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Review

A review on biosynthesis of nanoparticles by marine organisms

N. Asmathunisha, K. Kathiresan*

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai 608502, India

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ABSTRACT

Marine organisms produce remarkable nanofabricated structures in cell wall, shells, pearls and fish bones. Marine microorganisms such as bacteria (*E. coli*, *Pseudomonas* sp.), cyanobacteria (*Spirulina platensis*, *Oscillatoria willei*, *Phormidium tenue*), yeasts (*Pichia capsulata*, *Rhodospiridium diobovatum*), fungi (*Thraustochytrium* sp., *Penicillium fellutanum*, *Aspergillus niger*), and algae (*Navicula atomus*, *Diadesmis gallica*, *Stauroneis* sp. *Sargassum wightii*, *Fucus vesiculosus*) are reported to synthesize inorganic nanoparticles either inside or outside cells. Mangroves (*Rhizophora mucronata*, *Xylocarpus mekongensis*), salt marshes (*Sesuvium portulacastrum* and *Suaeda* sp.) and sand dune (*Citrullus colocynthis*) are also capable of synthesizing the nanoparticles, in addition to marine animals such as finfish and sponges. Biosynthesis of nanoparticles may be triggered by several compounds such as carbonyl groups, terpenoids, phenolics, flavonones, amines, amides, proteins, pigments, alkaloids and other reducing agents present in the biological extracts. Marine bio-nanotechnology has a great promise in nanomedicines, food stuff, pharmaceuticals and fabric industries for the future.

Contents

1. Introduction

Marine bio-nanotechnology is an exciting and upcoming area of research. The biologically diverse marine environment has a great promise for nanoscience and nanotechnology. Marine organisms produce remarkable nanoparticles of 1–100 nm size which constitute nanofabric structures such as seashells, pearls and fish bones. Diatoms and sponges are constructed with nanostructured cover of silica and coral reefs with calcium, arranged in remarkable architectures [1]. Dolphins and whales have rough skin surface due to presence of nanoridges. These ridges enclose a pore size of 0.2 μm^2 which is below the size of marine fouling organisms and hence, there is no attachment of biofoulers [2]. In spite of great potential, the marine bio-nanotechnology has limited research work. Most of the studies on biosynthesis of nanoparticles have been restricted to terrestrial organisms. This review was synthesized on available information on the marine biosynthesis of nanoparticles and their mechanism and biological activities to bring out the prospects of marine nanobiotechnology.

2. Types of nanoparticles

Nanoparticles are classified into major types viz. organic and inorganic nanoparticles. Carbon nanoparticles are called the organic nanoparticles. Magnetic nanoparticles, noble metal nanoparticles (platinum, gold and silver) and semiconductor nanoparticles (titanium dioxide and zinc oxide) are grouped as inorganic nanoparticles. Inorganic nanoparticles are increasingly

* Corresponding author. Tel.: +91 4144 243223x210; mobile: +91 9442068003.
E-mail address: kathirsum@rediffmail.com (K. Kathiresan).

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Table 1
Outline of work on biosynthesis of nanoparticles using marine organisms.

Organism	Species	Name of the species	Types of nanoparticles	Size (nm)	Biological activity	Author and year
Marine microbes	Cyanobacteria	*Spirulina platensis*	Silver Gold Biometallic	7–16 6–10 17–25	–	Govindaraju et al. (2008)
		Oscillatoria willei	Silver	100–200	–	Mubarak et al. (2011)
		Phormidium tenue	Cadmium	5	–	Mubarak et al. (2012)
	Bacteria	*E. coli*	Silver	5–20	Antimicrobial	Kathiresan et al. (2010)
		Pseudomonas sp.	Silver	20–100	–	Muthukannan and Karuppiah (2011)
	Yeast	*Pichia capsulata*	Silver	50–100	–	Manivannan et al. (2010)
		Rhodosporidium diobovatum	Lead	2–5	–	Sesadhri et al. (2011)
	Fungi	*Penicillium fellutanum*	Silver	5–20	–	Kathiresan et al. (2009)
		Thraustochytrium sp.	Silver		–	Gomathi (2009)
		Aspergillus niger	Silver	5–35	Antimicrobial	Kathiresan et al. (2010)
	Diatoms	*Navicula atomus*, *Diadesmis gallica*	Gold	9 Gold–silica	– 22	Adam et al. (2011) –
		Stauroneis sp.	Silicon–germanium			Mubarak et al. (2011)
Marine algae	Seaweed	*Sargassum wightii*	Gold	8–12	–	Singaravelu et al. (2007)
		Sargassum wightii	Silver	–	Antibacterial	Govindaraju et al. (2009)
		Turbinaria conoides	Silver	–	Fabric strengthening	Mercy Sheeba and Thambidurai (2009)
		Gelidiella acerosa	Silver	22	Antifungal	Vivek et al. (2012)
		Ulva fasciata	Silver	28–41	Antibacterial	Rajesh et al. (2012)
	Brown alga	*Fucus vesiculosus*	Gold	–	Biosorption	Mata et al. (2008)
	Marine alga	*Cladosiphon okamuranus* *Kjellamaniella crassifolia*	Gold	8.54–10.74	–	Suwicha et al. (2010)
Marine spermatophytes	Mangroves	*Xylocarpus mekongensis*	Silver	5–20	Antimicrobial	Asmathunisha et al. (2010)
		Rhizophora mucronata	Silver	60–95	Larvicidal	Gnanadesigan et al. (2011)
	Salt marshes	*Sesuvium portulacastrum*	Silver	50–90	Antimicrobial	Asmathunisha (2010)
	Sand dune	*Citrullus colosynthis*	Silver	85–100	Anticancer	Satyavani et al. (2011)
	Coastal plant	*Prosopis chilensis*	Silver	5–25	Antibacterial to control vibriosis in *Penaeus monodon*	Kathiresan et al. (2012)
Marine animals	Sponges	*Acanthella elongata*	Gold	7–20	–	Inbakandan et al. (2010)
	Fin fish	Cod liver oil	Silver	5–10	–	Khanna and Nair (2009)

used in drug delivery due to their distinctive features such as ease of use, good functionality, biocompatibility, ability to targeted specific cell and controlled release of drugs [3].

3. Biological synthesis of nanoparticles

Use of chemical and physical method in the synthesis of nanoparticles is very expensive and cumbersome. The chemical and physical methods of nanoparticle synthesis lead to the presence of some toxic chemicals absorbed on the surface that may have adverse effects in applications, so there is a growing need to develop environmentally benign nanoparticles. Researchers have used biological extracts for the synthesis of nanoparticles, by adopting simple protocols, involving in the process of reduction of metal ions by using biological extracts as a source of reductants either extracellularly or intracellularly.

Synthesis of nanoparticles may be triggered by several compounds such as carbonyl groups, terpenoids, phenolics, flavonones, amines, amides, proteins, pigments, alkaloids and other reducing agents present in the plant extracts and microbial cells [4–8]. The exact mechanism of nanoparticles synthesis by biological extracts is yet to be understood.

4. Biosynthesis of nanoparticles by marine microorganisms

Microorganisms such as bacteria, cyanobacteria, actinomycetes, yeast, fungi, and algae are known to synthesize inorganic nanoparticles such as gold, silver, calcium, silicon, iron, gypsum and lead, in nature either inside or outside cells. At present, microbial methods in the synthesis of nanomaterials of varying compositions are extremely limited and confined to metals, some metal sulfide, and very low oxides. All these are restricted to the microorganisms of terrestrial origin. Marine microbes have potential ability to synthesis nanoparticle for the reason that the marine microbes exist in the sea bottom, over millions of years in the past for reducing the vast amount of inorganic elements deep in the sea. It is important to study the marine microbes for biosynthesis of nanoparticles and to elucidate biochemical pathways that lead to metal ion reduction by the different classes of microbes to develop nanoparticles. The biosynthesis of nanoparticles with the use of microorganisms depends on culture conditions and hence standardizing these conditions for high synthesis of nanoparticles is necessary. Many marine microorganisms are known to produce nanostructured mineral crystals and metallic nanoparticles with properties similar to chemically synthesized materials, while exercising strict control over size, shape and composition of the particles (Table 1).