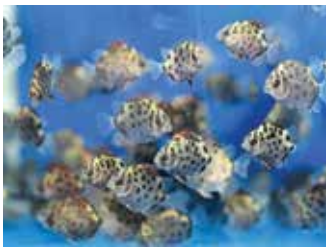
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Editor,
Fish Tech Digest



From the desk of Dean…

Dear esteemed Authors and Readers

It gives us immense pleasure to present this special issue of Fish Tech Digest, dedicated to the fisheries wealth, aquatic ecosystems, and coastal communities of Kanniyakumari District. Located at the southernmost tip of India, Kanniyakumari is blessed with diverse marine and inland aquatic resources that support livelihoods, biodiversity, and economic development.

This issue features insightful articles on the Ramsar wetlands of Vembannur and Suchindram–Theroor, the rich seaweed resources of Cape Comorin, and the vital role of Thengaipattinam Fishing Harbour in the marine fish export chain and coastal economy. Together, these contributions highlight the district's unique ecological and fisheries significance.

We are particularly pleased to showcase articles contributed by the faculty and students of St. Devasahayam Institute of Fisheries Science and Technology (DIFST), reflecting the institution's commitment to fisheries education, research, innovation, and sustainable development.

As the Blue Economy gains momentum, Kanniyakumari stands as a model where natural resources, traditional knowledge, scientific research, and community participation converge to create opportunities for sustainable growth. We hope this issue inspires readers to appreciate, conserve, and responsibly utilize these valuable aquatic resources for future generations.

I extend my heartiest congratulations to all the authors for their invaluable contributions. Your insights significantly enrich our collective academic knowledge and will undoubtedly inspire future research pathways. I trust that this issue of Fish Tech Digest will serve as a highly inspiring and practical resource for you all, as we continue to uphold our institutional benchmark for excellence in fisheries education, research, and community extension.

Best regards,
Prof. S. Felix
Chief Editor
Fish Tech Digest

CONTENT

List of Contents

S.No	Title	Page No
1.	**The Scientific Journey of Zebrafish. Ambika Binesh and Kaliyamurthi Venkatachalam.** *Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU), OMR Campus*	5
2.	**Ramsar Wetlands of Kanniyakumari: Fisheries and Ecological Perspectives N. Karthik, M. Subhashini, S. Thamizhanthi & S.Felix** *St. Devasahayam Institute of Fisheries Science and Technology, Amanattantheri, Kanniyakumari Dist. Tamil Nadu.*	9
3.	**Cape Cameron's Seaweed Bounty : A report N. Mukeshbabu and V. Mary Kensa** *PG & Research, Department of Botany,S.T. Hindu College, Nagercoil-600 002*	17
4.	**Cost-Effective and Nutritious Protein Alternatives for Fishmeal in Aqua Feeds K. Abarna1, C. Rajeswari1, N. Manimozhi[2], S. Felix[1]** *St. Devasahayam Institute of Fisheries Science and Technology, Amanattantheri, Kanniyakumari Dist. Tamil Nadu.*	20
5.	**Labor Dynamics and Human Resource Management in Modern Fisheries. Green Sea K** *Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Nagapattinam*	26
6.	**Nanobubble Technology as a New Health Tool in Aquaculture J.G. Jerlin Mol , S.A. Raj Vasanth, Arumugam Uma** *Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Dr.M.G.R Fisheries College and Research Institute, Ponneri*	29
7.	**The Role of Binders in Aquafeed: Enhancing Nutritional Stability and Promoting Sustainable Aquaculture. Madhan .M, Jenisha Mol J G, Porkodi M, S. Felix** *St. Devasahayam Institute of Fisheries Science and Technology, Amanattantheri, Kanniyakumari Dist. Tamil Nadu.*	34
8.	**Role of Thengaipattinam Fishing Harbour in Marine Fish Export Chain and coastal livelihoods in Kanniyakumari District, Tamil Nadu Akash Arul A** *St. Devasahayam Institute of Fisheries Science and Technology, Amanattantheri, Kanniyakumari Dist. Tamil Nadu.*	41
9.	**Exploring India's Aquatic Biodiversity: Newly Discovered and Newly recorded Fish species (2024) .Rose Ruby F** *St. Devasahayam Institute of Fisheries Science and Technology, Ammanattantheri, Kanniyakumari – 629 193*	46

Nanobubble Technology as a New Health Tool in Aquaculture

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Abstract

Maintaining clean and oxygen-rich water is a persistent challenge in aquaculture. Nanobubble technology, which involves creating extremely small gas bubbles in water, has emerged as a promising, energy-efficient method to enhance dissolved oxygen levels, improve water quality, reduce pathogens, and support the health of fish and shrimp in aquaculture. Initial field trials and laboratory research have shown that using ozone or oxygen nanobubbles can lead to faster oxygen transfer, better growth and survival rates in certain species, and effective control of algae and microbes. However, the evidence is still developing: the effectiveness depends on the method of bubble generation, dosage, species, and system design, and there are ecological and safety concerns (such as impacts on bacterial communities and antibiotic-resistance genes) that require careful consideration. While nanobubbles are not a cure-all, they offer a practical and increasingly cost-effective tool that, when combined with good husbandry practices, can enhance the productivity and resilience of aquaculture.

Keywords: Nanobubbles, Oxygenation, Water quality, Aquaculture, Biosecurity

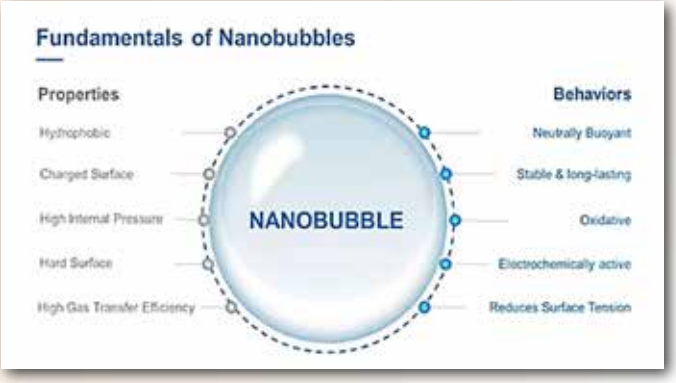
Introduction

Aquaculture is essentially the art and science of maintaining water conditions that allow animals to thrive. Fish and shrimp have specific requirements: oxygen levels must be high and stable, ammonia and nitrite need to be controlled, and opportunistic bacteria and algae must be managed. Traditional methods like paddlewheel aerators, diffusers, and chemical treatments are effective but often require significant energy, incur ongoing costs, or have side effects. This is where nanobubble technology comes into play: these tiny bubbles behave very differently from the familiar foam on your coffee. Early research and industry trials suggest that these ultrafine bubbles can deliver oxygen more efficiently, assist in disinfection, and help manage water quality with less energy and fewer chemicals.

What are nanobubbles?

Nanobubbles are gas bubbles with diameters typically less than a few hundred nanometers (one nanometer equals one billionth of a meter). At this size, they do not quickly rise to the surface like larger bubbles; instead,

they remain suspended in water for extended periods. This results in two practical outcomes: (1) they significantly increase the gas–water contact area, enhancing gas transfer (such as oxygen dissolving into water), and (2) they can produce reactive species, especially when ozone is used, which can inactivate microbes and break down organic matter. In summary, nanobubbles combine a long residence time with unique physical and chemical properties that can be utilized in aquaculture.



How nanobubbles function

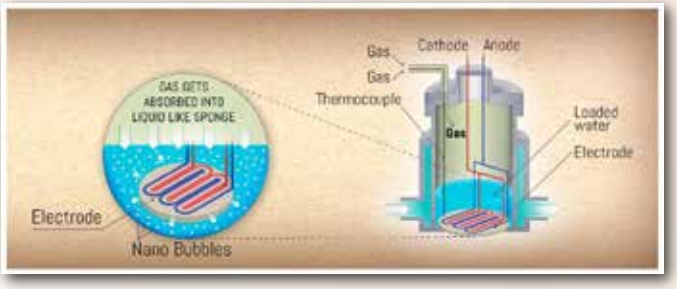
Visualize countless invisible, slowly drifting beads of oxygen or ozone dispersed throughout a tank. Each bead acts as a tiny transport mechanism, allowing gas to remain in contact with water for a longer duration than traditional bubbles.

For oxygen nanobubbles:

They increase dissolved oxygen levels more rapidly and sustain them with less continuous airflow compared to macrobubbles. (Hare Ram Devkota et al.,2024). Due to their suspension, oxygen is accessible throughout the water column, which is beneficial for high-density systems.

For ozone nanobubbles:

Ozone bubbles are more effective at oxidizing and deactivating algae, bacteria, and organic matter because they deliver ozone close to contaminants and generate reactive radicals when the bubbles burst. This can swiftly reduce turbidity and surface scums. (Ng et al.,2023)

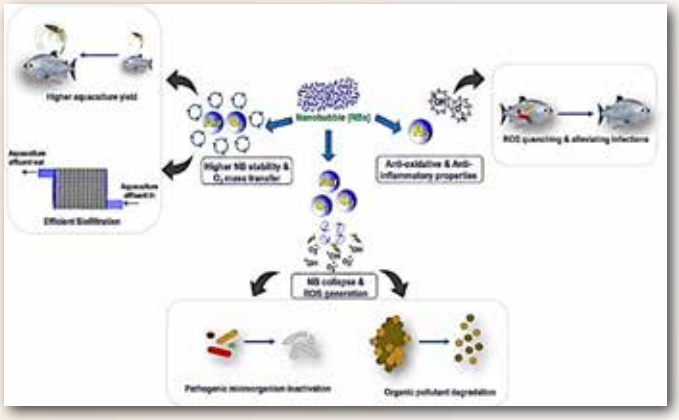


Benefits for aquaculture

- Quicker and more efficient oxygenation. Various field and laboratory studies indicate that nanobubble aeration rapidly increases dissolved oxygen (DO) and can achieve higher DO with less energy than traditional aeration methods in ponds and RAS (recirculating aquaculture systems). This can alleviate stress, enhance feed consumption, and promote better growth.
- Enhanced survival and growth in certain species. Experiments with white-leg shrimp and various fish species have shown improved weight gain and survival when oxygen nanobubbles are utilized, likely because the animals experience less hypoxic stress. Results vary by species and dosage but are promising for commercially significant species. (Nghia *et al.*, 2022)
- Algae and pathogen management (with ozone NBs). Low-dose ozone nanobubbles can quickly decrease algal biomass and turbidity and reduce the presence of some harmful microbes without extensive chemical use. This is appealing for controlling algal blooms and short-term disinfection. (Hare Ram Devkota *et al.*,2024)
- Potential energy and cost savings. Some comparative evaluations suggest that

micro/nanobubble systems can be more energy-efficient for oxygen transfer than certain aerators, especially when oxygen solubility and delivery efficiency are crucial (e.g., high-density RAS or transport scenarios). Savings depend on the system's scale and electricity costs. (Pirozzi., 2024)

- Improved nitrification and biofilter performance. By stabilizing DO and mixing at the micro-scale, nanobubbles may enhance the performance of nitrifying bacteria in biofilters, helping to maintain low ammonia and nitrite levels in intensive systems.



Case studies and practical examples

Shrimp trials: Research on Pacific white shrimp found that oxygen and ozone nanobubbles improved survival rates and reduced Vibrio count in some experiments; improvements varied based on bubble type and exposure regimen. (Nghia *et al.*, 2022)

Pond algal control: Trials using low-dose ozone nanobubbles quickly reduced algal load, sometimes achieving over 60% reduction within minutes under treatment conditions suitable for emergency bloom response.

Recirculating systems: Research trials and pilot farms using air-nanobubbles reported better DO stability and enhancements in water clarity and nitrification, although longer-term and larger-scale commercial studies are still being conducted.

Risks and caveats

While nanobubble technology offers significant advantages, it is not without risks or universally suitable: The type and amount of gas are crucial. Oxygen nanobubbles are typically safe and beneficial, whereas ozone nanobubbles are strong oxidants that require precise dosing. Excessive exposure to ozone can damage gills, decrease survival rates, or disrupt microbiomes. (Him *et al.*,2023)

Changes in microbial communities. Recent metagenomic studies indicate that certain disinfection methods, including ozonation, can alter microbial communities and, in some cases, increase the prevalence of antibiotic-resistance genes (ARGs) or efflux mechanisms, necessitating further research and caution. This doesn't imply avoiding ozone nanobubbles altogether but rather suggests careful monitoring and the use of conservative, well-planned protocols. (Huang *et al.*,2024)

Results vary by system. The effectiveness of nanobubbles depends on factors such as tank shape, water chemistry, organic load, and stocking density. What works in a laboratory shrimp tank might not perform as well in an open-pond farm unless adjustments are made.

Quality and upkeep of equipment. Not all nanobubble generators are created equal. Poorly designed units may produce larger bubbles or consume more energy than advertised; regular maintenance and a reliable power supply are essential. (Mulyadi *et al.*,2025)

Practical guide for farmers and technicians

Define the objective. Is it oxygenation, emergency disinfection, or algae control? The appropriate gas and protocol depend on the goal. (O_2 for dissolved oxygen; O_3 for cleaning/ disinfection; air for mixing and biofilter support.) (Foudas *et al.,* 2023)

Start with small-scale trials. Test nanobubble units on a single pond or tank while monitoring dissolved oxygen, temperature, pH, ammonia, nitrite, and animal behavior. Keep detailed records.

Use ozone cautiously. Apply low doses and limit exposure times; assess gill health and mortality, then make adjustments. Install degassing units or contactors if residual ozone could reach the animals. (Ng *et al.,*2023)

Tailor generation to the system. High-density recirculating aquaculture systems benefit more from efficient dissolved oxygen delivery; open earthen ponds may require different methods and scaling.

Maintain and verify equipment. Measure bubble size distribution, dissolved oxygen gains per kilowatt, and energy consumption; compare with existing aeration systems to determine cost-effectiveness.

Future directions

Research in this field is expanding. Key short-term priorities include:

- Conducting larger, multi-season farm trials to evaluate economic viability and animal performance under commercial conditions, as many current studies are limited to lab-scale or short-term experiments. (Yaparatne *et al.,* 2024)
- Investigating microbiome and ARG dynamics to ensure disinfection strategies do not inadvertently create selection pressures. Metagenomic tools are beginning to uncover subtle ecological changes following ozonation.
- Enhancing energy efficiency and generator designs to make nanobubble systems cost-effective even for farms with low profit margins.
- Developing hybrid approaches that combine nanobubbles with probiotics, biofloc, or smart feeding strategies to optimize animal health while reducing chemical interventions.

Conclusion

Nanobubble technology exemplifies how small-scale physics can yield substantial benefits. For aquaculture producers dealing with oxygenation challenges, algal blooms, or persistent water-quality issues, nanobubbles offer a practical, energy-efficient solution. The technology is advanced enough for pilot implementation, but like any tool, success relies on selecting the right gas, precise dosing (especially with ozone), system-specific adjustments, and monitoring. With prudent use and more real-world testing, nanobubbles can become a standard component of the aquaculture toolkit, contributing to healthier, more productive, and sustainable farms.

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