THERAPEUTIC POTENTIAL AND NUTRACEUTICAL PROFILING OF SOUTH INDIAN SEAWEEDS: A REVIEW

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Abstract

Seaweeds with their widespread use in the food and feed industries, they are untapped as a nutracueutical and medicinal products despite their significant antioxidant properties. South Indian coast provide a suitable environment for the luxuriant growth of diverse species of seaweeds. Some of the economic important species are Gelidiella acerosa, Gracilaria edulis, Gracilaria crassa, Gracilaria verrucosa, Sargassum sps. and Turbinaria sps. In addition, seaweeds are the chief sources of commercially important agar, carrageenan and alginate. The diverse bioactive components of seaweeds and their nutritional, pharmacological and industrial applications for human welfare have been focus of this review.

Key words: Pharmacology, Seaweeds, Therapeutic potential

Introduction

The use of plants as medicines has a long history in the treatment of various ailments (Prakash et al., 2008; Kingston et al., 2009; Jeeva and Femila, 2012; Rasingam et al., 2012; Sukumaran et al., 2021). The use of seaweeds as traditional food and complementary medicine was recorded in early archeological data of ten thousand years back. They are traditionally consumed in many Asian countries like China, Indonesia, Philippines, South Korea, North Korea, Japan and Malaysia for centuries; however the culinary use of seaweed started in Japan and China (Bocanegra et al., 2009). Nowadays, particularly of seaweed has become a more versatile form of a food ingredient that can be incorporated directly or indirectly in the preparation of food and beverages. Due to it’s functionally seaweed and its products are of particular importance in the food industry as components in fertilizers, animal feed supplements and addictives for functional foods (Rajauria et al., 2015). They are low calorific food but rich in vitamins, minerals and essential trace elements, polyunsaturated fatty acid, bioactive metabolites, proteins, polysaccharides and dietary fibres. A part from regular consumption, many studies advocated the health benefits of seaweed supplementation alongside a regular diet. Regular consumption of seaweed effectively reduced the depressive symptoms among pregnant Japanese woman as well decreased the risk of suicide in adults (Miyake et al., 2014; Nanri et al., 2013). They are also utilized as hydrocolloids, as emulsifier and as gelling agents in various food product preparations (Miyake et al., 2014). In addition to benefits of regular consumption of seaweed in diet, the medicinal properties of seaweed bioactive have been historically recognized. For example, seaweeds are used for treatment and or for prevention of goitre, which is caused by the lack of iodine in the diet (Rosenfeld, 2000). Several studies have shown various remedial effects of algal species against non-
communicable disease such as inflammation, obesity, diabetes, hypertension and viral infections (Rajauria et al., 2016). Besides its extensive medicinal properties, seaweeds are recognized for its antioxidant capacities and bioactive polyphenolic compounds (Stephens et al., 2017). Studies have also demonstrated potential roles in HIV protection, primarily linked with compounds present in algae such as phlorotannins, sulfated polysaccharides, certain diterpenes and lectins (Nagarajan and Mathaiyan, 2015). Though some evidence suggests that the effect of bioactive compounds on the human body is moderate and may last over relatively short periods but they could contribute significantly if consumed routinely as part of the daily diet (Wang et al., 2019). Therefore, to facilitate discussion on this issue, this review focuses on the therapeutic role of seaweed-derived compound as a nutraceutical or functional food ingredients for health maintenance and disease prevention

**Therapeutic potential of seaweeds**

Seaweeds are therapeutically one of the most important marine natural resources and used by human beings in various forms such as food and fodder as early as 2500 years ago in Chinese literature (Tseng, 2004). Globally, 7.5-8 million tons of wet seaweeds are being produced every year (MCHugh, 2003). Antioxidants compounds play an important role to prevent health from harmful factors. It is known that seaweeds contain several bioactive compounds with potential higher antioxidant activity as compared to the terrestrial plants due to the presence of up to eight interconnected polyphenol rings (Sullivan et al., 2011). Antioxidant activity of seaweeds as due to the presence of pigments chlorophyll, xanthophylls (Fucoxanthin), carotenoids, leutein and zeaxanthin, phenolics, lignin, tocopherols, tannins and phenolic acid and hydroganones, phospholipids particularly peptides and other antioxidative substance which directly or indirectly contribute to the inhibition or suppression of oxidation process (Shahidi, 2009; Jeeva et al., 2012; Joselin et al., 2012; Kong et al., 2012; Farvin and Jacob, 2013; Domettila et al., 2013; Joselin et al., 2013; Sathya et al., 2017). The economic potential of the seaweeds may be dealt under the following major heads (Table 1).

**Seaweeds in food industry**

Several seaweeds are widely used as foods. In India, however seaweed consumption is negligible, but due to the importance of seaweeds and their derived product as nutraceuticals the seaweed derived food supplement is gaining importance in the market (Mohapatra, 2013). The uses of seaweeds in the form of food are well known in many Indo-pacific countries since long ago. Many of the South East Asian countries like China, Japan, Thailand, Korea etc have started large scale utilization of seaweeds for food industry. Seaweeds are rich in both minerals and trace elements (Chapman, 1970) and contain good quality of fibers and minerals which help in improving the mineral content. In Indian perspective, around 30% of the populatives close to the coast, the uses of seaweeds in the form of food are still limited. Therefore seaweed eating has not become habituated in the Indian food systems at large scale (Gansen et al., 2019). As the population is increasing rapidly and the agricultural lands are shrinking.

**Seaweeds as fodder**

Seaweeds have been used historically in Agriculture since long time. Today it is being used as Animal feed on large scale in a number of countries like Iceland, Norway and other European countries. Many seaweed based factories in the countries to dry and grind it into the form of cattle feed. Seaweeds are the rich source of macronutrients (particularly dietary fiber and micronutrients and used to enhance the nutritional quality of animal feed (Michalak & Mahrose, 2020). Some of the common seaweeds as fodder and found along the Indian coast are Monostroma, Ulva, Bryopsis, Caulerpa, Padina, Sargassam etc.
Industrial applications of Seaweeds

Seaweeds are the natural sources of raw materials for many of the industries. They are the only sources of thickening agents and gels (Phycocolloids) like agar-agar, algin, carrageenan, etc and widely used in various biochemical industries (Mantri et al., 2019). Three major phycocolloids are Agar-Agar, Alginates and Carrageenan. Agar, Agarose and Carrageenan are mainly extracted from red seaweeds like Gelidium, Gelidiella, Gracilaria, etc. Similarly Alginate also known as Algin or Alginic acid is a polysaccharide and is mainly extracted from the brown seaweeds like Sargassum, Turbinaria, Cystocea, Dityota, Padina, Colpomenia, Spathoglossum, Stoechospermum, etc (Anantharaman and Balasubramanian, 2010).

Table 1. Economically Important South Indian Seaweeds

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the seaweed taxa</th>
<th>Economic Importance</th>
<th>References</th>
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<tbody>
<tr>
<td>1</td>
<td>Ulvella lens P. Crouan &amp; H Crouan</td>
<td>Fodder (Aquaculture)</td>
<td>Hanon et al., 2014</td>
</tr>
<tr>
<td>2</td>
<td>Ulva compressa L.</td>
<td>Edible, Fodder, Medicinal (Antioxidant activity)</td>
<td>Kaliaperumal et al., 2014</td>
</tr>
<tr>
<td>3</td>
<td>Ulva lactuca</td>
<td>Edible, Fodder, Medicinal</td>
<td>Shyna et al., 2014</td>
</tr>
<tr>
<td>4</td>
<td>Chaetomorpha antennina</td>
<td>Medicinal, Paper industry</td>
<td>Jha et al., 2009; Abhishek et al., 2018</td>
</tr>
<tr>
<td>5</td>
<td>Cladophora prolifera (Roth) Kutz</td>
<td>Edible, Fodder</td>
<td>Shyna et al., 2014</td>
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Phaeophyceae

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<tbody>
<tr>
<td>6</td>
<td>Sargassum ilicifolium (Turner) J. Agardh</td>
<td>Medicinal (Immunomodulatory activities)</td>
<td>Simpi et al., 2013</td>
</tr>
<tr>
<td>7</td>
<td>Sargassum tenerrum J. Agardh</td>
<td>Edible, Manure, Industrial (Agaroid)</td>
<td>Kaliaperumal et al., 1995</td>
</tr>
<tr>
<td>8</td>
<td>Sargassum wightii Grev.</td>
<td>Edible, Fodder, Industrial (Algin)</td>
<td>Kaliaperumal et al., 1995; Sobha et al., 2008</td>
</tr>
<tr>
<td>9</td>
<td>Turbinaria conoides (J. Agardh) Kutz</td>
<td>Industrial (Algin)</td>
<td>Kaliaperumal et al., 1995</td>
</tr>
<tr>
<td>10</td>
<td>Turbinaria ornata (Turner) J. Agardh</td>
<td>Edible, Industrial (Agaroid)</td>
<td>Kaliaperumal et al., 1995</td>
</tr>
</tbody>
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Rhodophyceae

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</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Gelidiella acerosa (Forssk) J. Agardh Feldmann &amp; G. Hamel</td>
<td>Industrial (Agar)</td>
<td>Kaliaperumal et al., 1995</td>
</tr>
<tr>
<td>12</td>
<td>Gracilaria edulis (S.G. Gmel) P.C. Silva</td>
<td>Edible, Industrial (Agar)</td>
<td>Kaliaperumal et al., 1995</td>
</tr>
<tr>
<td>13</td>
<td>Gracilaria verucossa</td>
<td>Manure, Industrial (Agar)</td>
<td>Kaliaperumal et al., 1955; Shyna et al., 2014</td>
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Nutraceutical Profiling

It is predicted that global population will be virtually 10 billion people by 2050, up from 7.3 billion today (Ehrlich and Harte, 2015). Even the current population does not have enough food for healthy and active life. To solve this greater food demand many countries have started to explore alternative food sources including marine bioresources. Approximately 70% of the earth’s surface is covered by seas and oceans (Jimenez-Escrig et al., 2011). Marine organisms have high potential as source of compounds that can be applied in the food industry, cosmetic industry, nutraceutical and pharmaceutical industry and other industrially important compounds (Tanna and Mishra 2018). Seaweeds do not require extra fertilizer to grow and they absorb carbon dioxide from sea runoffs, giving them a carbon negative footprint. The growth rate of seaweeds is much higher than that of plants and other food sources. Seaweeds can be collected naturally but at this time are increasingly cultivated (Vallinayagam et al., 2009).

Proteins

Proteins are polymers of aminoacids which are bound together by peptide bonds (Figure 1). The protein composition and content of marine algae vary among species and depend on season and habitat (Pangestuti and Kim, 2015). Accordingly the nutritional value of seaweed proteins varies depending on the geographical location and environmental conditions (Kadam et al., 2017). It is well established that brown seaweeds contain the least protein while moderate concentration of protein are reported from green seaweeds and the highest content is estimated in red seaweeds (Ganesan et al., 2019). Seaweed proteins have been reported to have different biological activity such as hypertensive, antioxidant and antidiabetic effects (Admassu et al., 2018). The physiological activities of human body are affected by bioactive peptides which are part of food diet. In parent proteins, a short sequence of aminoacid is present in an inactive form, but they break in to short bioactive peptides during food processing, gastrointestinal digestion or fermentation and research suggests that these activated bioactive peptides have nutraceutical potential to promote human health (Wijesekara and Kim, 2010).

Figure 1. Structure of proteins

Polysaccharides

Seaweeds are considered as a source of novel and unique types of polysaccharides (Figure 2) having diverse applications (Tanna and Mishra, 2019). Monosaccharides linked together by glycosidic bonds results in the formation of polysaccharides, they may be homopolymers or heteropolymers depending on their monosaccharide composition (Stiger-Pouvreau et al., 2016). Polysaccharides have several important commercial applications including as thickeners, stabilizers, beverages, feed, emulsifiers, food, etc. (Tseng, 2001). Their low calorific value makes seaweeds nutritionally important (Pereira, 2011). Another widely explored polysaccharide, laminarin
commonly obtained from brown seaweeds, is made up of β (1-3) linked side chains (O’Doherty et al., 2010). It has antibacterial and antiviral activity and also acts as a prebiotic. The antioxidant activity of laminarin depends on its chemical structure and molecular weight (Li and Kim, 2011). The importance of seaweed polysaccharides in industrial and biomedical applications has been proved (Cosenza et al., 2017).

Figure 2. Structure of Polysaccharides

Mineral contents

Seaweeds contain high concentrations of a wide range of diversified minerals due to their habitat (Figure 3). Most of the minerals required for human health such as potassium, sodium, phosphorous, calcium, iodine, magnesium, iron and zinc are present in sufficient quantities in seaweeds, thus they have the potential to be widely used health-beneficial supplements (Rao et al., 2007). A high mineral content has been reported in seaweeds, sometimes up to 40% of biomass (Kumar et al., 2011).

Figure 3. Structure of Minerals

Vitamins

Vitamins are important nutrients for achieving specific and essential functions of the body and are also essential for maintain health (Bellows et al., 2012). Seaweeds are rich in all essential and non-essential vitamins (Ganesan et al., 2019). Some seaweed possesses vitamins that have many health beneficial effects and antioxidant activity and thus reduce various health related problems including high blood pressure, cardiovascular disorders and the risk of cancer (Gupta et al., 2020). Seaweed consumption (about 100g/per day) gives more than the daily requirements of vitamins A, B2 and B12 and fulfils two-thirds of the vitamin C requirements (Ortiz et al., 2006).

Pigments

Pigments are lipid soluble polyenes and natural pigments not only function as factors providing color but also participate in many biological activities (Li and Kim, 2011). Pigments are widely found in seaweeds, plants,
invertebrates and mammals (Figure 4). Marine algae are potential sources of unique natural pigments (Pangestuti and Kim, 2015). Seaweeds contain three classes of pigments: Chlorophyll, Phycobiliproteins and carotenoids (Pereira et al., 2014). Seaweeds that are rich in pigments have potential to be used as dietary supplements (Holdt and Kraan, 2011). A number of studies have confirmed the antioxidant properties of seaweed carotenoids and their role in preventing diseases that are linked to oxidative stress (Okuzumi et al., 1993).

Figure 4. Structure of pigments

![Structure of pigments](image)

**Polyphenols**

Polyphenols are a group of chemical compounds consisting of a hybrid group (-OH) that is directly linked an aromatic hydrocarbon group (Figure 5; Mekinic et al., 2019). Seaweed polyphenols include flavonols, catechins and phlorotannins (Sathya et al., 2017; Gomez-Guzman et al., 2018). The antioxidant properties of seaweeds are highly affected by their polyphenols composition (Sathya et al., 2017; Martins et al., 2019). Polyphenol content also shows a significant temporal correlation with a reproductive state of seaweeds (Ragan and Jensen, 1978). Phlorotannins extracted from the brown seaweed inhibits adipogenesis by activating the AMP signal pathway (Ko et al., 2013). The flavonoids in green seaweed have therapeutical potential as type 2 diabetes suppressors (Domettila et al., 2013; Yan et al., 2019).

Figure 5. Structure of Polyphenols

![Structure of Polyphenols](image)
Fatty acids

Seaweeds contain low concentrations of lipids about 2-10% of their dry weight (Figure 6). It has also been noticed that tropical seaweed species have lower lipid concentrations than cold water algae (Holdt and Kraan, 2011). The most common lipids found in seaweed are phospholipids and glycolipids (Balic et al., 2020). Omega 3 and omega 6 fatty acids are essential for balanced human metabolic procedures and thus are important ingredients in the human diet. A hugely imbalanced omega 6/omega 3 ratio is the reason behind various health issues such as cancer and inflammatory, cardiovascular and autoimmune diseases (Simopoulos, 2016).

Figure 6. Structure of fatty acids

Conclusion

Seaweeds have been ascribed as potential sources of functional compounds derived from secondary metabolisms such as fucoxanthin, Phlorotannin, fucoidans, laminarin, carrageenan, alginate and agar. These compounds are widely used in food applications for various properties to improve the quality of food. The incorporation of seaweeds in food may solve health problems emerging as a result of protein, mineral and carbohydrate deficiencies. The bioactive compounds extracted from seaweeds provide multifold therapeutic activities (antitumour, anticancer, antithrombin, etc.) that make it essential to popularize the use of seaweeds in commercial food products as a natural source of antioxidants. Thus seaweeds are the potential marine living resources and integral part of the biodiversity. In addition to ecological and biological importances seaweeds have also immense economic potential in the form of food, fodder and also serve as raw materials for various industries.

References

References


