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Harvesting marine biotechnology

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Harvesting marine biotechnology

The DBT is likely to address several developmental issues in the sector of aquaculture and marine biotechnology through supporting projects in priority areas.

The interest in marine sector has been growing in recent years globally. It is reported that less than 1 percent of the extant marine and terrestrial bacteria have been isolated and studied.

Research in aquaculture and marine biotechnology is leading towards development of new and improved products from the seas and ocean through fundamental understanding of the genetic, nutritional, and environmental factors that control the production of primary and secondary metabolites, identify bioactive compounds, determine mechanisms of action and function of natural production system and provide models for new lines of selectively active materials for application in medicine and source for chemical industry.

The Indian sub-continent, having a coastline of above 7,500 km, offers potential for pursuing marine biotechnology research for discovering novel biologically active compounds that could be used in a large spectrum of human ailments and harvest bioresources for sustainable development.

Indian labs are concentrating on bioactive substances from marine animals such as horseshoe crab, green mussels, sponges and corals etc. for characterization of novel molecules. Some of the novel molecules have been isolated and commercialized.

The Department of Biotechnology (DBT) has been promoting marine biotechnology in India for last one and half decade. A large number of R&D programs sponsored on marine biotechnology are leading towards products and process development and development of viable technology for commercial production systems.

Pharmaceuticals and bioprocessing

Many bioactive substances from the marine environment have been isolated and characterized and several of them have shown great promise for the treatment of human diseases. Compound manoalide from Pacific sponges reported the development of more than 300 chemical analogs. A significant number of these are going for clinical trials as anti-inflammatory agents. Exploitation of natural agents from the sea has been a hindering problem with limited or sporadic distribution, production and development of selected metabolites. It suggested the need for exploring them either from whole organisms or in vitro cell or tissue cultures of plants and animals. It may help in developing large and complex molecules and synthesize them for standard production through fermentation process.

Enzymes

The ocean is the source for novel enzymes, produced by marine bacteria having range of unusual properties. Some are salt-resistant, a characteristic that is often advantageous in industrial processes. The extracellular proteases are of particular importance and it can be used in detergents and industrial cleaning applications in cleaning reverse-osmosis membranes. Vibrio species have been found to produce a variety of extracellular proteases. Species of Vibrio alginolyticus are reported to produce six proteases, including an unusual detergent-resistant, alkaline serine exoprotease. Researchers have developed methods to induce a marine alga to produce large amounts of the enzyme superoxide dismutase, which find enormous opportunity in medical, cosmetic, and food sectors.

Thermostable DNA-modifying enzymes, such as polymerases, ligases, and restriction endonucleases, already have important research and industrial applications. It has provided the first archaeon (Thermus aquaticus) from which thermostable DNA polymerases were isolated. An unusual group of marine microorganisms is reported to be explored for novel enzymes, isolated of hyperthermophilic archaea, which can grow at temperatures over 100°C. Archaea typically are found in extreme environments, such as hot springs, animal guts, hydrothermal vents, sewage sludge digesters, and hypersaline habitats, including the Great Salt Lake. These novel enzymes became the basis for the polymerase chain reaction (PCR), a useful technique for studying genetic material.

Biomolecular materials

Recent research has demonstrated that marine biochemical processes can be exploited to produce new biomaterials through a mechanisms used by marine diatoms, coccolithophorids, molluscs and other marine invertebrates to generate elaborate mineralized structures on a nanometer scale. With the unusual and useful properties, research is underway on engineering of the processes for creating bioceramics useful in manufacturing of medical implants, automotive parts, electronic devices, protective coatings and other novel products. Tissue Engineering is another promising area having immense potential in biomedical sciences, useful in organ development, replacement and substitution of damaged tissues.

Many marine plants and animals remain free of attached bacteria, either because they produce repelling compounds or because their surface structure neutralizes bacterial adhesives. A product reported to be made available by the seagrass Zostra marina (eelgrass), for example, is an effective agent for preventing fouling by bacteria, algal spores, and a variety of hard-fouling barnacles and tubeworms. Studies on molecular characterization of natural fouling resistance could provide new strategies for fouling control in industrial pipelines or heat exchangers, improved design of trickling filters or aquaculture circulation systems, and control of biofilm infections of medical implants and prosthetic devices.

Biomonitors and biosensors

Marine organisms can provide the basis for development of biosensors, bio-indicators, and diagnostic devices for medicine, aquaculture and environmental monitoring. Microbial diseases are recognized as a major factor limiting the future of the shrimp aquaculture industry in India, with lost productivity estimated at $6-8 billion per annum.

Biomonitor gene probes can be used to identify organisms that pose health hazards or it may also be useful in research.

Bioremediation

Bioremediation shows great promise for addressing problems in marine environments and in aquaculture. These problems include catastrophic spills of oil in harbors and shipping lanes and around oil platforms; movement of toxic chemicals from land, through estuaries, into the coastal oceans; disposal of sewage sludge, bilge waste, and chemical process wastes;

reclamation of minerals, such as manganese; and management of aquaculture and seafood processing waste. The full potential for marine organisms and processes to contribute new waste treatment and site remediation technologies can be realized by understanding of unique conditions in marine environments viz. oxidation- reduction (redox) states and its fluctuation in coastal and estuarine sediments.

Biopesticides

Natural marine products have the potential to replace chemical pesticides and other agents used to maximize crop yields and growth potential. Unique marine biopesticide in use today was developed from a bait worm's toxin known to ancient Japanese fishermen. This natural pesticide has demonstrated activity against larvae of the rice stem borer, the rice plant skipper, and the citrus leaf miner, among other pests. Novel biopesticides are required to be explored using marine species.

Energy biomass

It is estimated that approximately 40 percent of all primary energy production, or photosynthesis, occurs in the seas. In this process, oceanic plants viz. phytoplankton, seaweeds and sea grasses in uptake of carbon dioxide (CO2) and with light energy from the sun and convert it into organic carbon and oxygen. The oceans contain 50 times as much carbon dioxide as does the atmosphere and this abundant source of fuel for energy production has not been tapped commercially because it is not competitive with agricultural produce harvested, traditional sources of biomass and biomass is not competitive with other types of fuels. Marine microalgae are being genetically engineered to boost their lipid content, with the aim of providing a source of alternative fuels that is more economical than are conventional sources. Biotechnology is being used to convert biomass to ethanol and other alternative forms of energy and chemical feedstocks.

Aquaculture

Aquaculture, which long has been practiced in Asia and is increasingly popular in the US, Europe, and South America, will benefit tremendously from the use of new molecular tools and processes. With worldwide seafood demand projected to increase 70 percent in the next 35 years, and harvests from capture fisheries stable or declining, aquaculture will have to produce seven times as much as seafood generates now to supply global demand by 2025. The use of modern biotechnology to intervene in the rearing process and enhance production of aquatic species holds great potential not only to meet this demand, but also to improve competitiveness in aquaculture.

Enhancing reproduction and early development

Biotechnology can be applied to enhance reproduction and early development of cultivated aquatic organisms. The resulting benefits could include year-round production of gametes and fry of economically valuable species and creation of new markets for specialized, genetically improved broodstock. Similarly, aquaculture biotechnology may provide techniques for improving the reproductive success and survival of endangered species, thereby helping to preservation of the diversity of ecosystem. Improved technologies for cryopreservation of gametes and embryos and delivery systems for administration of natural and synthetic hormones, enhancing understanding of the pharmacokinetics of uptake and release of administered hormones need to be pursued.

Improving quality and value

Opportunities exist to apply biotechnology in improving seafood processing, for which dedicated research should be conducted to develop and improve technologies.

Genetic resources and biodiversity conservation

The preservation and enhancement of biodiversity in natural systems is an important priority for supporting programs to maintain and enhance biodiversity in aquatic systems through cultivation, stocking and enhancement. The tools of biotechnology can be used to identify and characterize important aquatic germplasm, including endangered species.

The marine environment represents a particularly fertile source for new bacteria, as evidenced by the recent discovery of unusual "cold water" archaea 100-500 meters deep in the oceans. These archaea comprise a high percentage of the total bacterial ribosomal RNA present in seawater samples, yet they have not been isolated in pure culture.

Viruses are another newly appreciated element of marine biological diversity. Specific viruses that infect species of marine phytoplankton have been cultured from coastal as well as open ocean sites. Viral infection of higher forms of marine life almost certainly affects global ocean processes, such as photosynthesis. Studies on marine viruses will provide new materials for development of genetic and biotechnological tools that can be used to study and manipulate marine organisms which can be used to genetically engineer higher forms of marine life.

Molecular ecology and resource management

Research on marine ecology can be conducted to benefit fisheries management. The need for development of understanding marine ecological systems must be developed in order to specify the "normal" baseline level of function and to monitor and predict potential changes and perturbations of systems due to physical, chemical, or biological impacts. The development of predictive models for analyzing potential global climate changes depends on the acquisition of fundamental information on molecular regulatory mechanisms of photosynthesis in the oceans.

New molecular tools and techniques

New molecular tools should be applied to gain insight into the basic molecular and cellular processes by which marine organisms adapt to extreme environments. These tools should be exploited to accelerate the discovery of unknown marine microorganisms and to expand understanding of known varieties. As new life forms and processes become known and as understanding of them grow, marine biotechnology will make significant contributions to the social and economic well-being.

Enhancing biomedical models

Marine organisms can provide unique models for research on biological and physiological processes, which could help in studies of developmental, cellular, and molecular aspects of marine organisms. The model systems can provide insights into the basis of disease mechanisms and pathogenesis in humans. Use of mammalian organisms as a basis for the development of some types of human disease models may be neither feasible nor cost effective, where aquaculture animals may be more suitable. Methods need to be developed for culturing tissues from marine organisms.

Impact of seas on global environments

Marine biotechnology may be useful in assessing the role of the oceans in affecting climate change and the global carbon cycle. Molecular techniques can facilitate and enhance the measurements of CO2 concentrations and total CO2 inventories being developed for global ocean models of carbon cycling.

Scientists are required to build a fundamental understanding of marine organisms and their specific adaptations to and interactions with their environment for developing new applications for marine products and processes, analyzing global climate change and improving fisheries management.

DBT initiatives

The Department of Biotechnology is likely to address several developmental issues in the sector of aquaculture and marine biotechnology through supporting projects in priority areas. Projects have been launched and yielded valuable research leads.

During the Eleventh Plan, apart from R&D funding support, major initiatives are likely to be taken up on supporting projects in gaps and priority areas. The possibility of establishment of an autonomous center for marine biotechnology is likely to be considered for discovering novel molecules of therapeutic and biological value. The institute can be dedicated for judicious utilization of marine bioresources using biotechnology tool and techniques. The serious constraint in manpower development in marine biotechnology could be overcome by introducing few M.Sc. / M.Tech. courses in Marine Biotechnology in the country. While understanding the unraveling ocean's hidden wealth and to gear up on scientific knowledge of marine life, establishment of oceanaria is essential as it would help in studying ocean biodiversity through awareness creation.

Note: The views expressed are of the author and not necessarily those of the Department of Biotechnology, Ministry of Science & Technology, Govt of India.