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Facets of Diatoms and Its Potential Application

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Abstract

Diatoms, single-cell eukaryotic microalgae with silicon-dioxide (silica)-based cell walls ranging in size from tens to hundreds of micrometres, can be found in practically every aquatic habitat. Diatoms obtain their energy from sunshine and grow use organic matter as food (Carbon source) grown in aquaculture pond. They are the world's largest oxygen producers, producing 20% of all oxygen on the globe. Different species of diatoms are cultured/ grown in both marine and freshwater, which helps the juveniles as a primary source of food for shrimp and fish fry, which are the most interesting features to be used in nanotechnology, including biosensing, drug delivery, molecular separation, molecular biology, biomimetics, frustule formation, and electronic, photonic, optical, and structural materials.

Introduction

Diatoms are photosynthetic microalgae with a siliceous skeleton (frustule), found in almost every aquatic environment, including fresh, marine and brackish waters, soils, moist locations. They are solitary or colonial, non-motile or capable of limited movement facilitated by secretion of mucus along the raphe or slit like grove. These are autotoropic and occupy thephotic zone in any aquatic body. These are formally classified as belonging to the Division Chrysophyta, Class Bacillariophyceae and about 20-200 microns in diameter or length, growing to a maximum of 2 millimeters. The cell may be solitary or colonial. Diatoms are divided into two orders. The Centrales, which have valve striae arranged around a point, an annulus or a central areola, and are radially symmetrical. The Pennales have valve striae arranged in lines that are bilaterally symmetrical. The diatom frustule is ornamented with pores (areolae), processes, spines, hyaline areas and other distinguishing features. These photoautotrophic diatoms are involved in various biogeochemical cycles, and it is the main ocean carbon producer. Diatom plays the main role in ocean biogeochemical regulation, by its contribution to the global carbon and silicon fixation. Thus diatoms are involved in carbon sequestration, which uptake carbon dioxide and sunlight in the environment to produce oxygen. The microalgae diatoms are dynamically focused by the biofuel industry as alternative energy production base due to easy biomass cultivation. Rich oils, fatty acids, steroids, and other metabolites in diatoms, makes it suitbable as a biofuel producer. The highly branched metabolites such as long-chain fatty acids and lipids are mainly useful for pharmaceutical applications and biodiesel production. This article describes the biomass of microalgae diatoms for syntheses of biomaterial and their potential aquaculture, environmental and biotechnological applications.

Diatoms in Aquaculture

Diatom is considered beneficial algae in aquaculture ponds due to its biochemical composition. They do not contain cellulose but are rich in sterols, polyunsaturated fatty acids, calcium, magnesium, iron, and other inorganic salts and various vitamins, can be well-fed and digested by aquatic animals. At the same time, they have a good effect on water purification and the ecological balance of the water body. Therefore, water bodies with diatom-dominated phytoplankton communities have been considered one of the best aquatic environments in aquaculture. Environmental and chemical factors influence diatom growth, and the concentration of silicon is an important factor as diatoms require silicon to form their cell wall. Nualgi is a patented (PCT/IN05/00195 US patent application no. 0070275856) nanosilica-based micronutrient mixture that has been used successfully in shrimp ponds in Southern India to promote diatom blooms. *Synedra* sp. is the most common diatom found in most freshwater bodies and can remove nutrients from the freshwater aquaculture ponds. Farmers are exploring algal based feed for aquaculture to increase production levels beyond that obtained using only formulated feeds. Some aquaculture farmers, particularly shrimp farmers, evaluate the abundance of the diatoms communities present in the pond water. They observed that enriched diatoms in their aquaculture ponds is desirable. Hence, there is an urgent need for desirable nutrition enriched livefeed for hatchery (larval stage) to harvest (adult stage) in shrimp as well as fin fishes (Kathir *et al.,* 2017). Diatomix is a novel micro-nutrient mix that stimulates the growth of diatoms. Diatomix helps generate live fresh feed in pond water, which helps achieve sustainable growth, disease-free, healthy feed for the survival of shrimps and fish, and achieve maximum production. In the shrimp pond, diatomix saves up to 15 percent dependence on commercial feed, since shrimp prefers live diatoms rather than pellet feed.

In pond unique form of plankton growth with "Golden Brown" water colour indicates the pond is enriched with diatoms species. Diatom species such as *Chaetoceros* sp*., Navicula* sp., *Nirzschia* sp., *Skeleronema* sp., *Cyclotella* sp., *Synedia* sp., *Achnanthes* sp. and *Amphora* sp. are often found in pond water which helps in stabilising the pond ecosystem and in minimising the fluctuations of water quality parameters. It also reduces toxic substances *viz* ammonia-nitrogen and heavy metals from pond water and prevents growth of filamentous and undesirable algae in pond. Healthy diatom blooms, provides suitable turbidity, reduces cannibalism in shrimp farming. Diatoms competing for nutrients and lower the pathogenic bacterial population. They are the most important components in the aquaculture system. A thoughtful utilisation of the diatom community will in a pond ecosystem with proper management practices certainly enhances fish and shrimp production.

Diatoms for the Synthesis of Biomaterial

Biomineralisation is the process of producing mineral elements from organic compounds which are involved with biosystems. Biosilica, is produced by diatoms, naturally and because of their unique structure, frustules find wide industrial applications such as use in water filters, building materials, chromatography supports, and drug carriers against cancer cells. The production of platinum metal (Pt) has recently been shown employing diatoms such as *Melosira nummuloides* in culture conditions. The cultivation of *Melosira nummuloides* has dihydrogen hexachloroplatinate and hexahydrate, which have been used for the production of platinum metal from frustules. Cadmium metal (Cd) is another element that can be produced by diatom *Pinnularia* sp. The biosynthesis approach is generally flexible, and diatoms can be applied to prepare a wide range of different metallic nanoparticles such as gold, silver and platinum. Diatoms mediated gold and silver metal nanoparticles exhibits strong cytotoxicity against harmful microorganisms (Rosely *et al.,* 2013). The mass culture of *Navicula atomus* and *Diadesmis gallica* was used to synthesise EPS gold-silica bionanocomposites by an eco-friendly method. Also, the freshwater diatom *Stauroneis* sp. synthesised silicon-germanium nanoparticles in specific sizes and shapes by green chemistry way. The diatom frustules enhanced the surface plasm on resonances of silver nanoparticles due to the silicon-made frustules in the cell wall of microalgae. Themicroalgae-derived nanomaterials have different therapeutic properties against chronic diseases, and it is due to the synergic effect of bioactive compounds surface of the synthesized metal nanoparticles.

Diatoms as an Energy Source

Algae are believed to be a good renewable energy source because of their rapid growth rate and their ability to be cultivated in wastewater or wasteland. Several companies are making efforts to reduce capital costs and operating costs to make algae fuel production viable. Algae theoretically are the fastest growing plant and produce more oil or biomass per acre compared to other crops. However, the energy efficiency ratio and carbon and water footprint for algal-based biofuels still need to be evaluated to understand the environmental impact of algal-derived biofuels fully. Almost 80-85% of petroleum hydrocarbons as an energy source for all mechanical and automobile devices (Fimbres-Olivarría *et al*., 2016). Hydrocarbons are mainly long-chain carbon molecules, which may create environmental pollution

in nature. The chemical production of diesel involves a long purification process that may cause environmental pollution and eventually expensive product costs. In this regard, we are insistent on developing a new source as environmental friendly with the low-cost green product. Biofuels are alternative for chemical energy and less expensive compared with fossil fuel production. Recently, Europe and many other developing countries have been using biodiesel as an alternative for diesel, representing 82% of total biofuels presently. Marine algae are highly suitable for biodiesel production due to the natural occurrence of lipids and long-chain polyunsaturated fatty acids. Therefore, the microalgae diatom could be a potential alternative for biodiesel production in large scale industries.

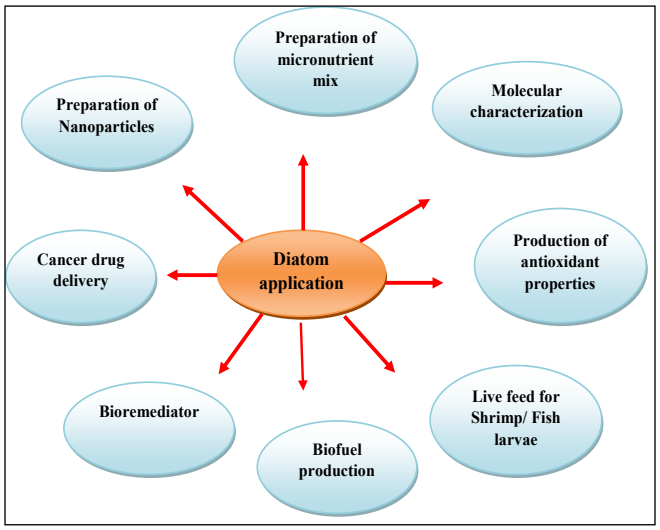

Figure 1: Application of diatom in various fields

Diatom Acts as an 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 artificial processes. The region-based specific diatoms and indices are used to evaluate the current environment characteristic of the lake, marine and other water resources by analysing surface sediment level of diatom samples. Quality of wastes such as solid and liquid wastes and gaseous emissions depend on the nature of the industry, raw materials used, manufacturing housekeeping and process. There are several methods used all over the world to overcome this problem. These methods consist of degradation physically, chemically or biologically. Due to release of secondary materials, chemical and physical methods are not considered suitable for getting rid of wastes. Biological methods and their unique features qualify them to use in the biodegradation of wastes. Biological methods involve transforming or mineralising contaminants into less toxic forms. Biological methods have the main advantage of degrading a wide range of organic waste substances and turning them into water and soil friendly products. In such biodegradation process bacteria, algae, and diatoms can be used. The diatoms are therefore, effective and alternative tools for treating wastewater.

Conclusion

Diatoms are performing incredible applications in aquaculture and allied industries. The broad diversity of diatoms could also be cultivated in mass culture, and it is useful in different applications such as bioindicators, nutraceuticals, cosmetics, phycoremediation, aquaculture, *etc*. The diatoms are found in marine and other natural forms such as lakes, seashores, rivers and wastewater. The natural availability of diatoms is abundant and need to be improved for large scale production by different culturing techniques. Thus, growing diatoms is the most sustainable and economical solution to meet the future demand of energy crises. On the above note, the diatoms easily attract the present generation for aquaculture and allied research due to their impressive structural and properties.

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