

Cultivating Hope: The Synergistic Potential of Aquaculture and Oncology in the Fight Against Cancer

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ABSTRACT

This article analyzes the overlooked opportunity of using aquaculture in the field of oncology with the aim to advance cancer research and therapy. Complete systems of the oceans can form ethical models for research which can lead to the discovery of marine organisms that serve as vital sources of bioactive anticancer compounds, and aquaculture could enable sustainable solutions for drug development and medicine profiling. This interdisciplinary framework is beneficial from both economic and ethical perspectives, such as the reliance on the goods of land. Also discussed in the article are the alternative methods to using vivisection, overcoming the scarcity of land-based resources, and animal monitoring. There are hurdles in scaling and regulatory policies, but the article makes a case for the need to collaborate more and for marine biologists and oncologists to use new approaches for treating cancer. Combining aquaculture with oncology is remarkably innovative because it creates sustainable ways to provide new hope in battling cancer.

Keywords: Aquaculture; Cancer Therapeutics; Oncology; Fisheries Science

Introduction

With a value exceeding \$258 billion in 2023, aquaculture, the farming of aquatic organisms, is a booming global industry, fueled by the need for sustainable food and biomass. In parallel, oncology focuses on the study of cancer, making it a \$200 billion industry that seeks to solve one of humanity's most harrowing health concerns. Even more surprising is how these two fields intersect. The ocean is home to an unparalleled array of life forms, many of which have developed extraordinary biochemical weapons to defend against harsh predators and conditions. Some of these marvels, such as halichondrin B from sea sponges (now eribulin for breast cancer treatment), have changed the face of cancer treatment. This article will discuss how aquaculture systems can provide sustainable and novel anticancer compounds, ethical research models, and innovative solutions for oncology, thereby marrying marine science and medicine to transform the fight against cancer.

Aquaculture and Bioactive Compounds

Marine organisms often form symbiotic relations with other organisms with the purpose of producing bioactive compounds with powerful anticancer potential. Such bioactive compounds can even be adaptive responses to stress like in the case of curcuminoids from marine algae. Unlike other forms of cancer treatment, halichondrin B, extracted from *Halichondria okadai*, is the base of eribulin mesylate, a microtubule inhibitory FDA cancer drug. Other than that, curcuminoids also show antioxidant and anti-inflammatory qualities which lower the oxidative stress that is encountered in tumors. Tumor modulation is achievable with these bioactive compounds through multiple mechanisms which include but are not limited to, apoptosis which is programmed cell death, angiogenesis of blood vessel growth, and immune system control. The bioactive compounds can be sustainably cultivated and aquacultured in a reliable system which guarantees the consistent supply of high-purity bioactive compounds. For exam-

ple, the yield from cultivated brown seaweed can be significantly enhanced by altering them for curcumin production, and the farms that culture sponges can be specialized to increase halichondrin excretion.

This integration not only accelerates drug discovery but also reduces reliance on wild harvesting, preserving marine ecosystems (Figure 1) (Kumar, et al. [1]).

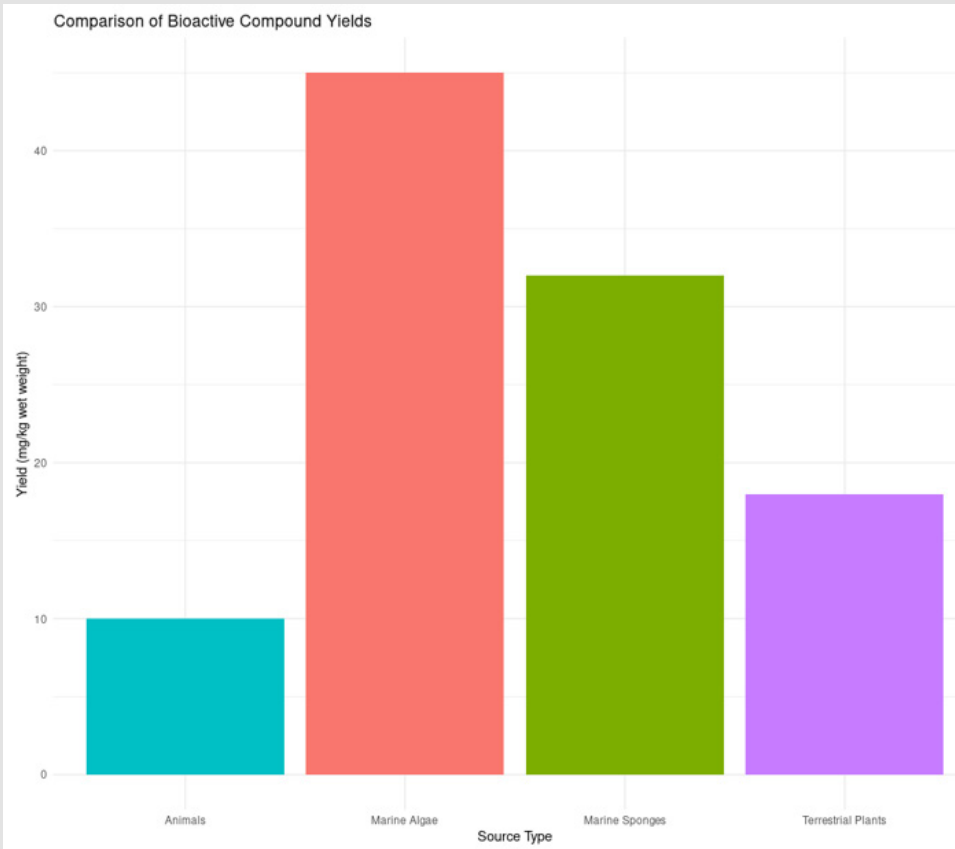


Figure 1: This bar chart illustrates the comparative yields of bioactive compounds with anticancer properties from marine sources (algae and sponges) versus terrestrial sources (plants and animals). Marine organisms, cultivated through aquaculture, demonstrate significantly higher compound yields, underscoring their potential as a sustainable and efficient resource for oncology research and drug development. The data highlights how aquaculture can strategically support the discovery and production of novel anticancer therapies by providing greater quantities of these critical bioactive substances.

Controlled Aquatic Environments in Oncology Research

Aquaculture technologies, such as bioreactors and recirculating aquaculture systems (RAS), create stable, controllable environments mimicking natural aquatic habitats. These systems are invaluable for oncology research. For example, zebrafish (*Danio rerio*), a staple in aquaculture, are emerging as powerful preclinical models for cancer. Their transparent embryos allow real-time imaging of tumor growth and metastasis, while their genetic similarity to humans (~70% shared genes) enables studies on gene expression and drug efficacy. Zebrafish xenografts—in which human cancer cells are implanted into zebrafish larvae—provide rapid, cost-effective insights into tumor be-

havior and therapeutic responses. Additionally, aquaculture-derived 3D bioprinted tissues, grown in marine-inspired hydrogels, replicate human tumor microenvironments. These models enhance precision oncology by enabling personalized drug screening using patient-derived cells, reducing the need for invasive biopsies and animal testing.

Economic and Ethical Synergies

The aquaculture-oncology nexus addresses critical ethical and economic challenges in biomedical research. Traditional oncology relies heavily on terrestrial resources, such as cell cultures from mammals or plant-derived compounds like taxol (from yew trees). However, these systems are land-intensive, resource-heavy, and ethically

contentious, particularly when involving animal models. Aquaculture offers sustainable alternatives: marine algae farms require less land and water than terrestrial crops, and lab-grown seafood could replace mammalian tissue cultures for drug testing. Ethically, marine models like zebrafish are less regulated than rodents, aligning with the 3Rs principle (Replace, Reduce, Refine animal testing). By shifting oncology research toward aquatic systems, scientists can minimize environmental impact while advancing therapies that are both effective and ethically sound.

Challenges and Future Directions

Despite its promise, integrating aquaculture with oncology faces hurdles. Marine compound extraction often yields low quantities; for example, halichondrin B is produced in trace amounts by sponges, necessitating complex synthesis methods. Scaling up production requires innovations in aquaculture engineering, such as designing sponge farms with optimized water flow to boost bioactive compound secretion. Regulatory frameworks also lag behind cross-disciplinary research; agencies like the FDA and EU's EMA must adapt guidelines to evaluate marine-derived therapies. However, global collaboration—such as the EU's Horizon Europe program funding marine biotechnology—offers pathways forward. Open-source databases cata-

logging marine bioactive compounds and public-private partnerships between aquaculture farms and pharma companies could accelerate progress.

Conclusion

The convergence of aquaculture and oncology represents a frontier of innovation with the potential to transform cancer treatment. From marine-derived drugs to ethical research models, these fields offer complementary solutions to address oncology's most pressing challenges. By fostering interdisciplinary research hubs, scientists can harness the biochemical diversity of marine life and the technological advancements of aquaculture to develop therapies. Policymakers, researchers, and industries must prioritize partnerships to overcome technical and regulatory barriers, ensuring that the ocean's untapped potential translates into life-saving treatments. As climate change threatens both marine ecosystems and global health, integrating aquaculture into oncology is not just a scientific opportunity—it is a moral imperative.

References

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