Pocket K

Marine Biotechnology

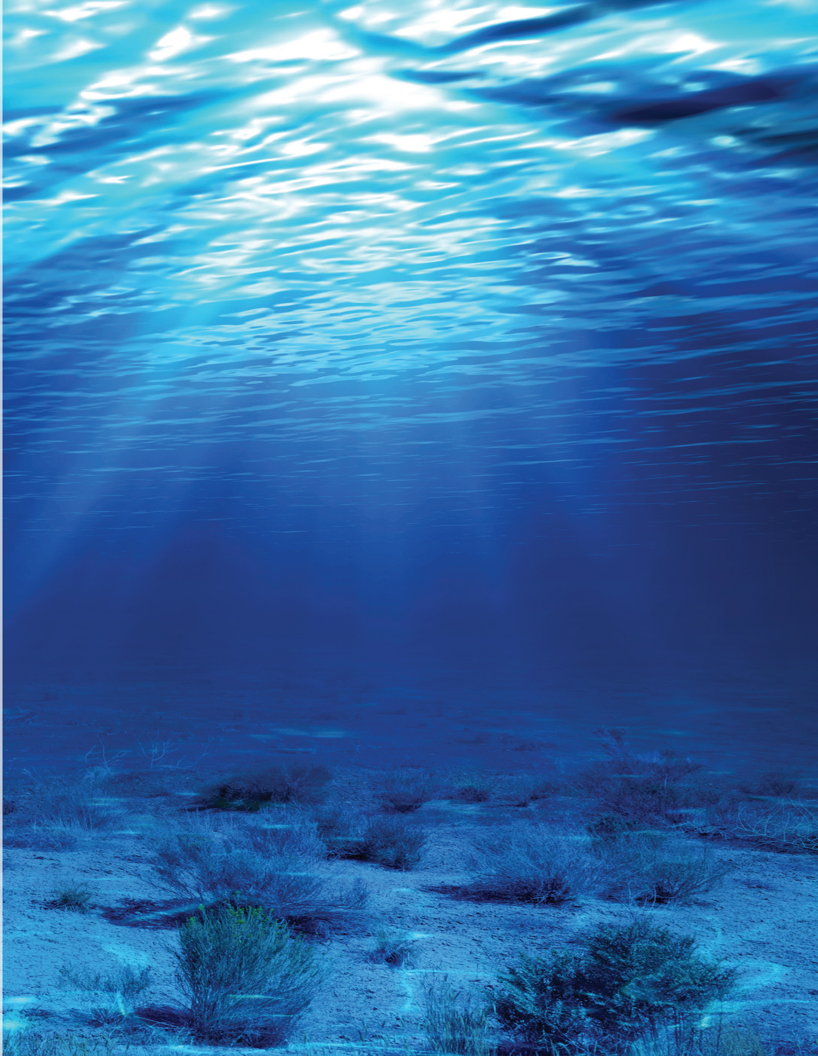
ISAAA
International Service for the Acquisition of Agri-Biotech Applications

Global Knowledge Center on Crop Biotechnology

Life started in the sea. The earth's surface is mostly ocean, which has the most ancient and most diverse forms of life. Thus, the marine environment is the treasure throve of biological and chemical diversity among all types of ecosystems. It has a wide variety of living organisms, from bacteria to eukaryotes, as well as unique chemical compounds which are of great importance to medicine, nutrition, cosmetics, agriculture, and other industries. Biotechnological applications can be used to harness the potential of the marine environment for human benefit and fundamental biological progress.[1, 2, 3]

Marine Biotechnology

Marine biotechnology is the creation of products and processes from marine organisms through the application of biotechnology, molecular and cell biology, and bioinformatics. It is the field of science that deals with ocean exploration for development of new pharmaceutical drugs, chemical products, enzymes, and other products and processes. It also deals with the advancement of aquaculture and seafood safety, bioremediation, biofuels, among others.[1]



Applications of Marine Biotechnology

Aquaculture and Fishery

Biotechnology has the potential to offer solutions to several problems areas in aquaculture.

Reproduction

Several fishes do not spawn spontaneously when placed under captive conditions. In the past, fish gonadotropin, a group of hormones that stimulate reproduction, were produced in small amounts by extraction and purification from crude preparations of thousands of pituitary glands. At present, large quantities of highly purified gonadotropin can be produced in the laboratory through recombinant DNA technology.

Hermaphrodism is a common phenomenon in many coral reef fishes. Some species are male in the early stages of their life cycle, and turn female on the later stages (protandrous hermaphrodite) or vice versa (protogynous hermaphrodite). It is necessary to have both sexes in the broodstock always. Through genetic engineering, sex of the species can be regulated as it reaches maturity.[3]

Nutrition

Trash fish or wild fish species for fish meal as protein source for aquafeeds are very limited. Thus, plant-based protein sources is a sustainable option with additional advantage of being cheaper. However, most plants have anti-nutritional characteristics that are not favorable for feed utilization. For instance, carnivorous fishes have limited ability to use up carbohydrates due to the digestability of polysaccharides. To address this concern, carbohydrate metabolism of salmonid fish was enhanced through genetic engineering. Glucose transporter and hexokinase genes were transferred to the salmonid fish.

Fish oil is economically important in fish feed production, as well as to human health. The demand for fish oil continued to grow alongside the expansion of aquaculture industry because it is a major lipid source in aquafeeds. The aquaculture industry takes up to almost 90 percent of the global fish oil production. With this growing demand, it is necessary to have other sources of fish oil.[3]

Rothamsted Research scientists developed camelina oilseed plants that were genetically engineered to produce omega-3 fish oils in their seeds. Omega-3 fish oils are known to be beneficial components of human nutrition. GM camelina has the potential to supply healthful fish oil for human diet.[4]

Health Management

Traditional disease diagnosis involves analysis of cells and tissues of organisms, which takes a long time to be done. Modern methods use polymerase chain reaction, a technique used in molecular biology to focus on a segment of the DNA and copy it million times over in a short span of time.[5] PCR enables accurate identification of pathogens in marine organisms even without visual symptoms of the disease. Since marine organisms are capable of transboundary movement, it is vital to diagnose diseases accurately because of their implication to quarantine and trade.[3]

The shrimp industry faces risk of losses due to several viral pathogens such as the white spot syndrome virus (WSSV), yellow head virus, Taura syndrome virus, hepatopancreatic parvovirus, and baculoviruses. Scientists find it hard to devise treatment for viral diseases in crustaceans like shrimps because they do not possess true adaptive immune response system and they react to diseases by non-specific innate immune mechanisms. Identification and characterization of genes involved in immune response in shrimps are vital to comprehend host-pathogen interactions. Genes from giant tiger prawns (*Penaeus monodon*) and Japanese tiger prawn (*P. japonicus*) exhibited antiviral activity after

Aside from antiviral agents, RNA interference (RNAi) or gene-silencing has also been used to control virus infection. A short interfering RNA (vp28-siRNA) targeting a major envelope protein gene of WSSV was used to induce gene silencing in *P. japonicus*. This resulted to significant decrease of viral DNA production and lower mortality rates. Furthermore, after three injections of vp28-siRNA, the virus was wiped out from the WSSV-infected shrimp.[3]

Antimicrobial peptides (AMPs) is a potential alternative to antibiotics for aquaculture because no resistance to AMPs has been reported to date. AMPs are considered as major components in the innate immune defense system of marine organisms because they exhibit antimicrobial properties and provide an immediate and fast action against invading microorganisms.[6, 3] Examples of AMPs found in marine organisms include penaeidins from shrimps, mytimicin from mussel, halocidin from sea peaches, callinectin from blue crab, big defensin from tri-spine horseshoe crab, and clavaspirin from club sea squirt.[6]

Vaccines are another cost-effective means to protect fish from viral diseases and prevent spread of diseases. Fish vaccines have been considered as the key reason in the success of salmon industry. An example of a vaccine for salmon is known as Apex-IHN which confers resistance to haemotopoietic necrosis virus (IHNV).[3,7]

Growth Promotion

Majority of transgenic research on commercially important fish species are focused on improving growth rates by transfer of growth hormones. This is economically sound because transgenic fish with altered growth traits reach maturity in a shorter span of time than non-transgenic fish and exhibit better feed conversion efficiency.[3] These advantages further translate to shorter production cycle, lower production costs, and reduced pollution in aquaculture facility.

In 2015, AquAdvantage salmon with growth hormone gene from Chinook salmon became the first genetically engineered fish approved for commercial use after it was proven to be safe to eat like non-GE Atlantic salmon, by the US Food and Drug Administration.[8] It was also approved for commercial use in Canada in 2016.[9]

Medicine

Over 2,000 years ago, extracts from marine organisms were used as medicine. In the 19th and 20th century, cod liver oil is one of the famous nutritional supplements. It was only in the middle of 20th century when scientists started to systematically navigate the oceans for medicines.[1]

When scientists were studying the defense mechanisms of sea creatures, they discovered the vast defensive chemical weapons of the organisms. In 1950s, Ross Nigrelli from New York Zoological Society extracted a toxin called holothurin from Bahamian sea cucumber (*Actynopyga agassizi*), which showed anti-tumor activity in mice. Holothurin was not commercialized but the number of potential bioactive compounds from the ocean spiked up and more are being discovered each year. Scientists have used biotechnology to make copies of the marine compounds in the laboratory so they don't have to be constantly harvested from marine life. Some have been commercialized, while others are undergoing clinical or pre-clinical tests.[1] Table 1 summarizes some of the commercialized medicines derived from marine organisms.

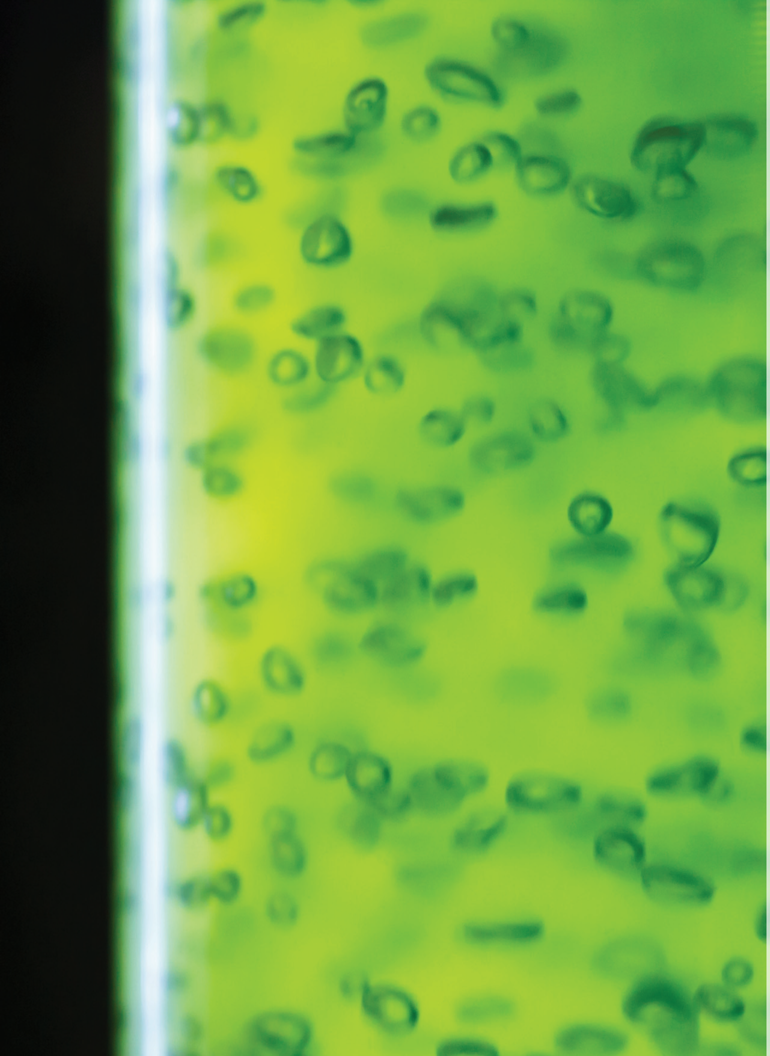
Other marine-derived drugs are still in clinical trials. These include cytotoxic compounds bryostatin 1 and the dolastatin derivatives soblidotin and synthadotin. Aside from these drugs, more products are in the preclinical pipeline. The number of marine compounds reported is increasing every year, with over 1,000 new compounds with varied potencies and biological functions added to the pipeline each year.[6]

Table 1. Drugs derived from marine organisms[1, 10,11]

Product	Source	Application
Cephalosporin	Fungi (*Cephalosporium*)	Antibiotic
Squalamine	Spiny dogfish (*Squalus acanthus*)	Antibiotic
Vidrabine/Ara-A	Caribbean sponge (*Tethya crypta*)	Antiviral
Cytarabine/Ara-C	Caribbean sponge (*Tethya crypta*)	Anticancer
Ziconotide	Cone snail (*Conus magus*)	Analgesic
Trabectedin	Caribbean tunicate (*Ecteinascidia turbinata*)	Anticancer
Eribulin mesylate	Marine sponge (*Halichondria okadai*)	Anticancer

Environment

Degradation of environmental pollutants is an important concern globally. Studies have shown that marine microorganisms exhibit unique biodegradation pathways for breaking down several organic pollutants. Immobilized cells of bacterium *Pseudomonas chlororaphis* produce pyoverdin, which hastens the breakdown of toxic organotin compounds in seawater. Other studies have also shown that some marine organisms produce eco-friendly chemicals like biopolymers and biosurfactants which can be used in environmental waste management and treatment. [1]



Biofuel

Biofuels from microalgae is one of the economically viable ways to reduce fossil fuel consumption. Microalgae are considered better sources of biofuels than higher plants because of their high oil content; ease of propagation (can be cultivated in seawater or brackish water, thus do not compete with the resources of conventional agriculture); residual biomass after oil extraction can be used as feed or fertilizer or fermented to produce ethanol or methane; and the biochemical composition can be controlled by modifying growth conditions. Microalgae with superior biomass productivity and lipid content include *Chlorella, Tetraselmis, Chaetoceros, Isochrysis, Skeletonema*, and *Nannochloropsis*.[3]

Marine biotechnology is one of the youngest biotechnology approaches. The marine ecosystem has rich biodiversity, and the organism themselves contain vital biochemical compounds with a wide array of uses in medicine, environment, and other industries. Thus, research on this field is vital to tap the vast potential of the marine environment to improve human life in any way possible.

References

[1] Thakur, NL and AN Thakur. 2006. Marine Biotechnology: An Overview. Indian Journal of Biotechnology 5: 263-268.

[2] Pomponi, SA. 1999. The Potential for the Marine Biotechnology Industry. In Trends and Future Challenges for U.S. National Ocean and Coastal Policy. DIANE Publishing: Delaware, USA. 143 pages.

[3] De Jesus-Ayson, EG. 2011. Trends in Aquaculture and Fisheries Biotechnology: Current Applications in the Philippines. In Selected Reviews in Biotechnology: Livestock, Forestry, and Fisheries. ISAAA and BCP: Philippines. 246 pages.

[4] Rothamsted Research. The First GM Oilseed Crop to Produce Omega-3 Fish Oils in the Field. 2015. http://www.rothamsted.ac.uk/news-views/first-gm-oilseed-crop-produce-omega-3-fish-oils-field.

[5] University of Utah. n.d. PCR. http://learn.genetics.utah.edu/content/labs/pcr/.

[6] Tincu, JA and SW Taylor. 2004. Antimicrobial Peptides from Marine Invertebrates. Antimicrob Agents Chemother 48(10): 3645–3654. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC521913/.

[7] Muktar Y, S. Tesfaye, and B. Tesfaye. 2016. Present Status and Future Prospects of Fish Vaccination: A Review. J Veterinar Sci Technol 7:299. http://www.omicsonline.org/open-access/present-status-and-future-prospects-of-fish-vaccination-a-review-2157-7579-1000299.php?aid=70000.

[8] U.S. Food and Drug Administration. 2015. FDA Has Determined that the AquaAdvantage Salmon in as Safe to Eat as Non-GE Salmon. http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm472487.htm.

[9] Health Canada. 2016. AquAdvantage Salmon. http://www.hc-sc.gc.ca/fn-an/gmf-agm/appro/aquadvantage-salmon-saumon-eng.php.

[10] Mayekar, TS, AA Salgaonkar, JM Koli, P. Patil, A. Chaudhari, A. Murkar, S. Salvi, D. Surve, R. Jadhav, T. Kazi. Marine Biotechnology : Bioactive Natural Products and their Applications. http://aquafind.com/articles/Marine-Biotechnology.php.

[11] Montaser, R and H Luesch. 2011. Marine Natural Products: A New Wave of Drugs? Future Med Chem 3(12):1475-89. https://www.ncbi.nlm.nih.gov/pubmed/21882941.

POCKET K NO. 52

Marine Biotechnology

Pocket Ks are Pockets of Knowledge, packaged information on crop biotechnology products and related issues available at your fingertips. They are produced by the Global Knowledge Center on Crop Biotechnology (http://www.isaaa.org/kc).

October 2016

For more information, contact

International Service for the Acquisition of Agri-biotech Applications (ISAAA) SEAsiaCenter
Khush Hall, IRRI, UPLB Campus, Los Baños, Laguna 4031
Tel.: +63 49 5367933
Telefax: +63 49 5367216
Email: knowledgecenter@isaaa.org

Visit the ISAAA website at:
http://www. isaaa.org