A review on phytoconstituents of marine brown algae

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Abstract

Background: From the last few years, the development and discovery of bioactive compounds and their potential properties from marine algae have been enhanced significantly. The coastal area is a huge storehouse for propitious algae. It has been the genuine reality that the consequence of marine algae as a source of different compounds is increasing.

Main body: Numerous advanced research devices are available for the discovery of synthetic compounds but still many researchers are working on natural bioactive compounds to discover their biological properties, which are useful to society. Marine algae are taking the preponderance of consideration from investigators owing to its phenomenon of biological activity like anti-cancer, anti-viral, cholesterol-reducing, and many more. A variety of compounds are collected from algae with specific purposes as they remain in an extremely ambitious and hard state; this condition is responsible for the synthesis of very particularly effective bioactive compounds. The present article is concentrating on the brown algae of the Gujarat coast, phlorotannins, polyphenol, phytosterol from brown algae, and their various applications. The main importance has been given to the secondary metabolites and various applications of marine brown algae.

Conclusion: From this review, it can be concluded that the prominent bioactive compounds from brown algae can cure many serious diseases. Besides, the potential biological activities of a special bioactive compound may represent the interest in the industry of pharmaceuticals, cosmeceutical, and functional foods.

Keywords: Marine Brown algae, Bioactive compound, Applications

Background

Seaweeds mean the varieties of macro algae available abundantly at sea or nearby areas which can be used commercially. Macroalgae/seaweeds are categorized as green algae (Chlorophyta), brown algae (Phaeophyta), and red algae (Rhodophyta) according to their pigmentation, nutritive, and chemical composition. Brown, red algae are mainly used in human nutrition as a source of many mineral elements, vitamins, protein, amino acids, etc. Brown algae are more abundant in a shallow rocky coastal area, especially when exposed at low tide. The vegetation of the algae provides an ideal habitat, food, and shelter for various animals. They act as epiphyte fauna. The holdfast of seaweeds binds the sediments together and prevents coastal erosion [1]. These are vast and various groups of organisms that play an important role in the marine ecosystem [2]. Marine algae have always aroused great interest in Asian culture as marine food sources [3]. Seaweeds come in an incredible variety of attractive shapes, color, and size, and are found in all the ocean of the world. In India, brown algae represent 0.2%, red algae 27.0%, and the other 72.8%. About 206 algae are reported in the mangrove environment [4].

Marine algae live in a harsh condition that promotes the formation of oxidizing agents and secondary metabolites [5], and these types of compound have the responsibility for specific biological activity [6]. A variety of chemically active metabolites in their body, potentially help to protect themselves against other organisms.
These active metabolites are also known as biogenic compounds, such as halogenated compounds, alcohols, aldehydes, and terpenoid, are produced by different species of marine micro and macro algae and have antibacterial, anti-algal, and anti-fungal properties that are effective in preventing biofouling and have other uses in therapeutics [1]. Sterols are the main nutritional component of seaweeds. Different species have different types of sterols, as green algae contain ucocholesterol, cholesterol, and β-sitosterol while brown algae contain fucosterol, cholesterol, and brassicasterol. Red algae have desmosterol, cholesterol, sitosterol, fucosterol, and chalnasterol [7, 8]. These properties make seaweeds more potential as a functional dietary supplement or for compound extraction. Seaweed extracts are rich in natural plant growth hormone and beneficial trace mineral. In algae extract, natural growth hormones like auxin, cytokines, and gibberellins are present in large quantities [9].

Brown algae were a huge and diverse class (Phaeophyceae) of golden-brown algae varying from small filamentous form to large/giant complex seaweed. The brown algae contain the fucoxanthin pigment and different pheophycean tannins that are responsible for the characteristic greenish-brown color like the name indicated. Brown algae also provide a number of active components including unique secondary metabolites such as phlorotannins and many of them have specific biological activities that offer opportunities for their economical use [10].

The major orders found worldwide are fucales, dictyotaless, and laminariales, these three orders are extensively used for bioactive compounds. More than 1140 secondary metabolites have been reported in phaeophyceae [11]. The different species of dictyotaless group produce a wide range of bioactive secondary metabolites with broad defensive action against herbivores in the marine environment [12]. Among the three marine algae group, brown algae have an immense source of polysaccharide namely alginate and fucoidans, which reveals good biological activities such as anti-cancer, anti-viral, anti-inflammatory, and anti-proliferative [1]. Bioactive compound fucosterol abundantly reported in brown algae and has so many biological activities such as anti-cancer [13], cholesterol-reducing [14], and anti-diabetic properties [15]. Brown algae are mainly used in different conditions such as hypothyroidism, cough, asthma, fatigue, stomach pain, hemorrhoids, and headache. It has been also used to promote weight loss and help in skincare [16]. There are various benefits of brown seaweed including reduced inflammation, blood thinning and cancer prevention [17]. Brown algae consist of a significant level of phenolic compound, a complex type of polysaccharide, extremely high biological activity, and more effective antioxidant compared to green and red algae [18]. Therefore, the objective of the present review is to focus on the distribution of brown algae along the coast of Gujarat, its bioactive compounds, and the bioactivity of isolated compound from it.

**Distribution of brown algae**

Eighty percent of the world’s plant diversity has been recorded only in the aquatic environment, including over 150,000 species of algae found in intertidal zones and tropical waters of the seas, and it is the main source of natural products [19]. There are approximately 8000 species of marine macroalgae discovered on the world’s coastlines, and they can exist up to 270 m deep. A total of 25 species of green algae, 90 species of brown algae, and 350 species of red algae are found in the global coastline area which is commercially important because of their biochemical content [20]. About 1500 species of brown algae has been identified worldwide [21]. Brown algae are observed in about 6, 91, 713 places around the world (Fig. 1).

There are about 265 genera and 2040 species belong to class Phaeophyta (Fig. 2), in which 95% of those species are most widespread in cold to temperate waters. All data shown in the figure was accessed via GBIF on 21 October 2020. The GBIF (Global Biodiversity Information Facility) is an international network and research foundation supported by government authorities around the world and providing data on all types of life around the world.

The main sources of algae are found in the northwest, west-central and southwest Atlantic, and in the central-east and southwest Pacific. India, with its long coastline, has vast marine resources along many open coasts and estuarine areas. Marine benthic algae of India were first published in 1970 with 20 species [22]. Based on the reports published in different journals, [23–25] prepared the updated checklist of algae. The checklist prepared in

![Fig. 1 A map published on GBIF, showing the worldwide occurrence of brown algae. Source: GBIF (© OpenStreetMap contributors, © OpenMapTiles, GBIF) (https://www.gbif.org/occurrence/map?has_coordinate=true&has_geospatial_issue=false&taxon_key=7073593&occurrence_status=present)](https://www.gbif.org/occurrence/map?has_coordinate=true&has_geospatial_issue=false&taxon_key=7073593&occurrence_status=present)
2001 comprises a total of 280 species from the Gujarat coast [24]. Seaweeds on the Indian coast consist of 814 species belonging to 217 genera. Out of these species, 216 species of Chlorophyta, 191 species of Phaeophyta, 217 species of Rhodophyta, and 3 species of Xanthophyta were recorded on Indian coasts among these 202 species were found only in Gujarat [26]. The coastline of Gujarat is made up of Deccan traps and tertiary stones and in places; there are fossilized forms of milliolite with limestone [27]. A list of brown algae recorded in the coastal area of Gujarat has been described in Table 1.

**Main text**

**Prominent secondary metabolites in brown algae**

Marine algae represent a good source of secondary metabolites/specialized metabolites. These specialized metabolites play important role in defense against pathogens. Phlorotannin, phytosterol, and polyphenol are prominent secondary metabolites groups that are found in brown algae. The variety of compounds within a particular group plays a vital role in many biological activities. Some prominent secondary metabolites from brown algae are as follows.

**Phlorotannins**

Polyphenols of marine algae are known as phlorotannins, which are observed in seaweeds and synthesized by the acetate-malonate pathway also known as polyketide pathway produced by the polymerization of phloroglucinol. Phlorotannins are extremely hydrophilic components with a wide range of molecular sizes between 126 kDa and 650 kDa [28]. Among the green, brown, and red seaweeds, phlorotannins are normally isolated from the brown seaweed. This phytochemical has been isolated through chromatographic methods [29, 30]. In addition, for characterizing the structure of compounds, nuclear magnetic resonance spectroscopy has been used [31, 32]. It has been recorded that members of laminariaceae are a rich source of phlorotannins compare to other seaweeds [33]. Phlorotannins have different biological activities such as anti-diabetic, antioxidant, anti-proliferative, anti-HIV, and skin protection, radio-protective, and anti-allergic activities [34].

*Cystophora congesta* have phlorotannin likes phloroglucinol triacetate, diplorehol pentacetate, and triphlorehol-A-heptacetate [35]. The extract of *Cystoseira* showed good antioxidant and cytotoxic results, which can suggest that it can be effectively used in the synthesis of the cytotoxic...
Table 1 List of brown algae recorded at Gujarat coast [27]

| Sr. no. | Name of algae | Distribution |
|---------|----------------|--------------|
| 1.      | *Colpomenia sinuosa* (Martens ex Roth) Derbes and solier | Okha, Shrivrajpur, Veraval |
| 2.      | *Cystosera indica* (Thivy and Doshi) Mairh | Dwarka, Okha, Porbandar Shrivrajpur |
| 3.      | *Cystosera trinoidis* (Forsskål) C. Agardh | Okha, Porbandar, Veraval |
| 4.      | *Dictyopteris delicatula* Lamouroux | Shrivrajpur |
| 5.      | *Dictyopteris acrostichoides* (J. Agardh) Bornet | Okha, Shrivrajpur |
| 6.      | *Dictyopteris austalis* (Sonder) Askenasy | Adri, Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 7.      | *Dictyota bartayresiana* Lamouroux | Adri |
| 8.      | *Dictyota cervicornis* Kützing | Kotada, Okha, Shrivrajpur |
| 9.      | *Dictyota ciliolate* Kützing | Dwarka, Kotada, Shrivrajpur |
| 10.     | *Dictyota dichotoma* (Hudson) Lamouroux | Okha, Shrivrajpur, Veraval |
| 11.     | *Dictyota pinnaflida* Kützing | Kotda, Shrivrajpur, Okha |
| 12.     | *Dictyota serrata* (Areschoug) Hyot | Okha |
| 13.     | *Harmophysa cuneiformis* (J. Gmelin) P. Silva | Okha, Porbandar, Shrivrajpur Veraval, Verala |
| 14.     | *Hinckisia michelii* (Harvey) Silva | Shrivrajpur |
| 15.     | *Hydroclathrus clathratus* (C. Agardh) Howe | Dwarka, Okha, Porbandar Shrivrajpur, Veraval, Verula |
| 16.     | *Iyengaria stellata* (Børgesen) Børgesen | Dwarka, Okha, Porbandar Shrivrajpur, Veraval, Verala |
| 17.     | *Levingia boergeseni* Kylin | Adri, Okha, Veraval |
| 18.     | *Lobophora variegate* (Lamouroux) Woronosy ex Oliveria | Adri, Okha, Porbandar, Shrivrajpur Veraval |
| 19.     | *Padina tetrastromatica* Hauck | Okha, Porbandar, Shrivrajpur |
| 20.     | *Padina boergeseni* Allender and Kraft | Okha, Porbandar, Shrivrajpur |
| 21.     | *Padina boryana* Thivy | Okha, Porbandar, Shrivrajpur |
| 22.     | *Rosenvingea intricata* (J. Agardh) Børgesen | Shrivrajpur |
| 23.     | *Rosenvingea orientalis* J. Agardh | Okha, Shrivrajpur |
| 24.     | *Sargassum cinctum* J. Agardh | Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 25.     | *Sargassum cinereum* J. Agardh | Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 26.     | *Sargassum johnstonii* Setchell and Gardner | Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 27.     | *Sargassum linearifolium* (Turner) C. Agardh | Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 28.     | *Sargassum plagiophyllum* (Martens) J. Agardh | Okha, Porbandar, Shrivrajpur |
| 29.     | *Sargassum prismaticum* Chauhan | Okha, Porbandar, Shrivrajpur |
| 30.     | *Sargassum swartzi* C. Agardh | Dwarka, Okha, Porbandar Shrivrajpur, Veraval |
| 31.     | *Sargassum tenerimum* J. G. Agardh | Dwarka, Okha, Porbandar Shrivrajpur, Veraval, Verala |
| 32.     | *Sargassum vulgare* C. Agardh | Okha, Porbandar, Shrivrajpur Veraval |
| 33.     | *Spatoglossum asperum* J. Agardh | Adri, Okha, Porbandar, Shrivrajpur Veraval |
| 34.     | *Stoechospermum marginatum* (C. Agardh) Kützing | Adri, Kotda, Okha, Porbandar, Shrivrajpur, Veraval |
| 35.     | *Turbinaria ornata* (Turner) J. Agardh | Okha, Porbandar |
Phytosterol
Sterols found in plants are known as phytosterol [47]. Phytosterol is a bioactive compound in marine algae, terrestrial, and marine plants. There are about 200 types of phytosterol have been found [48]. Stigmasterol and sitosterol are two common examples of phytosterols [49]. Mostly, brown seaweeds contain fucosterol and fucosterol derivatives [7]. These bioactive compounds are important because of the many beneficial health effects associated with them. The determination of phytosterols is generally performed by mass spectrometry or flame ionization detection [50].

The phytochemical compound fucosterol was first isolated by RP-HPLC method in Cystoseria foeniculacea and Dictyota ciliolate, and the fraction of compound also analyzed by NMR technique [51]. Bioactive compound fucosterol was responsible for anti-proliferative and antioxidant activity, due to the presence of phloroglucinol [45]. Ishige okamurae showed the presence of diphlorethoxyhydroxycarmalol phlorotannin [46]. A list of phlorotannins in brown seaweeds has been recorded in Table 2.

Table 2 List of phlorotannins reported in brown algae

| Sr. no. | Name of brown algae | Name of phlorotannins | References |
|---------|----------------------|------------------------|------------|
| 1.      | Cystophora congesta  | Phloroglucinol triacetate, diphlorethol pentacetate, triphlorethol-A-heptacetate | [35] |
| 2.      | Cystosera medicaulis | Bieckol, fucophlorethol, 7-phloroeckol, and phlorofucofuroeckol A | [37] |
| 3.      | Cystosera tamarscifolia | Bieckol, fucophlorethol, 7-phloroeckol and phlorofucofuroeckol | [37] |
| 4.      | Ecklonia bicyclis    | Phloroglucinol, eckol | [38, 39] |
| 5.      | Ecklonia cava        | Fucophlorethol G, phloroglucinol, eckol, dieckol | [38, 40, 41] |
| 6.      | Ecklonia kurume      | Phloroglucinol | [38] |
| 7.      | Ecklonia stolonifera | Eckol, dieckol, phlorofucofuroeckol A | [42, 43] |
| 8.      | Eisenia arborea      | Phlorofucofuroeckol B | [44] |
| 9.      | Himanthalia elongata | Phloroglucinol | [45] |
| 10.     | Ishige okamurae      | Diphlorethoxyhydroxycarmalol | [46] |

Polyphenols
Polyphenols are a group of prominent secondary metabolites, which support the plant in structural development and protect the algae from biotic and abiotic stress condition [57]. Brown algal species have unique secondary metabolites namely as polyphenols and phlorotannin compound are a class of these polyphonic compound [58], this type of compound were formed under harsh condition and able to absorb UV-radiation and repair wound [59]. Polyphenols have great biological activities; these characters make brown algae used as major ingredients forcosmeceutical and nutraceutical products [60]. Polyphenols have shown therapeutic properties such as anti-oxidative, anti-bacterial, anti-cancer, anti-allergic, anti-diabetes, anti-aging, anti-inflammatory, and anti-HIV activities [61, 62].

Different brown algae showed immense in vitro antioxidant activity and quantified the polyphenolic compound using the HPLC method [63]. It has been reported that Fucus species have gallic acid, protocatechuic acid, genistic, vanillic acid, and caffeic acid; Sargassum multicium have a good source of gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid, and syringic; Saccharina latissima have gallic acid, protocatechuic acid, genistic, vanillic acid, and Laminaria
*Laminaria digitata* showed the presence of gallic acid, protocatechuic acid, genistic, vanillic acid, and caffeic acid. These phenolic compounds are responsible for the great antioxidant activity of algae [63]. Brown algae *Himanthalia elongate* confirmed the natural antioxidant compound like gallic acid, chlorogenic acid, caffeic acid, ferulic acid, and quercetin [45]. It has been testified that *Padina boergesenii* have important phenolic compound such as gallic acid, caffeic acid, rutin, quercetin, and ferulic acid which can be used as cancer chemopreventive agent [64]. HPLC profiling of *Padina pavonica* confirmed the presence of polyphenol compounds like kaempferol, tannic acid, caffeic acid, quercetin, and epigallocatechin, and FTIR analysis confirmed the presence of various groups like phenol, alkanes, alcohol, and aromatic compounds [65]. Different species of *Sargassum* have shown the major polyphenolic compound like gallic acid and P-hydroxybenzoic acid, the presence of this compound was confirmed by RP-HPLC method [66]. A list of polyphenols reported in brown seaweeds has been recorded in Table 4.

**Biological importance of the isolated compound from the brown algae**

Diterpen bifurcdioli 76 has been isolated from *Bifurcaria bifurcata*; this diterpens shows cytotoxic activity against human tumor cell line; metaterpenoids from *Sargassum tortile* showed cytotoxic activity [67].

### Table 3 List of phytosterols reported in brown algae

| Sr. no. | Name of brown algae           | Name of phytosterol                | References |
|---------|--------------------------------|-----------------------------------|------------|
| 1.      | *Cystoseria foeniculacea*      | Fucosterol                        | [51]       |
| 2.      | *Dictyota ciliolate*           | Fucosterol                        | [52]       |
| 3.      | *Himanthalia elongate*         | Fucosterol                        | [7]        |
| 4.      | *Hormophysa triquetra*         | Fucosterol, stigmasterol, campesterol | [53]    |
| 5.      | *Laminaria ochroleuca*         | Fucosterol, cholesterol            | [7]        |
| 6.      | *Padina gymnospora*            | Fucosterol, brassicasterol, cholesterol, stigmasterol | [54] |
| 7.      | *Padina pavonica*              | Fucosterol, β-sitosterol, campesterol | [53]    |
| 8.      | *Padina sanctae-cruces*        | Fucosterol                        | [52]       |
| 9.      | *Pelvetia spiliosa*            | Fucosterol                        | [51]       |
| 10.     | *Sargassum angustifolium*      | Fucosterol                        | [54]       |
| 11.     | *Sargassum asplenifolium*      | Fucosterol, stigmasterol, saringosterone, saringosterol | [55]    |
| 12.     | *Sargassum fusiforme*          | Phytol, fucosterol                | [56]       |
| 13.     | *Undaria pinnatifida*          | Fucosterol, cholesterol            | [7]        |

### Table 4 List of Polyphenols reported in brown algae

| Sr. no. | Name of brown algae       | Name of polyphenols                                      | References |
|---------|----------------------------|--------------------------------------------------------|------------|
| 1.      | *Dictyota dichotoma*       | Gallic acid, protocatechuic acid, genistic, vanillic acid | [63]       |
| 2.      | *Fucus distichus*          | Gallic acid, protocatechuic acid, genistic, caffeic acid |            |
| 3.      | *Fucus serratus*           | Gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid |            |
| 4.      | *Fucus spiralis*           | Gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid |            |
| 5.      | *Fucus vesiculosus*        | Gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid |            |
| 6.      | *Himanthalia elongate*     | Gallic acid, chlorogenic acid, caffeic acid, ferulic acid, quercetin | [45]       |
| 7.      | *Laminaria digitata*       | Gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid | [63]       |
| 8.      | *Padina boergesenii*       | Gallic acid, caffeic acid, rutin, quercetin, ferulic acid | [64]       |
| 9.      | *Padina pavonica*          | Kaempferol, tannic acid, caffeic acid, quercetin, epigallocatechin | [65]       |
| 10.     | *Saccharina katsissima*    | Gallic acid, protocatechuic acid, genistic, vanillic acid | [63]       |
| 11.     | *Sargassum cinereum*       | Gallic acid, P-hydroxybenzoic acid                     | [66]       |
| 12.     | *Sargassum ilicifolium*    | P-hydroxybenzoic acid                                 | [66]       |
| 13.     | *Sargassum multicum*       | Gallic acid, protocatechuic acid, genistic, vanillic acid, caffeic acid, syringic | [63] |
| 14.     | *Sargassum swartzii*       | Gallic acid                                           | [66]       |
| 15.     | *Sargassum tenerrimum*     | Gallic acid, P-hydroxybenzoic acid                     | [66]       |
Tetrahydrofuran from *Notheia anomala* inhibit the larval developments of parasitic nematodes [68]. *Cystoseira tamariscifolia* have metaterpenoid-methoxybifurcarrene 138 which possesses anti-fungal and anti-bacterial activity [69]. Lopophorins from *Lophophora variegata* showed anti-inflammatory activity. Diterpens-Dictyol J 146, Dictyolactone, and Sanadaol were isolated from *Dictyota dichotoma*; these compounds have algicidal activity [67]. Phloroglucinol and its derivatives from *Ecklonia stolonifera* act as hepatoprotective agents [70]. Isolated compound Dollabelladiene derivative 147 from *Dictyota pfaffi* showed in vitro anti-HSV-1 activity. Bioactive compounds like tetraprenyltaluquinols, thunbergols, fucodiphlorethol G 192, taondiol, isoeptitaondiol, stypodiol, stypoldione, and sargaol which has been isolated from *Sargassum thunbergii* showed anti-cancer activity [77]. Phlorotanins are a type of tannin, belongs to the group of polyphenolic compounds, which has usually found in brown algae. These polyphenols inhibit colon cancer cells [78]. Terpenes are also recorded in brown algae. In terpenes, halogenated monoterpenes showed important anti-proliferative activity [79] (Fig. 3).

It has been testified that brown seaweeds are a good source of sterols like fucosterol and desmosterol, and it has been recorded that this type of sterols decreases the level of cholesterol, free triglyceride in the liver [80]. Phloroglucinol is polyphenolic compound, which showed different biological activity such as anti-oxidant, anti-diabetic, anti-inflammatory, anti-allergic, and anti-HIV [81–86]. The phlorotannins (phloroglucinol, eckol and diekcol) from brown algae *E. cava* have been used in cosmeceuticals products [80]. Edible brown algae *Eisenia arborea* have phlorofucofuroeckol-B, shown strong anti-oxidant activity, it suggests a potential use in anti-allergic drug preparations [44]. The sulfated polysaccharides from *Padina tetrastomatica* have been used in

| Sr. no. | Name of brown algae | Isolated compound | Biological importance | Reference |
|--------|---------------------|-------------------|----------------------|-----------|
| 1      | *Bifurcaria bifurca* | Bifurcadiol 76    | Cytotoxic activity   | [67]      |
| 2      | *Sargassum tortile* | Meroterpenoids, Sargol, Sargol-I And Sargol-II |                |           |
| 3      | *Notheia anomala*    | Tetrahydrofuran   | Nematocidal activity | [68]      |
| 4      | *Cystoseira tamariscifolia* | Meroditerpenoid | Anti-fungal activity against pathogenic fungi; anti-bacterial activity | [69] |
| 5      | *Lobophora variegata* | Lopophorins A 142 And B 143 | Anti-inflammatory activity | [67] |
| 6      | *Dictyota dichotoma* | Dictyol J 146, Diterpenes, Dictyolactone | Algicidal activity |           |
| 7      | *Ecklonia stolonifera* | Phloroglucinol, Eckstolonol, Eckol, Phlorofucofuroeckol A | Hepatoprotective agents | [70] |
| 8      | *Dictyota pfaffi*    | Dollabella diene  | Anti-viral activity. | [67]      |
| 9      | *Sargassum thunbergii* | Tetraprenyltaluquinols, Thunbergols | Free radical scavenger and antioxidant activities. |           |
| 10     | *Ecklonia cava*      | Fucodiphlorethol G 192 |                |           |
| 11     | *Taonia atomaria*    | Taondiol, isoeptitaondiol, stypodiol, stypoldione, sargaol |                |           |
| 12     | *Pelvetia siliquosa* | Fucosterol         | Anti-diabetic priciple from *Pelvetia siliquosa* | [71] |
| 13     | *Dilophus okamurae*  | Dictyterepenoids A 194 And B 195 | Anti-feedent activity against young abalone | [72] |
| 14     | *Eisenia arborea*    | Phlorofucofuroeckol-B | Anti-allergy activity | [73] |
| 15     | *Ecklonia stolonifera* | Eckol, phlorofucofuroeckol A, diekcol | Anti-hypertensive activity | [74] |

### Table 5

List of biological activity of isolated compound from brown algae
Fig. 3 Schematic diagram showing various biological activities of brown algae depended on its bioactive compounds.

Fig. 4 Schematic diagram showing applications of brown algae depending on its bioactive compounds.
cancer treatment because it showed strong antioxidant and anti-mitotic activity [87]. A brown algae *Sargassum vestitum* has active compound fucoxanthin which showed antioxidant activity, it suggests possible use in the food and pharmaceutical field [5]. Fucoaid component from *Dictyota mertensii*, *Spatoglossum Schroederi*, and *Fucus vesiculosus* which contain the inflammation response for their anti-inflammation activity [88]. *Lamina japonica* has strong antioxidant activity due to the fucoid component in it which inhibits the increased formation of lipid peroxide in serum and liver [89] (Fig. 4). Brown algae *Chnoospora minima* displayed significant anti-proliferative activity on cancer cell lines due to the bioactive fraction [90].

**Conclusion**

The review work on the phytoconstituents of brown algae makes it clear that this large group of marine algae is not only used to obtain food, fodder but is an enormous source of several secondary metabolites. This review paper holds studies of the bioactive compound of brown algae, which has many more functional properties compared to red and green algae because phaeophyta group are main representatives of polysaccharide and fucoids which are responsible for prominent biological activity. It has been noted that the types and proportions of phytoconstituents vary from species to species and depend on environmental factors. The multiple mechanisms of action promote the formation of complex bioactive compounds from brown algae, which directly enhance their biological activity, and such activities promote many drug industries for drug production. Thus, systematic work on this group of marine algae will be helpful in the formulation of new drugs that can be used for curing several fatal diseases of a human being.

**Abbreviations**

UV: Ultraviolet; KDa: Kilodaltons; HIV: Human immuno deficiency virus; GC-MS: Gas chromatography–mass spectrometry; RP-HPLC: Reverse phase high-performance liquid chromatography; NMR: Nuclear magnetic resonance

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