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Review Article

Potential pharmaceutical and biomedical applications of Diatoms microalgae - An overview

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Naturally occurring two girdle band valves of diatoms are made up of siliceous material as covering the cell wall of the organism. The unicellular microalgae are coming under bacillariophyceae groups and identified more than 10,000 species. It found in various natural sources such as sea water, river, ponds and wastewater. Diatom is very small in size approximately 20-200 nm. The microalgae diatoms are used in pharmaceutical and biomedical industries due to the smaller in size and structure. Also, the nanoscale structures of diatom frustules are highly observed and using as a drug delivery material for therapeutic approaches. On other hand, diatom is one of the main sources of the food chain in the marine system. It is the photosynthetic organism which synthesis the required foods themselves by photosynthesis. Diatoms utilize the atmospheric CO_2 and releases oxygen through the biochemical process and maintain the atmospheric CO_2 level when the biological process occurred. In addition, the diatom microalgae contain the high amount of unsaturated fatty acids (50-60%), lipids, polysaccharides and other biomolecules which are used in the chronic and acute diseases treatments. In this review, we are mainly focused on the diatoms for therapeutic applications in different pharmaceutical and biomedical arena.

[Keywords: Diatom, Secondary metabolites, nanomaterials, bio-fuel]

Introduction

Diatoms are most diverse and spectacular nanostructure cell wall organisms which also have various bio-geo chemical properties. Diatoms are mainly classified into two types based on the valve face of the diatom frustules. The diatom frustules were constructed with pores (areolae), spines hyaline areas, processed and other characteristic features. The two types of classification are centrales (biddulphiales) and pennales (bacillariales). The centrales valve striae arranged basically in relation to a point and central areola be likely to appear symmetrical. The pennales have valve striae arranged in relation to a line and tend to appear zygomorphic (bilaterally symmetrical)[1].

The photoautotrophic type of diatoms is mainly involved in various bio-geochemical cycle and it is main ocean carbon producers. Diatom plays a main role in the ocean biogeochemical regulation, mainly to contribute the global carbon fixation in carbon and silicon cycles. Also, diatoms are involved in carbon sequestration which is uptake carbon dioxide and sunlight in the environment to produce oxygen. The microalgae diatoms are potentially candidate to absorb unlimited nitrogen and carbon from natural resources. The microalgae diatoms are dynamically focused on the biofuel industry as an alternative energy production based on easy for biomass cultivation in large scalable. Particularly, the diatoms have a high content of oils, fatty acids, steroids and other primary and secondary metabolites. The highly branched metabolites such as long chain fatty acids and lipids are mainly useful for pharmaceutical applications and biodiesel production[2]. The decomposition of diatoms frustules were sinking to the bottom of the sea that sediment of diatom called diatomite or diatomaceous earth. These materials have found under the sea and studied extensively. The

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materials were using for different commercial uses such as mineral filters, sorbents, anti-caking agents, abrasives, insulation materials and so on.[3] This review demonstrates the biomass of microalgae diatoms for nanomaterial syntheses and their potential pharmacological, biomedical and environmental applications.

Diatoms frustules using as drug delivery material

Very often, we are use water soluble drugs for treating different acute and chronic diseases. So, it cannot cross the biological membrane due to the poor solubility and stability nature of drug molecule. However, the biological derived nano materials exhibit novel properties such as solubility in both water and organic solvents. As such, scientists nowadays focused on encapsulating drug with polymers to effectively bind and act an active site particularly. The encapsulated nanodrugs are well action in particular targeted site as well, reduces the soluble nature of the drug delivery systems. Since it is nanosized, it can cross the biological barriers easily. On the basis, the diatom nanostructure frustules using as drug carrier materials for drug delivery applications. The two main steps in the drug release using diatom frustules were observed. Firstly, the release of the drug is on active site and then, slow and sustained release of drugs over the couple of weeks. The natural material of diatom silica can be successfully applied as a drug carrier for both oral and implant drug-delivery applications[3]. So, the diatom is considerable interest in developing biodegradable polymeric encapsulated nanoparticles for drug delivery[4]. Therefore, the diatom frustules are mainly use as drug delivery materials in delivery system. Fig. 1 shows the various applications of marine diatom in diverse fields.

Nanoparticles synthesis using diatoms

The integration of nanoparticles with biological molecules has lead to the development of potential anticancer and antimicrobial agents. Recently, the diatoms have reported the production of gold and silver metallic nanoparticles via eco-friendly method.

Diatom biosynthesis of metallic nanoparticles using extra and intra cellular extract by environmentally benign method. The diatom biosynthesized gold nanoparticles are effectively involves apoptosis induction, anti-microbial agents and also inhibit the pathogens replication in the host. The biosynthesis approach is generally flexible and diatoms can be applied for the preparation of a wide range of different metallic nanoparticles such as gold, silver and platinum. Diatoms mediated gold and silver metal nanoparticles are exhibits strong cytotoxicity against harmful microorganisms. The mass of diatom culture *Navicula atomus* and *Diadesmis gallica* were used for synthesis of EPS gold –silica bionanocomposites by eco-friendly method[5]. Also, the freshwater diatom *Stauroneis* sp. synthesized silicon-germanium nanoparticles in specific size and shapes by green chemistry way[6]. The diatom frustules enhanced the surface plasmon resonances of silver nanoparticles due to the silicon made frustules in the cell wall of microalgae. The micro algae derived nanomaterials have different therapeutic properties against chronic diseases and its due to the synergic effect of bioactive compounds surface of the synthesized metal nanoparticles[7].

Bioactive constituents in marine diatoms

Diatom contains a wide range of secondary metabolites such as lipids, esters, sterols and acyl lipids, flavonoids and proteins[8,9]. The diatom cell membrane encompasses of free fatty acids and silicon materials. Also, the diatom is a one of the rich sources of lipids, saturated and unsaturated fatty acids. These bioactive metabolites can be act as anticancer, antibacterial and antioxidant drugs. Table 2 shows the identified various bioactive metabolites from marine diatoms. The two monogalactosyl diacylglycerol were isolated from the marine diatom *Phaeodactylum tricornutum* and the compounds effectively using for apoptosis based anticancer drug[10]. In addition, the *O. mobiliensis* and *P. angulatum* marine diatom have the highest amount of phenolic content which reduces the free radical scavenging formation from the metabolic pathways[11].

Nutritional value of diatoms

The biomass production of diatom is a very important in the food and pharmaceutical industries. The artificial cultured medium provides sufficient strength to grow microalgae in large scale[24]. The algal nutrient medium contains various minerals such as N_2, Cl_2 which tends to modify the amount natural lipid content

in the microalgae biomass production. On other hand, salinity stress is also an important factor which represents the increasing metabolites production of brown and green algae also diatoms[12].

Diatom contains different nutritional values materials mainly essential macromolecules, enzymes and toxins. So, the microalgae as a good source animals feeds and nutritional food for humans. Many research studies attempted to increase nutritional value of microalgae and its biochemical composition by strain improvement technology. Principally, diatoms S*keletonema* sp. *Chaetoceros* sp. *Navicula* sp. and *Nitzschia* sp. are commonly using mass cultured in large scale bioreactor and separated as a diet from the mass product[13]. Many of other species are directly used as feed for shrimps during the larval stage. The marine diatoms contain important pigments which are chlorophyll a, c, carotenes and xanthophylls. However, the diatoms are basically rich in carotenoids, antioxidant compounds and phenolics which are important for food and nutrition industries.

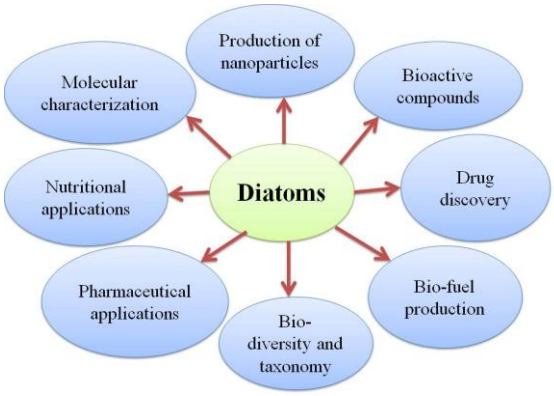

Figure 1. Application of diatoms in various fields

Therapeutic applications of diatoms

The marine derived chemical substances are protecting against various chronic and acute bacterial and viral diseases such as malignant, HIV and Alzheimer's diseases[14,15]. Diatoms are diversely involved in defense mechanism to produce chemical substances against various pathogenic organisms. The diatom contains various therapeutic compounds such as proteins and complex polysaccharides which are good platform in chronic disease management. Also, the marine algae are rich source of bioactive compounds that are used in various therapeutic applications[16].

The algae extracts were found to contain higher percentage of eisosapentaenoic acid and polyunsaturated fatty acid. These compounds play a key role in antimicrobial defense mechanism. Similarly, high levels of palmitoleic acid and other bioactive compounds found in the *P. tricornutum,* it is active against gram^{+} human pathogens. The marine diatom *Odontella aurita* contains carotenoid, fucoxanthin and sterols chemical substances which have potential antioxidant and anticancer properties[17]. Thus, the promising natural source of *Odontella aurita* extract is used as a novel antioxidant agent for human health.

Also, the natural water-soluble antioxidants were extracted from the benthic diatoms, *Achnanthes longipes*, *Navicula* sp. and *Amphora coffeaeformis*. The *A. coffeaeformis* diatom extracts exhibited the highest activity in DPPH radical scavenging. The benthic diatoms contain antioxidant compounds that effectively act against reactive oxygen species (ROS)[18]. However, the eco-geological variations and different seasons might be varied among the microalgae antioxidant property and their associated biological activity.

Production of bio-fuel using diatoms

Universally, we are using 80-85% petroleum hydrocarbons as an energy source for all mechanical and automobile devices. The hydrocarbons are mainly long chain carbon molecules it may create environmentally pollution in nature and mankind. The chemical production of diesel involves long purification process which may cause environmentally pollution and eventually expensive the cost of product. In this regard, we are insistent to develop a new source as environmental friendly with low cost green product. The biofuels are alternative for chemical energy and less expensive compared with fossil fuel production. Recently, the Europe and many other developing countries using biodiesel as alternative for diesel, and it is representing 82% of total biofuels presently. The marine algae are highly suitable for biodiesel production due to the naturally occurrence of lipids and long chain poly (un)saturated fatty acids[19,20]. Therefore, the microalgae diatom could be potential alternative for the biodiesel production in large scale industry.

Diatom act as environmental indicator

The diatom species are naturally stable in different environmental conditions such as acidification, salinity, high metal contamination and changes in lake trophic status by natural or manmade processes[21]. According to that, the region based specific diatoms and indices are used to evaluate the present environment characteristic of lake, marine and other water resources by the analyzing surface sediment level of diatom samples.

Moreover, the diatom shows more resistance to the heavy metals compares to other microbial community and eventually reduces metal toxicity in the water resources[22]. Therefore, the diatoms are effective candidates have the metal resistance property and can be used as an alternative tool for treating waste water.

Table 1 Potential bioactive compounds identified in diatoms and their applications

No	Bioactive compounds	Diatom culture	Applications	Cited
1	Aldehydes	*S.costatum*	Medicinal	[23]
2	Oil	*P.tricornutum*	Biodiesel	[24]
3	Sulfated polysaccharide	*Navicula sp.*	Biotechnological uses	[25]
4	Poly unsaturated short chain aldehydes	*T.rotula, P.delicatissima*	-	[26]
5	Oxylipins	*S. marinoi*	-	[27]
6	low-weight molecular compounds	*Cocconeis sp.*	Anti-apoptotic	[28]
7	Triterpenoids, monocyclic esters	*Rhizosole sp.*	Medicinal	[29]
8	Carotenoid- fucoxanthin	*O.aurita*	Antioxidant, Human nutrition	[30]

Future prospective

Diatoms perform incredible applications in nano-biotechnology, pharmaceutical, and environmental sciences. The broad diversity of diatoms could be also cultivated in mass culture and it is useful for therapeutic and commercial applications. The diatoms are found in marine and other natural forms such as lakes, seashores and rivers. The natural availability of diatoms is abundant and need to be improved for large scale production by different culturing techniques. On this above note, the diatoms microalgae easily attract present generation for medicinal and therapeutic research due to its impressive structural and medicinal properties.

Declaration

The author(s) declared no conflicts of interest in the study

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