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Review Article

Pharmacological Activities of Natural Products from Marine Seaweed *Turbinaria ornata*: A Review

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The marine biosphere is the primary source that has produced excellent bioactive metabolites. Natural compounds isolated from various algae, especially brown algae, gained interest because of their wide variety of biological activities and biocompatibility. Among brown algae, *Turbinaria ornata* (*T. ornata*), a highly prevalent alga, because of the presence of bioactive substances, primarily polysaccharides and proteins, could be used for a broad range of pharmaceutical applications. Hence, this study focuses on the biological activity of *T. ornata* as reported in earlier studies, which includes antioxidant, anti-inflammatory, antidiabetic, antiproliferative, and neuroprotective effects. Also, a few natural compounds isolated from the *Turbinaria* species have been used for the biogenic nanoparticle synthesis that was considered to be potential for desired biological applications. This review gives detailed information on the valuable natural resources being used as a potential component in pharmaceutical applications.

1. Introduction

The oceans are considered as an exclusive collection of rich bioactive metabolites, of which macroalgae have been found to be the greatest manufacturers of varied bioactive secondary metabolites with high medicinal perspective. Much consideration has been given recently to marine bioactive secondary metabolites because of their novel chemistry and varied biological properties [1]. The exploration of novel metabolites from the aquatic regions has led to the isolation of approximately 10,000 metabolites, of which many are gifted with pharmacodynamic properties [2]. Apart from marine sources, there has also been a great deal of interest in isolating biomolecules from different plant and microbial

sources [3]. Macroalgae with a wide variety of biological activities are regarded as the huge residual reservoir of undiscovered natural molecules.

Seaweeds represent the huge oceanic benthic algae that are multicellular, macrothallic oceanic algae, and are distinguished from the greatest algae. Seaweeds are rich in fibre and protein content [4]. Over 1.5 million seaweed species have evolved from the world's seas, but only a few have been identified [5]. Seaweeds are eukaryotic organisms that live in saltwater and identified as a prospective basis of bioactive natural products. They are most plentiful in superficial rocky seaside zones, particularly where they are revealed at low tide. Numerous kinds of brown, green, and red algae were flourishing alongside the Southern coast from Rameswaram to Kanyakumari which includes 21 islands in the Gulf of Mannar [6, 7]. Seaweeds comprise huge quantities of polysaccharides, particularly structural polysaccharides of the cell walls that are separated by the hydrocolloid industry: carrageenan and agar from red algae and alginate from brown algae, respectively. Seaweeds comprise storage polysaccharides [8], remarkably Floridean starch in red seaweeds and laminarin in brown seaweeds. Among the polysaccharides, fucoidans have been specially deliberate since they have shown remarkable biological activities (antiviral, anticancer, antithrombotic, antiproliferative, anti-inflammatory, anticomplementary, and anticoagulant agent). It is similarly a rich basis of biologically active compounds, for example, polyphenols, protein, fibre, carotenoids, vitamins, and minerals [9]. These properties expose an extensive area of prospective medicinal applications. The importance of seaweeds as a marine resource has been lately imposed because of the cumulative requirement for them as human medicinal products such as antibiotics [10], for instance, antiviral, antibacterial, antifungal, antitumor [11], and animal food.

Brown seaweeds are receiving the most attention from researchers due to their biological activities. *Turbinaria ornata* (*T. ornata*) is one of the main seaweeds in the marine ecosystem that has been used as a source of medicine among brown seaweeds. Several bioactive compounds with various pharmacological activities have been isolated from them. These pharmacological activities are caused by the presence of bioactive ingredients, and the phycochemical constituents exhibit these potentials of the seaweeds. The current study attempts to reveal a glimpse of the marine natural products, characterization of the isolated components of *T. ornata*, its phycoremediation, pharmacological activities, and finally biosynthesis of nanoparticles using natural products.

2. Marine Natural Products

The sea signifies a huge supply of novel bioactive natural products with usefulness in the basic investigation, biomedical sciences, and in the improvement of therapeutics. In current years, numerous bioactive compounds have been extracted from different oceanic sources like marine microbes, phytoplankton, marine-sourced bacteria and fungi, cyanobacteria, zooplankton, tunicates, sponges, seaweeds, macroalgae, green algae, brown algae, and red algae. The investigation of secondary metabolites has been further concentrated on macroalgae than phytoplankton [12]. Marine algae produce an extensive diversity of amazing natural compounds, generally mentioned as secondary metabolites that are not intricate in the elementary means of life. Although these molecules frequently donate only a very lesser portion of the organism's total biomass, the involvement of these compounds in existence might occasionally be similar to the metabolites generated from the primary metabolism. In that sense, the utilization of the term "secondary metabolite" appears less suitable, since these compounds similarly donate to the development, reproduction, and defence and hence play a major role in the organism's integrity [13]. Numerous compounds have been discovered in marine macroalgae in recent years, with brown algae being the primary producer of bioactive compounds.

2.1. Brown Seaweeds. The southwest coast of India has a diverse marine habitat of seaweeds, with brown algae being the most prevalent [14]. The brown algae are differentiated by their colour which differs from olive green via light golden shades of brown. This is due to the occurrence of a golden-brown xanthophyll pigment fucoxanthin in their chromatophores. The brown algae are brownish in colour because of the huge quantities of the carotenoid and fucoxanthin covering the residual pigment chlorophyll a and c, carotene, and other xanthophylls. The cell walls are composed of alginic acid, which was extracted as alginate or agent for industrial use. Brown algae range from smaller cords to the largest seaweed, and the majority are found in the intertidal belt. Brown seaweeds are mostly utilized to cure hypothyroidism, fatigue, cellulite, cough, asthma, stomach ailments, and headache. Brown seaweeds are also utilized to encourage weight loss besides assistance in skincare. The prospective antioxidant compounds in brown seaweeds were recognized as polyphenols and pigments mostly [15]. These compounds are dispersed in plants or algae and are widely known for displaying antioxidant activities by reactive oxygen species (ROS) recovery activity and lipid peroxidation inhibition [16].

Brown seaweeds are found to comprise huge quantities of cell-wall polysaccharides, the major part of which are the sulfated polysaccharide and fucoidan [17] that are not found in terrestrial plants. Fucoidan has a considerable element of L-fucose and sulfate ester groups [18] and has an extensive assortment of pharmacological and biomedical properties [19]. There have been more than a few investigations on the diverse bioactivities, structural parameters, molecular weights, and physiological features of seaweed polysaccharides. There are various species of brown algae, and among them, *Turbinaria* species, such as *Turbinaria ornata* and *Turbinaria conoides*, have been extensively distributed along the coastal waters of Tamilnadu. *Turbinaria ornata* (Turner) J. Agardh, 1848 as in Figure 1 is a brown alga from the Phaeophyceae family, abundant in fucoids and polysaccharides. It is usually established in small clusters connected to the fissures of basalt rocks in great wave act regions besides the fissures of coral heads at 20-30 meters. The morphological features of this alga allow it to

Figure 1: *Turbinaria ornata.*

live under great ecological circumstances [20]. The biodistribution of *T. ornata* along the coastal areas of Tamilnadu is shown in Figure 2.

In a study, the histochemical and fluorescence analysis of *T. ornata* was examined. The outcomes of histochemical investigations indicated an optimistic response to polyphenol, tannin, and phenolic compounds in the thallus [21]. The spherical mitogenome of 34981 base pairs comprises a rudimentary set of 65 mitochondrial genes. The organization and structure of *T. ornata* mitogenome are exactly alike to *Sargassum* species. *T. ornata* genes overlay via a whole of 164 base pairs in 12 dissimilar positions from 1 to 66 base pairs, and the noncoding sequences are 1872 base pairs found around 5.35% of the genome [22].

3. Characterization Techniques of the Isolated Compounds from *T. ornata*

The selection and characterization of the bioactive compounds in the brown seaweed *T. ornata* were evaluated. The crude extraction of the seaweed was done by petroleum ether, methanol, ethanol, acetone, and water. The methanolic crude extract was exposed to Gas Chromatography–Mass Spectrometer (GC-MS) analysis to expose the phytochemicals that work in the mode at 70 eV. The compound was identified using the NIST version 2 mass spectral library from the National Institute of Standards and Technology. Methanol was recognized as the greatest apt solvent to extract the bioactive constituents. Dissimilar volatile compounds and fatty acids were recognized in GC-MS analysis. The unstable blend encompassed acids, hydrocarbons, ketones, aldehydes, ethers, esters, alcohols, and aromatic and halogenated compounds [23]. In another study, the GC-MS analysis of crude methanolic extract of *T. ornata* revealed the presence of some major peaks with varying retention times and area percentage. The major phytochemical components studied were 2,2-dimethoxybutane (RT 3.36) with a peak area of 15.81%, 1-hexadecanol (RT 20.49) with a peak area of 15.23%, and 1-nonadecene (RT 25.47) with a peak area of 11.04% [24]. The presence of secondary metabolites demonstrates that the brown seaweed *T. ornata* has biomedical potential.

The diversity of compounds in a specific group plays a vital role in many biological activities. The chemical, as well as the structural conformation of an unfractionated compound like fucoidan or polysaccharides such as laminarin extracted from *T. ornata*, was elucidated using some characterization techniques. Electrospray ionization mass spectrometry (ESI-MS) has been utilized to assess the chemical structure and small angle X-ray scattering (SAXS) for the prediction of molecular composition. The outcomes displayed, for example, the fucoidan isolated from *T. ornata*, contain a sulfate content of 25.6% that consists of galactose and fucose deposits (Fuc : Gal ≈ 3 : 1). ESI-MS study showed fucoidan that contains a basis of 3-linked α-L-Fucp remainders together with branches, →4)- Galp (1→at C-4, which was the fucan chain. It involves the sulfate group at C-2 and occasionally at C-4 of galactose and fucose remainders. The molecular structure of fucoidan has been constructed by the chemical structure acquisition and dispersion curves assessed based on the molecular design with perceived SAXS dimension [25]. The isolated compound's functional groups and structural properties were identified using Fourier Transform-Infrared (FTIR) spectroscopy. The FTIR spectrum of laminarin which was isolated from *T. ornata* exhibited the typical absorption peak of –OH stretching vibration at 3373.50 cm^{-1}, and the peak at 2895.15 cm^{-1} confirms the stretching vibration of $-CH_2$ or $-CH_3$ collections along with absorption peak for sugar. A peak detected at 1078.21 cm^{-1} and 1654.92 cm^{-1} establishes the occurrence of C-O stretching vibrations and C=O asymmetric and symmetric stretching vibrations. The characteristic absorption peak at 894.97 cm^{-1} showed the presence of C-H scissor vibration appeared that showed the presence of β-type glycosidic bond [26].

Also, determination of molecular mass has been done utilizing Matrix-Assisted Laser Desorption Ionization–Time of Flight (MALDI-TOF). The mass spectra attained in the negative ionization mode of laminarin exhibited the dispersal of the extracted laminarin. The molecular structure prediction was performed using Nuclear Magnetic Resonance Spectroscopy (NMR). The ^{1}H-NMR spectra of laminarin exhibited absorption peaks in the region of δ 4.5-5.0 ppm which was solely responsible for the anomeric hydrogen of glucose. Meanwhile, the chemical shift of the anomeric hydrogen was found to be δ 4.41 ppm that was less than 5.0 ppm, which showed the glycosidic bond in laminarin of β type. Another similar extraction of polysaccharides study confirmed this type of linkage [27].

3.1. Phycoremediation. Phycoremediation reveals the potential of macroalgae and microalgae to eliminate contaminants in wastewater as in Figure 3. Although there are numerous benefits of using algae over biosorbent biomass, only a few studies have addressed the promising implications of algae for heavy metal removal from contaminated water. *T. ornata* could be utilized as a valuable absorbent and has achieved a distinctive percentage of 55.5, 70.9, 59.8, 57.6, 55.1, and 72.6% for Cd, Cu, Pb, Fe, Co, and Zn, respectively, i.e., heavy metal elimination. The results emphasized the necessity for the use of algae as a sustainable and inexpensive technique for wastewater remediation [28]. Apart from degradation, phytoremediation also contributes to the reduction, metabolism, and assimilation of one of the toxic heavy metals, lead, from the municipal wastewater. *T. ornata* biomass

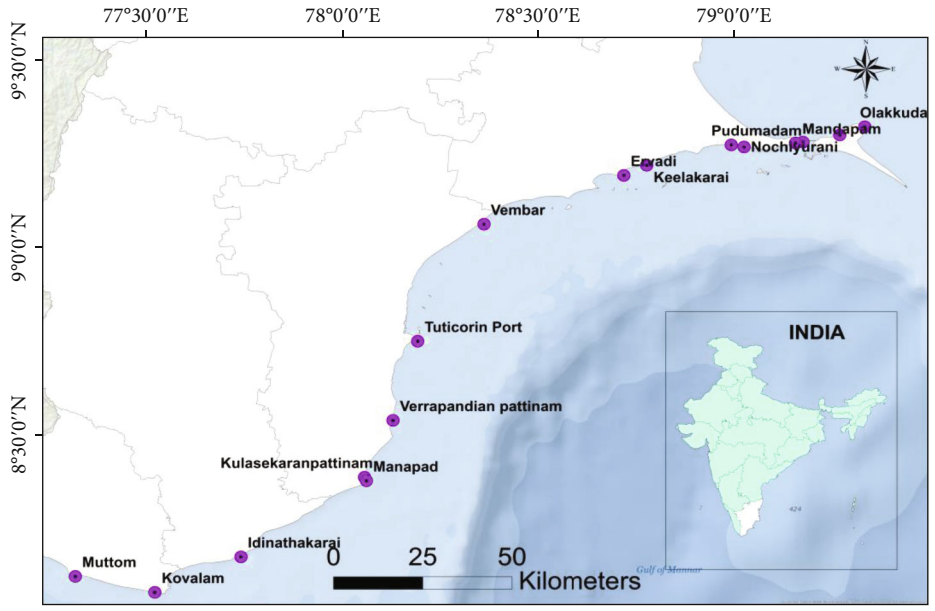

Figure 2: Distribution of *Turbinaria ornata* along Tamilnadu coastal region.

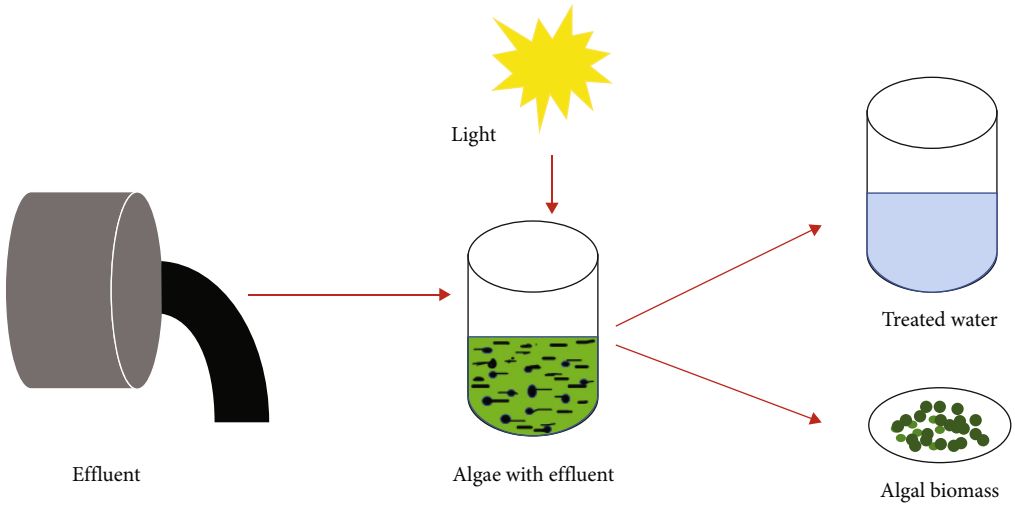

Figure 3: Algae in phycoremediation.

eliminated >98.5% of lead from wastewater under optimal conditions within 10 minutes [29].

It was examined *T. ornata* to assess its capacity to eradicate copper (II) present in water. Batch equilibrium experiments with different pH levels revealed a high copper absorption of 147.06 mg/g in the Langmuir model at 6. *T. ornata* was also examined for the ability of biosorbing copper into a packed column. The trials examined the impact of significant design factors, such as bed flow and height. Copper absorption was relatively consistent at about 68 mg/g, independent of bed height, while absorption declined at increased flow. The life-factor calculation for *T. ornata* was found to be 0.603 cm/cycle as far as critical bed length is concerned. The elution performance provided was greater than 98.8%, approximately seven cycles. This provides the capability of *T. ornata* to survive the intense states while maintaining the potential for copper biosorption [30]. Here, the use of algal strains such as *T. ornata* will improve heavy metal removal efficiency via biosorption and bioaccumulation mechanisms [31]. It is also, essential to consider the effects of heavy metals on the biochemical composition of algae in order to maximize the benefits of the biomass and metabolites produced during the phycoremediation process.

4. Pharmacological Activities of *T. ornata*

The solvent and aqueous extracts of *T. ornata*, which contain phytoconstituents, will exhibit pharmacological activities as in Figure 4.

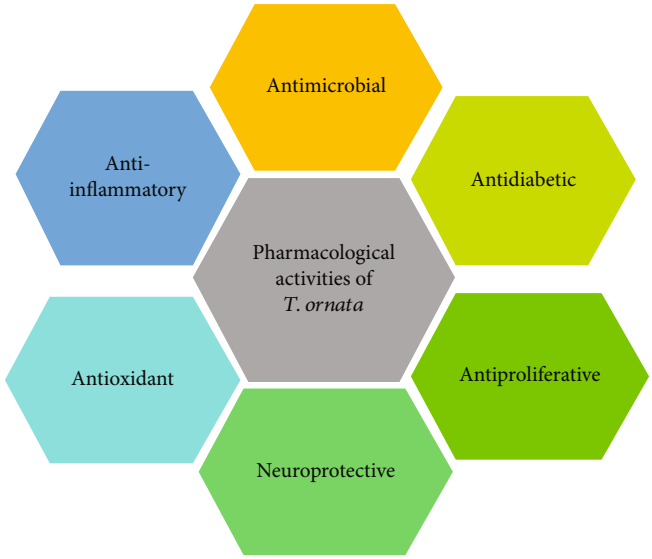

Figure 4: Pharmacological activities of *T. ornata*.

4.1. Antioxidant Activities. The aqueous-soluble unpolished polysaccharide from *T. ornata* (TCP) was associated with antioxidant activity. *In vitro* total antioxidant activity and free radical quenching of TCP were examined by nitric oxide (NO) scavenging, 1,1-diphenyl-2-picryl hydrazyl (DPPH), 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical assay, and lipid peroxidation (LPO) inhibition. Phytochemical analysis of TCP exhibited the occurrence of proteins, carbohydrates, and polyphenols [32]. The total antioxidant activity of the biological extracts from 37 algae samples was identified. Antioxidant activity has been estimated utilizing Ferric Reducing Antioxidant Power (FRAP) trials. Among the algae tested, *T. ornata* extract turned out to be a promising species that could be considered for certain medical uses [33]. The extracts of *T. ornata* with acetone were assessed for hepatoprotective, wound healing, and antiulcer activities. *T. ornata* extract showed the least decrease in the wound area at both dozes, while related to normal medicine on the 20^{th} day [34]. The antioxidant effects of *Turbinaria* species can vary according to the collection area, seasonal variations, salinity level, and temperature. The antioxidant activities and total phenolic contents of *T. ornata* in various in vitro systems have been evaluated. Ethyl acetate extracts of T. conoides recorded considerably greater phenolic content than that of *T. ornata* [35].

Antioxidant activity was ascertained using total antioxidant capacity, phenolic content, and DPPH free radical scavenging activity. The antioxidant activity of methanolic extracts and subfractions has been evaluated. The higher total phenolic content and antioxidant properties were observed in the F5 fraction. Based on Thin Layer Chromatography, UV-visible, and Fourier Transform-Infrared spectral examination, the F5 fraction contains phenolic compounds, solely, phlorotannin. Results have shown that the phenolic compound was responsible for the antioxidant activity of *T. ornata* [36]. Antioxidant and total phenolic content of ethanolic and methanolic extracts from *T. ornata* and *Sargassum polycystum* was investigated. Among all the extracts, methanol extract from *T. ornata* confined the maximum phenolic content (2.07 mg catechin/g) and showed the maximum antioxidant property. This was specified by the highest DPPH and ABTS radical scavenging activity besides reducing activity power (RAP) associated with additional extracts.

The methanol extract of *T. ornata* (TOME) was examined for its in vitro total antioxidant activity, DPPH scavenging assay, nitric oxide, reducing power assay, and hydrogen peroxide and superoxide scavenging assays. The antihemolysis and anti-inflammatory activities in the red blood cell model were done by collecting the blood from hale and hearty helpers of 22-25 ages. The result showed that *T. ornata* is affluent in bioactive compounds. TOME contains alkaloids, carbohydrates, phenolic compounds, saponins, tannins, flavonoids, coumarins, terpenoids, and steroids. TOME at 100 μg concentrations displays 89.11% of overall total antioxidant properties. The free radicals, nitric oxide, hydrogen peroxide, and superoxide dismutase activity are augmented with an upsurge dose of TOME. TOME at preferred concentrations (0.5, 0.75, and 1 mg/mL) shows a significant decline in hydrogen peroxide-induced hemolysis. The increase in TOME concentrations has increased the stabilization of the human RBC membrane, and the elevated concentration level (500 μg/mL) shows approximately 81% of the anti-inflammatory property was substantial as the Diclofenac standard. Thus, *T. ornata* with effective bioactive compounds indicates substantial antioxidant properties that preclude hydrogen peroxide-induced hemolysis within the RBC human model [37]. In another research, it was reported that *T. ornata* exhibited 43.72 mg GAE/g extract of phenol content and superior scavenging property of DPPH, superoxide anion, and hydroxyl radical [38].

The antioxidant and antibacterial properties of solvent portions of ethanolic extract of *Turbinaria* species were

performed, and its anticancer property was also assessed by cell cycle arrest, apoptosis, and cytotoxicity in HepG2 cells. The highest antibacterial properties were identified within the ethyl acetate fraction followed by the dichloromethane fraction, hexane fraction, and aqueous fraction. The cytotoxicity of the ethyl acetate fraction was 67% at 24 h and 83% at 48 h compared with the normal quercetin. Tumor cells were found to be much more prevalent in the G0/G1 proliferative stage, whereas considerably reduced at S phase [39].

4.2. Anti-Inflammatory Activities. There have been very few studies that show *T. ornata* has anti-inflammatory properties. The induced cotton granuloma in rats was investigated to assess the anti-inflammatory activity of the aqueous *T. ornata* extract (ATO) which was associated with dexamethasone, a normal anti-inflammatory drug. Plasma markers (LDH, GPT, and CRP), granuloma weight, and haematological parameters were assessed. Moreover, oxidative stress marker levels (GPx, GSH, SOD, Nitrite, and LPO) and inflammatory markers (MPO and Cathepsin D) in the liver tissue have been analysed. The ATO significantly reduced the scope of inflammatory and biochemical markers compared with vehicle-treated rats [40]. *T. ornata* methanolic extract concentrations improved human RBC membrane stability; the higher concentration level at 500 g/ml exhibits approximately 81% anti-inflammatory activity, which is comparable to standard Diclofenac [37]. In another in vitro study, *T. ornata* extracts alleviated chronic colitis by upregulating the Foxp3+ Treg cells and producing the anti-inflammatory cytokine IL-10, which effectively inhibits macrophages and proinflammatory cytokine production, resulting in less colitis [41]. It was also discovered that a polysaccharide isolated from the marine algae *T. ornata* had anti-inflammatory properties [42].

4.3. Antimicrobial Activities. The antimicrobial capacity of fucoidan was identified from *T. ornata*. The characteristic signal of the fucoidan was perceived in a dissimilar ppm of ^{1}H NMR analysis. The highest antibacterial activity (16.23 ± 0.11 mm) was attained for Vibrio parahaemolyticus, and the least activity (5.1 ± 0.24 mm) was obtained for Yersinia enterocolitica. The MIC value was shown between 2.5 to 10 mg/mL for the corresponding pathogens. Their report evidenced that fucoidan obsessed the notable antibacterial property contrary to the verified fish bacterial pathogens [43]. The antibacterial activities of methanolic extracts of brown seaweeds such as *T. ornata* and *Sargassum wightii* were studied. The antibacterial activities were tested against numerous Gram-positive and Gram-negative humanoid pathogenic microorganisms. This activity is owing to the presence of polyphenols, and these phenolic compounds affect the growth and metabolism of bacteria according to their composition, and the dose results recommend the use of methanol extracts of *T. ornata* as a good source of the antimicrobial agent [44]. They have also reported that the methanolic extracts of *T. ornata* achieved scavenging behaviour against an extensive variety of synthetic and naturally arising free radicals. The methanol and ethanol extracts of *T. ornata* do not inhibit the growth of *Salmonella enteritidis*, *Bacillus subtilis*, and *Aspergillus niger*, while, *Staphylococcus aureus* inhibited at 500 mg/L extracts for antimicrobial activity [45].

The antimicrobial activities of different extracts of *T. ornata* were verified contrary to twenty-three microorganisms, comprising Gram-positive and Gram-negative bacteria, fungi, and yeasts. The disc diffusion technique was tracked by altering the Resazurin Microtitre Assay (REMA). The outcomes attained from altered REMA utilizing both techniques of fluorometric and colorimetric were related. The highest antimicrobial properties were reported in dichloromethane extract for disc diffusion assay. Both techniques of altered REMA were considerably in accord per capita, and the other depends on Cohen's kappa statistical analysis (κ value = 0.712; $p < 0.0005$). The results recommended that the dichloromethane extract of *T. ornata*has the prospective to be utilized as antimicrobial components [46].

This work found the antifungal activity of other species of *Turbinaria*, *Turbinaria conoides* (*T. conoides*). The solvent extracts have been checked against some fungal strains such as *Candida albicans*, *Candida parapsilosis*, *Fusarium* sp., *Aspergillus flavus*, and *Aspergillus fumigatus*. Hexane, chloroform, and ethanolic extracts demonstrated very strong inhibitory activity against *Candida albicans* and *Candida parapsilosis*. Inhibitory activity was not observed with *Fusarium species*, *Aspergillus flavus*, and *Aspergillus fumigatus* in chloroform and ethanol extracts [47]. In a recent study, the antibacterial activity of *T. ornata* extracts was assessed against P. aeruginosa and found excellent inhibition against this multidrug-resistant strain at a concentration of 300 μg/mL. Therefore, the present analysis established that the marine *T. ornata* is potentially an antibacterial agent in intracellular as well as extracellular lesions [48]. Some of the antimicrobial activities of *T. ornata* have been mentioned in Table 1.

4.4. Antidiabetic Activities. The inhibitory action of the α-amylase of the extracted fucoidan from *T. ornata*was analysed. The sporophyll of *T. ornata* was used for the isolation of fucoidan by ethanol and calcium chloride precipitation technique. The average harvest was 2.6% with fucoidan extract accounting for 5970.69% fucose and 3370.42% sulfate. Structure elucidation was performed using various characterization techniques, and α-amylase analysis of the refined fucoidan was also performed. The value of IC_{50} was found at 33.6 mg, which is more efficient than the acarbose (125 mg) and the cytotoxic assays exhibited no effect [54].

The extracts of *T. ornata* for their antidiabetic activity of enzyme inhibitory assays (dipeptidyl peptidase-IV α-amylase and β-glucosidase) were evaluated. Of all the verified extracts, acetone and methanol extract exhibited important inhibitory properties on dipeptidyl peptidase-4 (55.2 g/mL), α-amylase (IC_{50} 250.9 g/mL), and β-glucosidase (535.6 g/mL) correspondingly. The free radical scavenging activity of these extracts was analysed by DPPH assay (65%). Extracts were analysed for in vitro toxicity by DNA fragmentation, hemolytic, and MTT assay. GC-MS analysis of lead extracts exhibited the occurrence of the main compounds, 1-heptacosanol and hentriacontane, z,z-6,28-

Table 1: Antimicrobial activities of *T. ornata*.

Sl. No.	Source	Antimicrobial activities	References
1	T. ornata	*Staphylococcus aureus*, *Escherichia coli*, and Pseudomonas aeruginosa	[49]
2		Candida albicans	[50]
3		*Staphylococcus aureus*	[51]
4		Escherichia coli and Bacillus subtilis Aspergillus niger and Fusarium oxysporium	[52]
5		Blue tongue virus	[53]

heptatriactontadien-2-one, and 8-heptadecene. *T. ornata* could also be utilized as a prospective basis for further in vivo studies in monitoring hyperglycemia [55].

4.5. Antiproliferative Activities. The phytochemical exploration of *T. ornata* revealed the existence of alkaloids, saponin, fixed oil, amino acids, fats, and some phenolic compounds (flavonoids, total tannin, and phenol). Increased antioxidant capacity was observed in hexane extract compared to aqueous extract. The range of antiproliferative efficacy (mg/mL) of hexane extract and water extract for cells such as A549 and Vero was 62.91 and 93.00 and 72.64 and 106.6 [56]. *T. ornata* boiled and normal water extract decreased tumor cell viability to 68.9% and 81.8%, respectively. Oleic acid and palmitic acid were extracted with 100 g organic solvents of *T. ornata* air-dried powder. Various concentrations of these acids showed antitumor activity against the carcinogenic cells of Ehrlich ascites. In addition, their study indicated that palmitic acid had higher anticancer activity than oleic acid. The effects of aqueous *T. ornata*extract, oleic acid, and palmitic acid on tumor cells in vitro have been shown to depend on time and dose [57].

There are reports that brown seaweed is a good source of sterols. They reported two hydroperoxysterols: (1) 24-hydroperoxy-24-vinyl-cholesterol and (2) 29–hydroperoxystigmasta-5,24(28)–dien-3β-ol as well as (3) fucosterol that has been isolated from *T. ornata* [58]. Hydroperoxide 2 is a new naturally occurring molecule and transformed into (4) 29-hydroxystigmasta-5,24(28)-dien-3-ol as a result of reaction with LAH. Sterols 1 and 2 showed cytotoxic activity compared to numerous other cancer cell lines. They investigated the benefit of fucoidan from *T. conoides* against the poor prognosis of pancreatic cancer (PC) progression. Fucoidan isolated and fractionated by ion-exchange chromatography has been tested for its potential against two (MiaPaCa-2 and Panc-1) lineages of genetically diverse PC cells. All the fractions studied had a significant regulation of cell survival as a function of dose and time. Coherently, fucoidans lead to apoptosis and activated caspase-3, caspase-8, and caspase-9 and cleaved PARP. Specific-pathway transcriptional analysis (QPCR profiling) identified inhibition of pathway molecule p57 and 38 NFκB with fucoidan-F5 in the correlated MiaPaCa-2 and Panc-1 cells. Also, fucoidan fraction F5 was also found to inhibit both the constitutive and DNA binding activity of NFκB (EMSA) mediated by TNF-α in PC cells. The upward regulation of cytoplasmic IκB levels and the significant reduction of NFκB-related luciferase activity strengthen the inhibiting potential of fucoidan in NFκB. In addition, fucoidan treatment boosts cellular p53 in PC cells. The findings indicate that fucoidan controls the development of PC and further imply that it could selectively point to p53-NFκB and determine apoptosis in PC cells. [59].

The impact of *T. ornata* on blood pressure and heart rate (HR) was assessed using normotensive Wistar-Kyoto and spontaneously hypertensive rats. In *T. ornata*, a significant ($p < 0.05$) HR reducing effect was produced. However, this effect was not observed with other brown algae tested. Evaluation of the ionic constitution present in the extracts disclosed that the salt solution with an equivalent ionic substance of each seaweed extract does not lead to a significant decrease in blood pressure in Sprague-Dawley rats [60]. The antiproliferative activities of *T. ornata* have been included in Table 2. The aqueous extract and the sulfated polysaccharide fractioned from *T. ornata* have been examined for their antiarthritic activity in Complete Freund's Adjuvant- (CFA-) induced arthritis in rodents. Antiarthritic activity of water extract of *T. ornata* (ATO) and sulfated polysaccharide of *T. ornata* (TSP) was evinced by the important decrease in arthritic score and paw volume. Antioxidant and inflammatory markers were found to be reinstated in the medically treated groups that was found to be in agreement with dexamethasone, a normal anti-inflammatory medicine [61].

4.6. Neuroprotective Activities. A flavonoid isolated from *T. ornata* in rotenone stimulated Parkinson's disease models of *Drosophila melanogaster* has been checked for the neuroprotective activity of myricetin. Myricetin produces a balance of oxidants and antioxidants, decreases oxidative stress, and inhibits apoptosis to delay neurodegeneration and sustain the dopamine level [66]. More molecular studies will be needed in the future to study myricetin defence processes in Parkinson's disease. Apart from these, the extracts of *T. ornata* exhibit several other biologically important properties as shown in Table 3, and the phytochemicals are represented in Table 4.

The several types of phenolic compounds present in the extract act as a dietary supplement and were found to relieve joint-related pain [65]. The methanolic extract was also found to have a protective action on the red blood cells [66]. Another study found that the ethanolic extracts exhibited excellent vascular inhibition in duck CAM assay and serve as potential cytotoxic agents [68]. The ethanolic extracts from this alga were found to possess antibacterial activity against several clinical pathogens such as *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*,

Table 2: Antiproliferative activities of *T. ornata*.

Sl. No.	Source	In vitro cancer cells	References
1	T. ornata	Retinoblastoma Y79 cells	[24]
2		Colon cancer HCT-116 cells	[62]
3		Breast cancer MCF-7 cells	[63]
4		Cervical cancer (HeLa) cells, breast cancer (MCF-7) cells, and liver cancer (HepG2) cells	[64]
5		Colorectal carcinoma HT-29 and cells Melanoma SK-MEL-28	[65]

Table 3: The biological properties exhibited by different extracts of *T. ornata*.

No.	Extract/compound	Biological property	Reference
1.	Methanol extract	Antibacterial	[34]
2.	Crude extract	Controls hyperglycemia	[49]
3.	Hentriacontane	Antimicrobial, anti-inflammatory, and antitumor activities	
4.	Sulfated polysaccharide and aqueous extract	Antiarthritic	[55]
5.	Methanolic extract	Cytotoxic activity against human retinoblastoma Y79 cell lines	[56]
6.	Fucoidan (F10)	Anti-inflammatory and antioxidant	[62]
7.	Sulfated polysaccharides	Antioxidant and anticoagulants	[63]
8.	Ethanol extract	Antioxidant and antimicrobial	[64]
9.	Glucosamine	Dietary supplement, pain relief for joint-related diseases	[65]
10.	Methanol extract	Antioxidant, antihemolysis, and anti-inflammatory	[66]
11.	Crude extract	Antiproliferative	[67]
12.	Ethanol extract	Cytotoxic, antiangiogenic, and vascular inhibition	[68]
13.	Turbinaric acid	Cytotoxic	[69]
14.	Methanol extract	Antimicrobial	[70]
15.	Alginate (Fraction G and M)	Antimicrobial, antioxidant, and cytotoxic activities	[71]
16.	Hexane, ethyl acetate, and methanol	Antibacterial	[72]
17.	Ethanolic extract	Antimicrobial, antioxidant, and wound healing activity	[73]
18.	1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester	Antimicrobial, antifouling, antiviral	[74]
19.	Hentriacontane	Antifungal against spore germination, antioxidant, antitumor activity, & antibacterial	
20.	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	Antiviral, anticancer, antimicrobial, antioxidant, cytotoxic, & anti-inflammatory properties	
21.	z,z-6,28-Heptatriactontadien-2-one	Vasodilator	
22.	n-Hexadecanoic acid	Antioxidant, pesticide, lubricant, 5-α reductase inhibitor	
23.	Tetradecanoic acid	Antioxidant, hypercholesterolemic, cancer-preventive	
24.	Cholest-5-en-3-ol, 24-propylidene-, (3-beta)	Antifungal activity	

Candida albicans, and Methicillin-resistant *Staphylococcus aureus*. This was further tested on zebrafish models and found to aid in effective wound healing and tissue regeneration capabilities [73]. Some compounds like Tetradecanoic acid, Heptatriactontadien-2-one also exhibit vasodilation and antihypercholesterolemic activities, respectively [74].

5. Biologenic Synthesis of Nanoparticles Using the Natural Products Using *Turbinaria* Species

Biogenic synthesis of nanoparticles has greatly fascinated scientists for the cause to elucidate the mechanism of synthesis. It can be predicted that nanomaterials with smaller sizes have a larger surface area and are more active [67]. Practically, all sort of biological entity such as microbes, algae, and plants has been utilized for the synthesis of nanoparticles in a shape and size-controlled way [68–72]. Because of the occurrence of various natural materials, plants and seaweeds are deliberated to have medical and pharmaceutical properties [73]. Hence, utilizing the seaweeds to biosynthesize nanoparticles has the prospective to provide an extra synergic effect with improved medicinal properties [74]. *Turbinaria* species function as tremendous candidates for the biosynthesis of nanoparticles such as silver and gold, as they are high resources of bioactive components, which

Table 4: The different types of phytochemicals extracted from *T. ornata*.

No.	Type of extract	Phytochemical	Reference
1.	Crude extract	Sulfate, phenol, tannins	[28]
2.	Crude extract	Hentriacontane, z,z-6,28-heptatriactontadien-2-one, 8-heptadecene, and 1-heptacosanol	[49]
3.	Extract	Fucosterol, 29-hydroperoxystigmasta-5,24-dien-3b-ol, 24xi-hydroperoxy-24-vinylcholestero	[52]
4.	Ethanol extract	Phenol, p-tert-butyl, dodecane, tetracosanoic acid, methyl ester, 5-eicosene, phenol-nonyl, pentanoic acid, 2-hydroxy-4-methyl-, methyl, 3-tetradecene, isobutyl pentyl ester, and 1,2-benzenedicarboxylic acid	[64]
5.	Aqueous extract	Flavanoid, saponin, tetradecanoic acid, n-hexadecanoic acid, hentriacontane	[74]
6.	Aqueous extract	Phenol, glycoside, terpenoids, flavanoid	[75]
7.	Methanol extract	Coumaric acid, ferulic acid, caffeic acid, gallic acid, catechin, syringic acid	[76]
8.	Ethanol extract	Quercetin, salicylic acid, chlorogenic acid, caffeic acid, gallic acid, catechin, epicatechin, syringic acid	
9.	Acetone extract	Fucosterol, oleic acid, palmitic acid, and glycerol-1-olyl-3-palmitoyl-2-galactoside	[77]
10.	Methanol extract	Fucosterol, 24-ketocholesterol, (22E)3b-hydroxycholesta-5,22-dien-24-one, saringosterol (sterols) and allenicnor-terpenoid, apo-90-fucoxanthinone	[70]
11.	Hexane extract	Alkaloids, terpenoids, flavonoids, polyphenols, and quinones	[78]

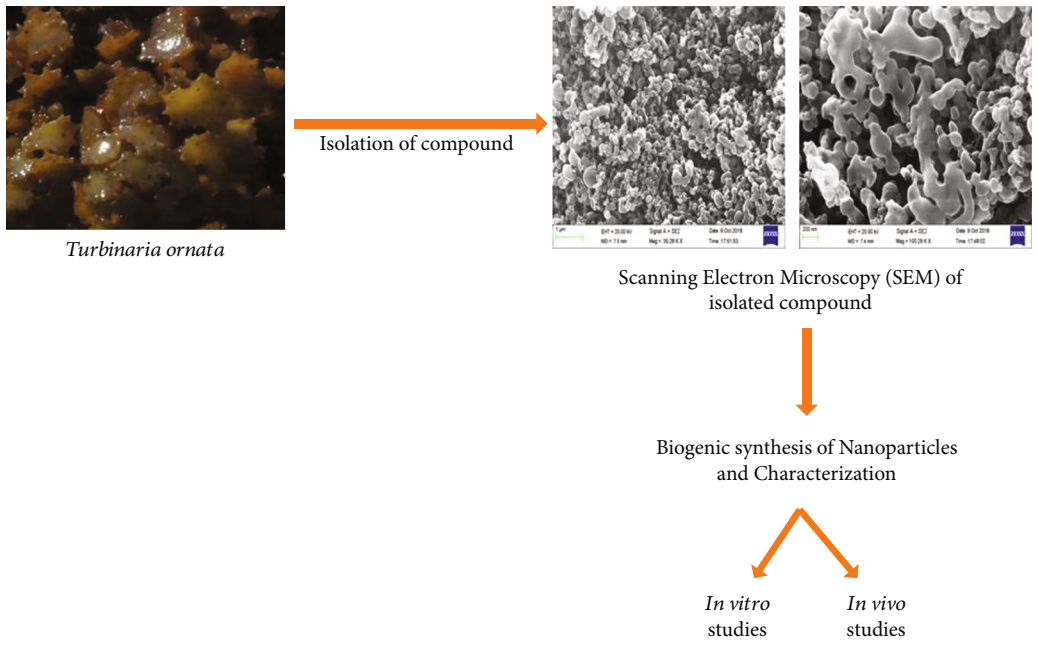

Figure 5: Biogenic synthesis of nanoparticles using natural compound.

perform as reducing as well as capping agents. The substantial quantity of exploration is crucial to distinguish and determine the function of particular biomolecules reliable for the reduction and capping of nanoparticles during the algae facilitated biosynthesis procedure. Through innovative developing characterization techniques, restrained and relative synthesis of natural compounds like laminarin [26] and fucoidan [75] centred nanoparticles have been prepared, were characterized to identify the presence of the nanoparticles such as Ultraviolet-visible (Uv-vis) spectroscopy, scanning electron microscopy (SEM), energy dispersive X-ray (EDX), X-ray diffraction (XRD), high resonance-

transmission electron microscopy (HR-TEM), Fourier Transform-Infrared (FTIR) spectroscopy, and dynamic light scattering (DLS) technique.

The compounds isolated using the seaweeds will facilitate enhancing the eminences of nanoparticles for their biomedical purposes as in Figure 5. Very few studies have been reported so far regarding the synthesis of nanoparticles using the natural compounds from brown seaweeds. Hence, extensive work should be carried out to evaluate and compare the biological functions and their applications.

6. Conclusion

Phytochemical screening for *T. ornata* in recent years has been successful in the extraction and isolation of several compounds. Bioactive compounds are considered to be the major constituents of *T. ornata* that exhibit numerous pharmacological effects, including antioxidant, anti-inflammatory, and anticancer potentials. These seaweeds are distributed widely and have adapted to a wide range of environmental conditions. This has allowed it to develop a wide range of resistance to environmental conditions, and this advantage caused considerable use of algae in contaminating bioremediation, resulting in water treatment that included the processing of useful biomass. Natural compounds from *T. ornata* and the nanoparticles derived from them are innately biocompatible, biodegradable, sustainable, and nontoxic, prompting researchers to employ them in the development of therapeutic drugs that are effective and could be used to treat various diseases. Purification and separation techniques should also be developed to ensure that there are no impurities in the product. There are insufficient details on the pharmacokinetics and toxicity of this alga and the isolated compounds, particularly toxicity to the target organs. To further verify the accuracy of *T. ornata* extracts and their isolated bioactive compounds for human well-being, in vivo studies and clinical evaluation should be undertaken.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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