Bioactive Compounds Derived from Microalgae Showing Antimicrobial Activities

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Abstract

Microalgae have been explored for their bioactive compounds with promising applications encompassing antibacterial, antiviral, antifungal and antialgal activities. Considering the present status of widely used treatment therapies and their limitations to tackle their adverse effects, the application of bioactive compounds derived from algae will prove beneficial and much more effective as compared with traditional treatment methods. Due to the emerging infectious diseases, viral infections (epidemic and pandemic) and raise in antibiotic resistant bacteria, there is an urgent need for development of alternative treatment therapies against infectious diseases. Present work provides a brief introduction about the algal bioactive compounds and their activities against various pathogens.

Keywords: Microalgae; Antibacterial; Antifungal; Antiviral; Antimicr algal

Introduction

Algae has wide span of ecosystems contributes to the innumerable chemical compounds that they are able to synthesize. A number of antimicrobial compounds have been identified in microalgae as well as macroalgae [1]. More than 18,000 new compounds have been isolated from marine sources, yet majority of them have not yet been obtained nor characterized [2]. Therefore, microalgae represent a unique opportunity to discover novel metabolites. The rate of finding metabolites already obtained from other biological sources is less in microalgae as compared with other microorganisms [3]. Due to their metabolic plasticity under stressed vs. nonstressed conditions microalgae possess the extra advantage of triggering secondary metabolism [4]. As microalgae where potentially explored only after 1950s, they were not considered previously for therapeutic purposes. Extensive search is presently undergoing to find novel therapeutically useful agents [5-7]. Microalgae have meanwhile been found to produce antibiotics. A large number of microalgal extracts and/or extracellular products have proven antibacterial, antifungal, antiprotozoal and antiplasmodial [6-13]. Efforts to identify the compounds directly responsible for those antimicrobial features have been made, but are still embryonic.

We have been working with algae like Chlorella and Chlamydomonas (Figure 1) isolated, maintained and extracted as described by Salem et al. [14]. These extracts were later used for antibacterial assay and determination of minimum inhibition concentration (MIC). Antibacterial activity of algal extracts determines the MIC of algae used in this study in vitro [14].

Algal cell-free extracts are already being tested [15-17]. Our aim is to provide information about the recent trends in the discovery of bioactive compounds derived from algae which have shown their potential as antimicrobial agents. We have briefly summarized the recent works carried out by the researchers globally in the field of algal antimicrobial activities.

Antimicrobial activities of algal extracts

Antibacterial activity of algae: The needs for development of alternative antibiotic agent were investigated since the emergence of antibiotic resistant microbes. Due to the emergence of drug-resistant pathogens they endanger people in affluent, industrial societies like the United States, as well as in less-developed nations.

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Examples of clinically important microbes that include *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* or *E. coli* and infections transmitted healthcare malpractices enterococci, *Acinetobacter baumanii*, *Pseudomonas aeruginosa*, and *Klebsiella* spp [18]. The development in the field of algal therapeutic research has made it possible by their bioactive compounds which have been found effective against most of the pathogens (Figures 1 and 2). The list of some of the algal bioactive compounds is summarized in the Table 1 [19-24].

**Antiviral activity of algae:** The viruses have been the cause of mass epidemic and pandemic outbreaks of potentially harmful and deadly diseases like influenza, hepatitis, etc. Due to the unavailability of proper treatment facilities and precautionary measures they have been causing a great panic worldwide. Considering the present situation the discovery of antiviral compounds which were derived from algal bioactive compounds provide us a great relief. These compounds, which are tabulated in Table 2 [25-28] has a great prospective in the future.

A number of infectious diseases caused by viruses have re-emerged in recent years, new antiviral measures are necessary for those who are not exposed to them previously. Due to this microalgae have received a strong attention to be explored for potential antiviral agents [29].

**Antifungal activity of algae:** The study of resistance to antifungal agents has lagged far behind that of antibacterial resistance likely because fungi were not recognized as important pathogens [30,31]. The associated increase in fungal infections prompted search for newer and safer agents to combat fungal infections [32] and a few noteworthy results encompassing microalgae are listed in Table 3 [19,24,33].

### Table 1: Antibacterial activity of selected compounds from microalgae.

<table>
<thead>
<tr>
<th>Algal species</th>
<th>Extract source</th>
<th>Target bacteria</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pithophora oedogonium</td>
<td>Ethanol extract</td>
<td>Gram negative and Gram positive bacteria</td>
<td>[19]</td>
</tr>
<tr>
<td>Rivularia bullata, Nostoc</td>
<td>Methanol Chloroform</td>
<td><em>P. aeruginosa</em> (ATCC27853), <em>S. typhi-B, E. coli</em> (ATCC27860) (E. amylovora), Enterobacter aerogenes (MTCC111) (E. aerogenes), Proteus vulgaris (MTCC1771) (P. vulgaris), Klebsiella pneumonia (ATCC15380) (K. pneumonia) and E. coli (ATCC25922); gram-positive bacterial strains were Methicillin resistant S. aureus,</td>
<td>[20]</td>
</tr>
<tr>
<td>Sargassum wightii, Chaetomorpha</td>
<td>Acetone, methanol</td>
<td>Vibriod algirionidys, Vibrio vulnificus and Aeromonas salmonicida subsp. salmonicida Photobacterium damselae subsp. Damselae and Photobacterium damselae subsp. piscicida, Salmonella sp., Vibrio cholerae, Vibrio harveyi and Vibrio para-haemolyticus</td>
<td>[21]</td>
</tr>
<tr>
<td>Chlorococum humicola</td>
<td>Bioactive compounds</td>
<td>Escherichia coli, Pseudomonas aeruginosa, Salmonella typhimurium, Klebsiella pneumonia, Vibrio cholerae, Staphylococcus aureus, Bacillus subtilis, Candida albicans, Aspergillus niger and Aspergillus flavus.</td>
<td>[22]</td>
</tr>
<tr>
<td>Gloeocapsa sp. Synechocystis sp.</td>
<td>Ethanol extract</td>
<td>Staphylococcus aureus 209, Streptococcus pyogenes 981, Bacillus cereus 2421 Escherichia coli 3702, Pseudomonas aeruginosa 1396, Salmonella typhimurium 123, and Yersinia enterococcolitha 623</td>
<td>[23]</td>
</tr>
</tbody>
</table>

### Table 2: Antiviral activities of selected compounds from microalgae.

<table>
<thead>
<tr>
<th>Algal species</th>
<th>Extract source</th>
<th>Target virus</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haematococcus Pluvialis and</td>
<td>Pressurized liquid</td>
<td>Herpes simplex virus type 1</td>
<td>[25]</td>
</tr>
<tr>
<td>Dunaliella salina</td>
<td>extraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyrodinium Impudicum (sulfated</td>
<td>Sulfated polysaccharide</td>
<td>Influenza virus</td>
<td>[26]</td>
</tr>
<tr>
<td>polysaccharide, p-KG03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navicula directa</td>
<td>Polysaccharide</td>
<td>HSV1 &amp; 2, Influenza A virus</td>
<td>[27]</td>
</tr>
<tr>
<td>Gyrodinium impudicum p-KG03</td>
<td>exopolysaccharides</td>
<td>Encephalomyocarditis Virus</td>
<td>[28]</td>
</tr>
</tbody>
</table>

### Table 3: Antifungal activities of selected compounds from microalgae.

<table>
<thead>
<tr>
<th>Algal species</th>
<th>Extract source</th>
<th>Target fungi</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pithophora oedogonium</td>
<td>Ethanol extract</td>
<td>Penicillium vindaticum 1101, Fusarium solani 1127</td>
<td>[19]</td>
</tr>
<tr>
<td>Gloeocapsa sp.</td>
<td>Exopolysaccharides</td>
<td>Candida albicans</td>
<td>[24]</td>
</tr>
<tr>
<td>Haematococcus Pluvialis</td>
<td>Butanoic acid and methyl lactate</td>
<td></td>
<td>[33]</td>
</tr>
</tbody>
</table>
However, Pratt [36] was the first to report that growth of C. vulgaris was depressed by a compound (chlorellin) that was produced and excreted into the medium - and several other extracellular metabolites able to inhibit their own growth and the growth of other species have meanwhile been reported [37].

Antiprotozoal and Antiplasmodial activity of algae: The antiprotozoal activities algal extracts have recently been discovered against Trypanosoma brucei rhodesiense, Trypanosoma cruzi and Leishmania donovani and were found effective. The development of antiprotozoal algal extracts may prove effective in controlling various protozoan diseases and their preventive measures [38]. The crude seaweed extracts from green marine algae Cladophora rapestris, Codium fragile sp. tomentosoides, Ulva intestinalis and Ulva lactuca have shown anti protozoan activity against Trypanosoma brucei rhodesiense, Trypanosoma cruzi, Leishmania donovani [39]. Clau et al. [40] studied the antiprotozoal activity of brown alga Lobophora variegata against Giardia intestinalis, Entamoeba histolytica and Trichomonas vaginalis. They have extracted antiprotozoal compound by chloroform, the major compounds included -O-palmitoyl-2-O-myristoyl-3-O-(6''-sulfo-a-D-quinovopyranosyl)-glycerol, 1,2-di-O-palmitoyl-3-O-(6''-sulfo-a-D-quinovopyranosyl)-glycerol and a new compound identified as 1-O-palmitoyl-2-O-oleoyl-3-O-(6''-sulfo-a-D-quinovopyranosyl)-glycerol [40]. The ethanolic extracts of freshwater macrophytes Potamogeton perfoliatus, Ranunculus crispus and Cladophora glomerata as well as marine macroalgae Dictyota dichotoma, Halopteris scoparia, Posidonia oceanica, Scaiaua furcellata, Sargassum natans and Ulva lactuca are assayed for their in vitro antiprotozoal activity against Trypanosoma brucei rhodesiense, Trypanosoma cruzi, Leishmania donovani and Plasmodium falciparum [41].

Trypanosomiasis is one of the most important parasitic diseases worldwide. The undesirable side effects and low efficacy of classical trypanocidal drugs underline the necessity of the development of new drugs from natural products. Although marine algae have been recognized as attractive sources of known and novel bioactive compounds, very little research has been focused on antiprotozoal activity. Aqueous and organic extracts of Rhodophyta, Phaeophyta and Chlorophyta were evaluated for their antiprotozoal activity in vitro against Trypanosoma cruzi trypomastigotes. The organic extracts from Dictyota carieba, Lobophora variegata, Turbinaria turbinata Linnaeus, and Laurencia microcladia Kützing possess promising in vitro activity against T. cruzi trypomastigotes. Laurencia microcladia is effective against Artemia salina and the high cytotoxicity exhibited by T. turbinata is required to be investigated further [42].

Red alga from genus Chondria produces cyclic polysulfides, terpenoids, amino acids and amines. Domic acid derivatives from Chondria armata show larvicidal and blood pressure lowering activity [43]. The algal extracts have also been explored for their antiplasmodial activities, [38]. The P. falciparum (Erythrocytic stages), T. cruzi (Trypomastigotes) and L. donovani (Axenic amastigotes) are growth inhibited with the ethanol and ethyl acetate extract of algae belonging to Chlorophyta, Heterokontophyta and Rhodophyta. Antimalarial leads from marine algae, four metabolites, sargarquinic acid, sargahydroquinic acid, sargarquinical and fucoxanthin, were isolated from the Sargassum heterophyllum. Fucoxanthin and sargualin showed good antiplasmodial activity toward a chloroquine-sensitive strain of Plasmodium falciparum [44] Ethylacate (EtOAc) extract of Sargassum swartzii and Chondria dasypylla were investigated for larvicidal activities in larvae of malaria vector Anopheles stephensi and the mortality rate of Anopheles stephensi was 96 and 95%, respectively [45]. The endemic marine red alga Plocamium cornutum (Turner) Harvey show antimalarial activity in organic extracts. Interestingly, compounds bearing the 7-dichloromethyl substituent showed significantly higher antimalarial activity toward a chloroquine sensitive strain of Plasmodium falciparum [46].

Conclusion

We have screened the antibacterial activities of organic extracts of isolated culture of algal species and had evaluated them by agar well diffusion method. Methanol extract and ethyl acetate extract of algae were effective against few bacterial species including Staphylococcus spp. and E.coli. Methanol extracts were more effective as compared with ethyl acetate extract of alga. The antibacterial and antifungal activities were seen predominantly from the chlorella sp. as well as Chlamydomonas sp. Our work clearly summarizes the importance of microalgal extracts which have potential implication as antibacterial, antiviral, antifungal, antimicroalgal antiprotozoal as well as antimalarial agents. This information can prove very helpful in further research and discovery of new drugs. The work briefly explains the work carried out by various researchers by clearly elaborating the important implications of algal bioactive compounds for the application against infectious diseases and as an antimicrobial therapy.

References


