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Editorial: Marine Biotechnology, Revealing an Ocean of Opportunities

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Editorial on the Research Topic

Marine Biotechnology, Revealing an Ocean of Opportunities

RELEVANCE AND THE MAIN CHALLENGES OF MARINE (BLUE) BIOTECHNOLOGY

The ocean, including its coastal areas and covering more than 70% of the Earth's surface, has always represented an important environmental and economic resource. Indeed, almost 40% of the global population lives in coastal communities (United Nations, 2017). With its ecosystem services, the ocean represents a pivotal role in human society (Rayner et al., 2019). Undeniably, the ocean provides food, regulates the climate, provides oxygen and ensures economic resources through its shipping routes and tourism opportunities. Additionally, the ocean is home to organisms that have for centuries sparked the scientific interest of many research groups to uncover the biodiversity and functions of these fascinating marine ecosystems. Through their biological and chemical diversity, marine organisms synthesize unique secondary metabolites, biopolymers and enzymes produced in response to environmental stimuli. Secondary metabolites play important biological roles in improving competitiveness, providing chemical defence against predators or competitors and facilitating reproductive processes (Rotter et al.). Screening of these natural products and their producer organisms, coupled with the search of their unique biological activities that could be used in various industries, is tackled within marine (blue) biotechnology. Marine organisms and microorganisms can be investigated, and their primary and secondary metabolites, biopolymers and enzymes can be used as lead agents for nutraceutical and pharmaceutical industries to improve processes (e.g., in drug delivery) and as a source of bio-inspired materials for numerous biotechnological applications. Although this field has been appearing since the 1960s and 1970s, it is still considered an emerging field and marine biotechnology is still in its infancy (Rayner et al., 2019; Rotter et al.). This is because many marine environments are extreme ones that are either hardly accessible for sampling and harvesting and/or are home to organisms that cannot be cultured or grown in laboratory conditions. Consequently, a lot of advancement in the field of marine biotechnology was hampered until recent advances in science were achieved, including sampling methods, high-throughput methods and transdisciplinary collaborations.

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Here is where the Research Topic "Marine Biotechnology, Revealing an Ocean of Opportunities" comes into play. The Research Topic was initiated to provide an overview of the current status of research activities in this exciting field, generating a compendium of processes and technologies and mapping the current scientific actors in the field of marine biotechnology. All steps of marine biotechnology development pipeline were tackled; from bioprospecting, metabolite/protein/enzyme/polymer isolation and characterization, dereplication, synthetic optimization, toxicology, bioassay screening, scale-up production, exploration of wider use, ethics, intellectual property, legislation, to commercialization and sustainability. This enables the creation of a so-called cookbook for maximizing the impact of marine biotechnology development, which can be used for initiating, improving, and facilitating the dialogue amongst adjunct scientific fields, providing data, promoting collaborations between experts, and showcasing their expertise that will, directly and indirectly, enhance blue growth.

MARINE BIOTECHNOLOGY TODAY

This Research Topic provided an interesting insight into the current state of affairs in marine biotechnology. To get an overview of the spotlight research and give insight to the field, regardless of the expertise level of the reader, we provide keywords to this field that map the published manuscripts.

Introduction to Marine Biotechnology. Marine biotechnology is embedded in various European initiatives, national smart specialization strategies and international collaborations. As such, it inherently demands the collaboration of several disciplines and experts. An overview on the important aspects of marine biotechnology workflow, including the organisms, biodiversity hotspots, methodologies for exploration, production scaling up and use case scenarios was provided in Rotter et al.

Marine Macroorganisms With Valorization Potential. Jellyfish have emerged as organisms with great potential for biotechnological valorization in several publications (Borchert et al.; Lengar et al.; Mearns-Spragg et al.). Brown seaweeds from Tunisian coasts were assessed for their contents of high added-value bioactive metabolites (Ktari et al.). Novel conopeptides were isolated from cone snail *Conus quercinus* (Zhang et al.). Bioprospecting of 37 marine invertebrates from extreme (i.e., polar) regions with a wide range of bioactivities and the chemical structure of the main bioactive compounds was reviewed by Avila and Angulo-Preckler. The underexplored potential use of cephalotoxins, a group of proteinaceous toxins produced by the salivary glands of coleoids, i.e., octopuses, squids and cuttlefishes, was reviewed by Gonçalves and Costa. The use of sponges, ascidians and gorgonians was reviewed by Pech-Puch et al., while marine fish skin mucus was reviewed by Tiralongo et al. Fish skin can be an important waste valorization strategy to decrease fishing and aquaculture waste. Other waste valorization strategies, with marine organisms, their biopolymers and application biofuel, fertilizers, feed, food, food packaging, bioremediation and other industries were reviewed in Rudovica et al.

Marine Microorganisms, Associated to Macroorganisms. Marine microorganisms, especially those associated with macroorganisms, have often been overlooked as a novel biotechnological resource. Huang et al. investigated the potential of the fungal strain *Aspergillus* sp., isolated from a red seaweed *Grateloupia filicina* in Qingdao, China. Additionally, Furtado et al. presented the potential of bacteria associated with the Brazilian endemic ascidian *Euherdmania* sp. An overview of the potential of biologically active peptides by marine organisms and their microbial symbionts was provided by Macedo et al., along with the bioprospecting techniques and potential industrial uses.

Marine Microorganisms With Potential Valorization. The biotechnological potential of marine phytoplankton was tackled in two publications. Diatoms with their varied silica walls and capabilities to survive in extreme environments were reviewed in the biotechnological perspective by Sharma et al. The dinoflagellate *Prorocentrum* spp. was assessed as a potential source of phycotoxins with reviewed strategies to enhance their production, including chemical and genetic engineering and culturing techniques (Camacho-Muñoz et al.). The potential of marine bacteria was also researched: *Stenotrophomonas maltophilia* in Chu et al., *Vibrio brasiliensis* in Ouyang et al., bacteria from rock samples and associated to deep-sea invertebrates in the submarine volcano in the Canary Islands, Spain (García-Davis et al.). Importantly, when optimizing the production of the metabolite of interest for biotechnological applications, several techniques are used. One of them, the co-culturing of microbial species, was optimized for astaxanthin-producing marine bacterium *Paracoccus haeundaensis*, where the medium conditions were optimized for its co-culturing with lactic acid bacterial species *Lactobacillus fermentum* (Choi et al.).

Omics. Omics techniques have become a must in modern molecular biology laboratories. In biotechnology, metabolomics is one of such high-throughput techniques that enables a faster exploration of chemical diversity than classical approaches, that rely on culturable species and provide a limited overview within a single experiment. The potential of metabolomics was assessed to investigate patterns in metabolite variation, which could assist in unravelling the multiple pathways affected by environmental factors (Reverter et al.).

Application in Various Industries

(1) Biomedical applications. Jellyfish collagen is becoming an important alternative in various industries due to the safety concerns of using mammalian-derived collagen. An important application of jellyfish collagen is its use as a matrix of cell cultures to model human diseases. Results reveal that jellyfish collagen is comparable and, in some indicators, even superior to rat tail collagen for culturing human iPSC-derived microglia (Mearns-Spragg et al.).

(2) Pharmaceutical applications. Marine organisms (sponges, ascidians and gorgonians) collected in the Yucatan peninsula showed antiviral activity against human adenovirus in 17% of the extracts and antitumor activity against one or more tumor cell lines in 37% of extracts (Pech-Puch et al.). The potential of

marine fish skin mucus for antibacterial and antifungal activities was reviewed by Tiralongo et al. Anticancer activity by *Streptomyces* isolated from the Brasilian endemic ascidian *Euherdmania* sp. was shown by the proteasome inhibitor and potent cytotoxicity in glioma cell lines (Furtado et al.). Algicidal activity against harmful algal blooms is important to maintain fishery resources, marine ecosystems and human health. Repeated batch fermentation of immobilized algicidal bacterium *Vibrio brasiliensis* H115 was preformed to enhance the productivity of the algicidal compounds (Ouyang et al.). Finally, the analgesic potential by novel conopeptides from the carnivorous cone snail *Conus quercinus* was demonstrated (Zhang et al.).

(3) Wellbeing applications. Phenolic compounds have antioxidant activities, a characteristic used in the cosmetic industry. The potential of dissolved organic matter for antioxidant potential was quantified from porewaters and water column in Wadden Sea, where this potential was higher than what is commonly found in microalgae and macroalgae (Catalá et al.).

(4) Pigment production. Pigments from marine organisms can be used in various food, cosmetics, pharmacological and other industries. The optimization of astaxanthin and fucoxanthin isolation was provided by co-culturing (Choi et al.) or optimization of extraction conditions (Ktari et al.).

(5) Agriculture applications. Eleven new compounds have been isolated from the seaweed-derived fungus, *Aspergillus* sp., revealing anti-phytopathogenic bacterial activity that could contribute to increased global food safety (Huang et al.). Jellyfish was assessed as a valuable potential biofertilizer, considering the impact on greenhouse emissions and the cost of material pre-processing (Borchert et al.).

(6) Alternative energy sources. Bioethanol is becoming an important renewable energy source as an alternative to fuel. A resource with promising potential for bioethanol production is seaweed biomass, where its alginate needs to be efficiently degraded into alginate monosaccharide by alginate lyases. A novel oligoalginate lyase from the marine bacterium *Stenotrophomonas maltophilia* was shown to completely depolymerize alginate to monomers (Chu et al.).

(7) Plastics and bioplastics. Marine pollution caused by plastics is becoming an increasing environmental, societal and technological challenge. This was tackled in the Research Topic by including an overview of marine Actinobacteria and marine fungi to biodegrade (micro)plastics, methods to detect and analyze biodegradation and potential for bioplastic production. Moreover, the most important methods for plastic degradation and recycling valorization were reviewed by Oliveira et al. The potential sequestration of microplastics using jellyfish mucus provided a novel bioremediation potential for this material (Lengar et al.).

Transdisciplinary collaboration. To advance the field of marine biotechnology, there is a need to create effective, operational, inclusive, sustainable, transnational and transdisciplinary networks with a serious and ambitious commitment for knowledge transfer, training provision, dissemination of best practices and identification of the emerging technological trends through science communication activities. This network, Ocean4Biotech, an Action within the European Cooperation in Science and Technology (COST) that connects all stakeholders interested in marine biotechnology in Europe and beyond, was introduced in Rotter et al. An open-access map of experts and their expertise in the marine biotechnology field was further provided by Rotter et al.

FUTURE PROSPECTS

The field of marine (blue) biotechnology is gaining visibility worldwide in many complementary scientific fields and has inspired the creation of several legislative, infrastructural and scientific collaborative networks. Ultimately, this field can become an important driver in economic development, creating innovative clusters and managing the sustainable development of coastal areas globally. However, to promote the exploitation of scientific outputs and commercialization of innovative products from marine organisms and microorganisms, a constant dialogue needs to be maintained between the scientific community, the legislative authorities, the industry, and the general public, who are the final beneficiaries and consumers of the developed products and processes. This is seen in the marine biotechnology field through several white papers, research, innovation and governance projects, ocean literacy initiatives, and media exposure activities. These demand the involvement of transdisciplinary communities. They provide a different approach to such applied science, in contrast to the basic one, and building dialogues and collaboration between different actors (e.g., the scientific community and governance authorities that provide financing). This is also seen in this Research Topic where the 25 published manuscripts provide an overview of methodologies and marine micro and macroorganisms with biotechnological potential, their use in various industries, and the importance of transdisciplinary collaborations and sustainability. Based on the diversity of studies that have been provided in this Research Topic, we believe that the field of marine biotechnology is slowly but surely establishing itself as an important scientific and innovation field that will provide for economic prosperity, circularity and sustainability for decades to come.

AUTHOR CONTRIBUTIONS

AR designed the editorial concept and drafted the manuscript. All authors contributed in summarizing the articles they edited, writing, reading, edited, and approved of the final version of the editorial.

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