrocarbons and xanthophyll contain one or more oxygen molecule [18]. Different seaweeds have different carotenoid pigment like green seaweeds species have β-carotene, luetin, violaxanthin, neoxanthine and zeaxanthine while red seaweeds contain mainly α and β carotene, luetin and zeaxanthin. In brown seaweeds β-carotene, violanxanthine and fucoxanthine are present [19]. Several specific changes in the basic structure of caratenoids are found in natural algal caratenoids, including variation in the number of carbon atom and also the presence of unusual groups such as allene groups and lactones found in peridinin and fucoxanthine [20].

2.4. Polysaccharide

Marine algae contain huge amount of polysaccharides mainly cell wall structure and also mycopolysaccharides and storage polysaccharides [4] [5]. 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 etc. [21] [22]. 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* [3]. 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 body [23]. 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 *Rhodophyceae* or 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 [4] [5].

2.5. Dietary Fibers

Seaweeds dietary fibers composition, chemical structure, physiochemical property as well as their ability to be

fermented by the colonic flora and its biological effects on human and animal cell, all is very diverse to each other [24]. The total fibers contain in an edible seaweeds are 33% - 62% of the dry weight which is much higher than the fiber found in higher plant [25] [26]. The dietary fibers in seaweeds are classified into water soluble fibers and water insoluble fiber. The water insoluble fibers are cellulose, mannans and xylan whereas soluble fiber include agars, alginic acid, furonan, laminarin and porphyran. The seaweeds dietary fibers contain some valuable nutrients as well as substances, and there has been a deal of interest in seaweeds meal, functional foods and nutraceutical for human consumption [27] because polysaccharide show antitumor, antiherpetitic bioactivity, anticoagulant, decrease LDL that is low density lipid-cholesterol in rats, antiviral activity, they prevent from obesity, large intestine cancer and also prevent from diabetes [5] [28]-[31]. The undigested polysaccharide of seaweeds form an important dietary fibers, even they modify the digestibility of dietary protein and minerals [32].

2.6. 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. [33]-[35]. 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 β 9(1-3)-D-galactose residues with having esterification of sulphatein small amount which is up to 6% (w/w) [36] The low quality agar is used in food products like candies, fruit juice, frozen foods, bakery icing, meringues, desert gels etc. Agar also has an industrial application include paper coating, adhesives, textile printing dyeing, impressions, casting etc. 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, immunodiffusion 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 agar affects the absorption of ultraviolet rays [5], 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 [37]. 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 [38]. 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* [39].

2.7. Carrageenan

It is the generic name for the family of natural water soluble sulfated galactans, having alternative backbone consisting of α (1-4)-3, 6-anhydro-D-galactose and β (1-3)-D-galactose [40]. 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 etc. 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 [41] [42]. Carrageenan can also be used as a potential pharmaceutical as anti-tumor, anti-viral, anti-coagulant and immunomodulation activity [43] [44]. 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 as an anti-coagulant in blood products and also for the treatment of bowel problems such as diarrhea, constipation

and dysentery. They also used for making internal poultices to control stomach ulcers. New research from biocide properties shows that carrageenan gel from *C. crispus* may block the transmission of HIV virus as well as other STD viruses such as gonorrhea, genital warts and the herpes simplex viruses (HSV) [45]-[48].

2.8. 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 [49]. 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 biomass [34] [50]. 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 [5] [51] [52]. 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 [53] [54] and they result in hypocholesterolemic and hypolipidimic responses [55]-[57].

2.9. Phycocolloids

Phycocolloids are the structural component of seaweeds cell wall and involve in the detection mechanism between seaweeds and pathogens [58]. It is a polysaccharide of high molecular weight composed of polymer of sugar unit. The three major groups of phycocolloides are alginates, carrageenan and agar, these are mainly use in cosmetic and food industry [59]-[61].

3. Properties of Seaweeds

3.1. 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 *Aghardhiella tenera* and *Nothogenia fastigiata* [62]-[64]. It was tested that galactan sulphate (from *Aghardhiella tenera*) and xylomannan sulphate (from *Nothogenia fastigiata*) show antiviral activity against the most infectious viruses like human immunodeficiency 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 [65] [66]. 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 *Aghardhiella tenera* and *Nothogenia fastigiata* [65]. 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 *Schizymenia pacifica* inhibits the HIV reverse transcriptase *in vitro*, which is a later stage in HIV replication [67] [68], 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 [69]. Fucoidan has potent antiviral activity against HSV type 1 and 2, human cytomegalovirus [70] and HIV [71]-[74]. Fucoidan show antiviral property by inhibiting the binding of viral particle to host cell [75]. It also has the property to inhibit the binding of sperm to the zona pellucid [76].

3.2. 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 [77]. 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 [77]. A halogenated furanone also known as fimbrolide which is a promising antibacterial agent, belong to class of lactones from *Delisea pulchara*. It has been examined as effective result on bacterial anti-fouling [78] 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 [79]. 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 [80]. 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.

3.3. Anti-Inflammatory Activity

Macro algae especially red seaweeds are rich in 20 carbon atom of polyunsaturated fatty acids mainly eicosapentaenoic and docosahexanoic, also known as PUFAS [81] [82]. Seaweeds are capable of metabolizing C20 PUFAS by oxidative pathways and the two main products are Gracilariales and prostaglandin. There are two main alternative method used for the production of prostaglandins, the first method involves fatty acid cyclooxygenase acting on archidonic acid as in mammalian cell and the second method uses lipooxygenase also acting as archidonic acid [83] [84]. In many red algae the metabolized products of PUFAS are called as oxylipins also resemble as eicosanpoid hormone in higher plant and animals which fulfill the physiologically function [85] [86]. The anomalous production of these compounds produce a number of disease related to inflammation [82], and eicosanoid and its derivatives are received much more attention in research because of its anti-inflammatory drugs [87]. Eicasanoids such as leukotriens and hydroxyleicotetraenoic acid shows some physiologically active properties like chemo attraction of netrophills or smooth muscle cell, the contraction of muscles and have the connection with several of diseases in mammals. The combined effect of prostaglandins and expansion of *Laminaria* stipes are well known in obstetrics and gynecology, where it is used as a cervical dilator [88]-[90].

3.4. Anti-Thrombic and Anti-Coagulant Activity

Fucoidan have *in vivo* and *in vitro* heparin like activity that show anti thrombic and anti-coagulant activity, which are mediated by blood coagulation inhibitors such as heparin cofactor II or anti-thrombin III [91] [92]. When fucan and thrombin interact with each other directly than anti-coagulant activity is produce in result and it usually increase with the amount sulphation [93]-[95]. Sulphated fucan from *Fucus vesiculosus* and *Ascophyllum nodosum* have been patented as anticoagulant substances. The work was mainly motivated by the need to find a replacement for cattle derived heparin and the fear of the transmission of bovine spongiform encephalitis (BSE) [96], through the use of bovine derived products. There are several advantages of sulphated fucan over heparin like it show concentration dependent inhibition of thrombin generated from platelets, it exhibits concentration dependent inhibition of thrombin induced platelet aggregation, it lack the hypotensive effect found in thrombin, it reduce the sticking of polymorph nucleated leucocytes from rabbit aorta, it shows a dose dependent inhibition of thrombin induced thrombosis [97].

3.5. Antilipemic, Hypocholesterolaemic Activity

Nowadays there are so many drastic diseases which are not good for our society, some diseases like cardiovascular disease which mainly cause by high plasma cholesterol level and high blood pressure. There are some macro algal like alginate, funoran, fucoidan, laminaran, porphyran and ulvan have been noted to produce hypocholesterolemic and hypolidemic response due to reduced cholesterol absorption in gut [55]-[57]. This is produce by the increase in the fecal cholesterol content and a hypoglycemic response [54] [98] [99]. Other have been reported causes lowering of systolic blood pressure also known as hypertensive response and lower the level of total cholesterol, free cholesterol, triglyceride and phospholipids in the liver [52]. A methanolic extract from *Pelvetia babingtonii* shows an inhibitory effect on α-glucosidase which could make it effective in suppressing postprandial hyperglycemia [100]. Ethanolic extract from *Solieria robusta*, *Iyengaria stellata*, *Colpomenia si-*

nuosa, *Spatoglossum asperum* and *Caulerpa racemosa* show hypolipidemic activities, as a result shown decrease in the serum total cholesterol, triglyceride and low density lipoprotein cholesterol level in rats [101]. Nutraceutical companies most likely to be exploited these substances or mainly the fibers and market them as health product.

3.6. Enzyme Inhibitors and Stimulants

In human the phospholipase A_2 is secreted known as PLA_2, it involve in variety of inflammatory disease via the production of archidonic acid by the precursor of prostaglandins and leukotriene [102]. The Phospholipase A_2 therefore used to act as target for the class of anti-inflammatory drugs and that's why researcher mainly focused on this group of enzyme. There are many compounds which show active against phospholipase A_2, they are rhiphocephalin a linear sesquiterpene from *Rhipocephalus phoenix*, caulerpenynesesquiterpene from *Caulerpa prolifera*; cymopol, cyclocymopol, prenylated bromohydroquinones from *Cympolia barbata*; an acetylene containing fatty acid derivative from liagora farinose; a macrocyclic enol-ether from *Phacelocarpus labillardieri*; and stypoldine, an orthoquinine from *Stypopodium zonale* [103]. Fucoidan also known for several activities but one of its important activities is that it inhibits cytotoxic and myotoxic activities of PLA_2 myotoxins from crotaline snake venom that result in muscle necrosis caused by snake bite [104]. Extract from *Caulerpa taxifoliahas* been purified to work as inhibitor for pancreatic lipase [105].

4. Brown Seaweeds

Although thousands of year the nutritional and medicinal benefits of seaweeds are known but the health benefits on scientific basis has been established recently. Brown seaweeds are usually brown in color having a photosynthetic pigment and are classified in the division of Heterokontophyta and class Phaeophyceae. This group contain many properties and mainly founded along rocky shores and shallow water environment, these algae mainly attached to the rocks or other firm surface. Morphology of this group of algae varies dramatically with size and species range. Brown seaweeds are mainly produced in intertidal shallow and deep sub tidal reefs. Some species of brown seaweeds are grazed by herbivores invertebrates and fish while other producing compounds which protect it from grazing. Brown seaweeds also produced organic material released in water column as dissolved compounds and particulate fragments and these become food sources for bacteria and species feeding on detritus as well as suspension feeding invertebrates. Brown seaweeds are also produce swimming spores but the dispersal abilities of most of the brown seaweeds are unknown. It is also been studied that it appears that spores and gametes settle relatively quickly. Brown algae are also used in commercial products in human food like in sea vegetable, dietary supplements, food garnish, salt substitute, in seaweeds based fertilizers as well as polysaccharide alginate.

4.1. Uses of Brown Seaweeds

Brown seaweeds are mainly used in conditions like hypothyroidism, Fatigue, Cellulite, Cough, Asthma, Hemorrhoids, Stomach ailments, Headaches. Brown seaweeds also used to promote weight loss as well as aid in skin care [106]. Brown seaweeds extract of *Laminaria japonica* (Kombu) shows a strong anticancer activity and decreases the expansion of cancer. Regular use of *Laminaria japonica* inhibit the risk of the breast cancer considerably [107].

4.2. Benefits of Brown Seaweeds

Benefits includes cancer prevention, reduced inflammation and blood thinning [108]. Some types of brown seaweed can be consumed as a food (in salads, soups, and stir-fries, for instance). Although brown seaweed is also available in supplement form, there is limited scientific evidence to support the use of brown seaweed supplements. Brown seaweeds show antiviral activities from sulfated fucans from *C. indica* against herpes simplex virus 1 and 2 without cytotoxicity for vero cell cultures [109]. Stypoldione, acytotoxiccompounds derived from *Stypodiumzonale*, inhibits microtubule polymerizationand sperm motility [110].

4.3. The Brown Pigment

The brown colour of brown algae is due to presence of green pigment (chlorophyll a and c) and the brown fu-

coxanthine. The seaweeds which live in deep water absorb different wavelength of light due to the presence of these different types of pigments and manufacture their food by the process of photosynthesis. Laminarin, a unique type of starch, is produced in brown algae [111].

4.4. Examples of Brown Seaweeds

4.4.1. Kelp

Sea bamboo (*Ecklonia maxima*), the spilt fan kelp (*Laminaria pallida*) and the bladder kelp (*Macrocystis angustifolia*) are three common species of kelp found in the west coast of South Africa. The stipes or stem of Kelp has the strengthening tissue and tubular cells to transport the food through the plant. To deter herbivores, the blades of the kelp have a protective outer layer, starch and tannin containing storage tissue and pigmented photosynthetic cells [111].

4.4.2. Dictyota Group

Plants are thick green and dichotomously branched, also known as flat forking branches. Dictyopteris species are similar but the blades have a central midrib [111].

4.4.3. Wracks

Wracks are also known as carpets of hanging wracks. The tough cylindrical axes hang from creeping holdfasts. The wracks are related to the common seaweeds *Fucus*. *Splachnidium rugosum*, aptly called the dead-man's fingers, has spotted, elongated, cylindrical branches. These branches sometime filled with clear viscous mucilage, this mucus enables it to withstand a high degree of desiccation stress [111].

4.4.4. Zonaria Group

It is a fan shaped brown seaweeds grow from a meristem along the rim of the fan. They are especially common along the east coast of South Africa, where delicate light brown turkey tails, Padina boryana, cluster shallow in mid tide pools, and the large more flexible *Zonaria* and *Stypopodium* species occur low on the shore erosion [111]. Brown seaweeds are mainly rich in iodine. Tablets of Kelp are used to treat goiter. Dried Kelps are used for the extraction of alginic acid. Alginic acid gel widely used as stabilizers and emulsifiers in ice creams, tooth paste, cosmetics and thousands of products. Alginic acid used to remove radioactive strontium the body. Insoluble alginate salts are as waterproof purposes for tiles and seal fine paper [111].

4.4.5. Anti-Viral Activity

The brown seaweed *Adenocystis utricularis* (family Adenocystaceae, order *Ectocarpales sensu lato*) are known to produce different polysaccharides namely fucoidans. The analytical features indicate that two different types of fucoidans (namely galactofucan & uronofucoidans) are present in this seaweed. The galactofucans show a high inhibitory activity against herpes simplex virus 1 and 2, with neither anticoagulant nor antibacterial properties, whereas the uronofucoidans have a very slight inhibitory action against herpes virus. Furthermore, an increased antiherpetic activity is shown by galactofucans with an increase in sulfate content. Hence the degree of sulfation and molecular weight are some important factors for antiviral activity. Some galactofucans fractions obtained from *A. utricularis* have antiviral activity against wild type and drug resistant HIV-1 strains [112].

4.4.6. 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 [113]. Hydrolyzed fucoidan from sporophyll of *Undaria pinnnatifida* 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 be significantly enhanced by lowering the molecular weight, only when they are depolymerized by mild condition [114].

5. Red Algae

There are thousands of red algae found along the coast of South Africa. Some of the algae are flat some are

branched, blood red sheets but majority are succulent. Red algae seaweeds are basically from phylum rhodophyta, that are different from other seaweeds due to presence of red and blue pigment, phycocyanin and phycoerythrin, in addition to chlorophyll a. The red and blue pigment in this seaweeds make a great advantage so that it absorbs blue-green light in deep water by passing the energy to the chlorophyll for food production by photosynthesis. Red algae live in both high on the shore and at great depth. Algae that are present in deep water having the red pigment but the algae present in inter tidal water having the yellowish, reddish brown or almost black pigment, that's why many of red algae are confused of brown algae that are yellow brown in color. The red algae palatable and provide the staple diet for many of the marine herbivores, such as mollusks, crustaceans and fish. The food reserve is Floridian starch. Red algae is also a source of agar, a gelling substance, it is used as economic importance in confectionary and as a growth medium for bacteriological studies. Due to a diverse range of plant forms & a variety of life cycles, there are many different species of red algae.

5.1. Adapted Condition

The seaweeds are adapted themselves for different types of physical stresses they encounter where they live. Those living high on the shore are adapted to withstand severe desiccation during low tide and are often large and flat to absorb the maximum nutrients and sunlight for photosynthesis than they are submerged. The agar component enables them to retain water and reduce drying out. Some red seaweeds grow epiphytically on kelps and held up themselves to the sunlight & delicately branched to flow with water as the kelps sway in the waves.

5.2. Examples of Common Red Seaweeds

5.2.1. Purple Laver

Porphyra capensis is a fast growing membranous seaweed, when dried looks like crumbled black plastic. When the tide raises the fronds expands and soften by absorbing water into the mucilaginous layer between the cells. The female plants and male plants have pink and yellow edges repectively, from which gamete released. *Porphyra* used as a food or somehow in the diet and also used for making laverbread, a traditional Welsh dish.

5.2.2. Slippery Orbits

Aeodes orbitosa is a tough, flat, slippery, leaf-like seaweed. Color varies from yellow-brown to reddish-brown. *Iridea capensis* forms brown strap-shaped blades with dark spots when fertile. Unlike *Aeodes* it has a rough texture and is not slippery.

5.2.3. Hedgehog Seaweeds

Notogenia stiriata varies in colour from yellow-brown to almost black and occurs on sheltered rocks. It consists of elongated leaf-like blades which becomes tough and leathery when wet, and papery when dry. The blades bear tuft-like out growths which appears like hedgehog. The gametophytic phase of life cycle is covered with small, branched outgrowths while the tetrasporophyte is usually fairly smooth with a few papillae along the margin. When held to the light, the dark spots indicate the pockets of four spores (tetraspores) [115].

5.3. Anti-Viral Activity

5.3.1. Anti-Viral Activity of Sulfated Galactans from the *Gymnogongrus griffithsiae* and *Cryptonemia crenulata*

Sulphated galactan crude extract and main fraction obtained from the red seaweeds *Gymnogongrus griffithsiae* and *Cryptonemia crenulata* show the anti-viral activity against herpes simplex virus type 1 (HSV-1) and 2 (HSV-2). The galactans lacked cytotoxic effects. These compounds causes the inhibitory effect on virus adsorption. Sulfated galactans treatment provides a significant protection against a murine vaginal infection with HSV-2 [116].

5.3.2. The Antiviral Activity of Sulfated Polysaccharides

The sulfated polysaccharides kappa carrageenan *G*3*d* and the dl-galactan hybrid *C*2*S*-3, obtained from the red seaweeds *Gymnogongrus griffithsiae* and *Cryptonemia crenulata*, were assayed for their antiviral properties against the four serotypes of dengue virus (DENV) in different host cell types. These sulfated polysaccharides

were selective inhibitors of DENV-2 multiplication in Vero cells with inhibitory concentration 50% (IC50) values around 1 µg/ml.

5.3.3. Antiviral Activity of Polysaccharides from *Gracilaria corticata*

Chemical analysis shown that that Polysaccharide extracted from *Gracilaria corticata* having most of the sulphate groups are alkali labile and are located at c-4 of the 1,3 linked D-galactose units and c-6 of the 1,4 linked L-galactose residues. The high molecular weight galactan sulfate inhibit the initial virus attachment to the host cell and hence causes selective antiviral activity against herpes simplex virus types 1 and 2 [117].

5.4. The Anti-Cancer Activity

Champia feldmannii (cf-pls) does not show any *in vitro* cytotoxicity at the experimental exposure but showed *in vitro* anti-tumor effect. Cf-pls acts as immunomodulatory agent, raising the production of specific antibodies, and increasing the production of ovaspecific antibodies. Cf-PLS has some interesting anticancer activity that could be associated with its immunostimulating properties [118].

6. Green Algae

The green algae are common inhabitants of both salt and fresh water. Green algae belong to the Phyllum Chlorophyta are green in color due to the presence of the chlorophyll a and b, manufacture their own food by photosynthesis. Animals depend on algae for food.

6.1. Life Cycle of Green Algae

Most seaweeds have at least two alternate generation during their life cycle. An asexual spore producing generation or the sporophyte produces many spores, which settle and grow into male and female gametophytes. The gametophytes produces gametes. The male and female gametes fuse during fertilization and the resulting zygote develops into a new sporophyte generation. The gametophyte are haploid while the sporophyte are diploid. In case of *ULVA* the sporophyte and the gametophyte look alike.

6.2. Examples of Green Seaweeds

6.2.1. Flat Sheet with One or Two Cells Thick (Order Ulotricales)

Sea lettuces (*Ulva* and *Monostroma* species) and Intestine weeds (*Enteromorpha* species) are common in estuaries. They are able to tolerate a wide range salinities. The spores are formed along the edges of the fronds and are released on the rising tide. The spores are dispersed by the waves to colonize new areas. Sea lettuces are widely eaten & a potential future source of food for South Africa.

6.2.2. Filaments of Cells End to End (Order Cladophorales)

Chaetomorpha species and *Cladophora* species, the unbranched & branched hair weeds respectively germinate like tufts of grass on the side of pools. They flow with the movement of the waves and are not easily broken. Their spores are released from the tips of the hairs.

6.2.3. Complex Green Seaweeds (Order Siphonales)

The green seaweeds comprise of fine branching tubes having many nuclei and almost negligible cross wall. These green sea weeds also contain some kind of chemical that causes hindrance in herbivores growth. Three green seaweeds the wedge weed, *Halemeda cuneata*, having flattened calcified green discs, green fans, *Udotea-rientallis* and the black-green bubbles of *Valonia macrophysa*are found on the east coast of South Africa [111].

6.3. Anti-Viral Activity

6.3.1. Antiviral Activity of *Gayralia oxysperma*

A homogeneous sulfated heterorhamnan was obtained by aqueous extraction, then by ultrafiltration, from the green seaweed *Gayralia oxysperma*. Besides α-l-rhamnose it contains glucuronic, galacturonic acids, xylose and glucose. The heterorhamnan backbone is constituted by 3 and 2 linked rhamnosyl units, the latter being ~50%

substituted at C-3 by side chains containing 2-sulfated glucuronic and galacturonic acids and xylosyl units. The 3 and 2 linked rhamnosyl units are unsulfated (20%), disulfated (16%), and mostly monosulfated at C-2 (27%) and C-4 (37%). The branched and sulfated heterorhamnan had high and specific activity against herpes simplex virus [119].

7. Conclusion

The seaweeds and sea grasses are one of the vital components of all ecosystems. So, the studies based on them have become the most important aspect as they are highly productive and play a vital role as nursery grounds for many commercially important species. Seaweeds also used in medical purpose as well as used as food supplements. The chemical means of this macro algae can overcome many problems of human like drastic disease as well as invent new technologies like natural anti-foulants, and UV-sunscreens. Perhaps this review touch the main points of the important bioactive metabolites, as well the antiviral and anti-cancer property of the seaweeds in detail, there are also many bioactive metabolite or compounds which are still a mystery and researchers are tries to find out all the important compounds to help the human welfare. Seaweeds are also rich source of iron and other minerals which are important for our normal body function.

8. Future Directions

In future seaweeds will be useful in various ways and that will be benefit for human welfare. Seaweeds are used to curevarious drastic diseases like herpes simplex virus, AIDS, malaria and many others. Seaweeds may be used in future as immunomodulatory, anti-viral, anti-biotic, anti-inflammatory as well as anti-tumor.

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