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Sustainable, Cost-Effective Processes to Produce Healthier Fish

New research reveals the unprecedented success of Electro-Chemical Water Treatment (ECWT) systems

BioFishency
AQUACULTURE OPTIMIZED

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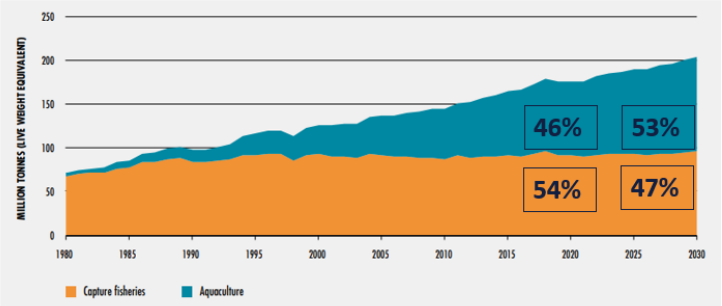
Aquaculture: Preserving and Enhancing Life – Beneath the Sea

Aquaculture is the farming of aquatic organisms for profit, deemed the fastest-growing sector in animal protein production. The most sought-after solution to meet the increased global demand for fish, projected at 50 million tons by 2030, aquaculture accounts for over 50% of the total global seafood supply. Overfishing, depleted wild fishery stocks, and feeding a fast-growing global population, have driven aquaculture's massive expansion in both production volume and value.

But with the limited availability of land and water, the only viable solution is *intensification* – to produce more fish per unit of area and water. Advanced technology has made it possible to grow food in coastal marine waters and the open ocean. This has single-handedly shifted the focus towards the *longevity* and *sustainability* of aquaculture, now driven by innovative, highly sustainable and cost-effective solutions.

World Capture Fisheries and Aquaculture



Aquaculture production is projected to reach 109 million tons in 2030, an increase of 32% (26 million tons) over 2018 (FAO - *2020 SOFIA* report)*

One such solution, a disruptive and innovative **Electro-Chemical Water Treatment (ECWT) system** for ammonia removal and disinfection, has taken sustainability to new heights, yielding a significantly small carbon footprint, and substantial CAPEX and OPEX savings.

This document illustrates the testing of **BioFishency ELX™**, a highly-sustainable, fully controlled electro-chemical water treatment system, to **efficiently decompose MIB and Geosmin in the purging (depuration) process**. It details a recent study and lab experiments of the removal of MIB and Geosmin using the electro-chemical process, and how BioFishency ELX yields formidable results – **the production of healthier fish**.

The proprietary research was in collaboration with BioFishency's longtime technology partner, Prof. Ori Lahav, Department of Civil Engineering, Environmental & Water Resources, Technion – Israel Institute of Technology, Haifa, Israel.

Recirculating Aquaculture Systems (RAS) Water Treatment Solutions

Today's global aquaculture industry has one fundamental goal – to find the optimal balance between the environmental, social, and economic sectors. To that end, many aquaculture solution providers have already or are in the process of transitioning towards sustainable system development and deployment.

One such solution, Recirculating Aquaculture Systems (RAS), are based on the reuse and treatment of water via the application of mechanical, followed by biological processes for ammonia removal. Growing in popularity, it's estimated that by 2030, more than 40% of the world's aquaculture production will be generated via RAS.

A recirculation system is relatively simple. From the fish tanks' outlet, water flows to a mechanical filter, followed by a biological filter for the removal of ammonia and carbon dioxide, oxygenation, and disinfection, and returned to the tanks. A closed land-based system that reduces water consumption and the release of nutrients into the environment, where some systems require a 5%-15% in the discharge of the total water per day. This enables fish farms to control all of the water parameters (e.g., temperature, oxygen), with the potential to grow virtually any aquatic species, anywhere in the world, with exceedingly low environmental risks.

While conventional RAS may yield stellar results, more recently, RAS has been deemed problematic, is often difficult to manage, and presents significant technological challenges, namely in its biological approach. RAS can also lead to the deterioration of water quality, if its water treatment processes are not properly controlled. This can cause negative effects on fish growth, increased risk of infectious disease and fish stress, and, the most detrimental of all, ***off-flavors.***

Off-Flavors and its Implications

Off-flavors are undesirable flavors in both fish and shellfish that render them permanently or temporarily unmarketable. According to reports by the Global Seafood Alliance (GSA), **off-flavors are currently responsible for an unprecedented 25%-54% of fish harvesting delays**, creating a critical challenge for the global aquaculture industry.

Off-flavors are currently responsible for an unprecedented 25%-54% of fish harvesting delays

A mature RAS can potentially contain MIB and Geosmin at high concentrations. These compounds are absorbed in the fish flesh and cause off-flavors that harm the product quality, may lead to disqualifications, and therefore, to a severe economic loss.

In the conventional procedure, the fish are depurated by being exposed to large volumes of fresh water (saline or freshwater) for a period of 10-14 days, that contain no off-flavor agents. During the purging process, the MIB and Geosmin are desorbed from the fish back to the water, due to a negative concentration gradient between the water and the fish tissue.

Since the conventional purging process is done under starvation conditions, the fish actually lose ~5% of their body weight (mass), evaluated at $0.5-0.7 per kg fish, if it is performed according to all recommendations, making it the most squandering procedure in the Atlantic Salmon production in RAS.

BioFishency ELX™

Sustainable, fully controlled electro-chemical water treatment systems

An entirely new approach to aquaculture water treatment solutions, and the first of its kind on the market today, **BioFishency ELX™** is a highly-advanced Electro-Chemical Water Treatment (ECWT) system for sustainable, cost-effective ammonia removal and disinfection. Operational in a fully-controlled environment, BioFishency ELX raises the bar on conventional RAS by delivering a robust zero discharge water treatment system that outpowers the inefficiencies of biological RAS, while eliminating off-flavors.

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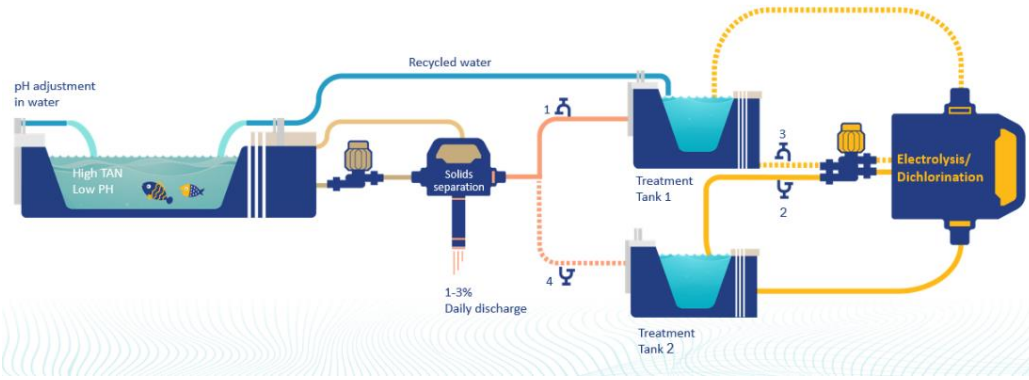
Ideal for cold and warm water species (i.e., temperature independent), BioFishency ELX is a built-in disinfection, multi-stage solution in a single cycle, directly transforming ammonia to nitrogen gas. The system's disinfection processes facilitate comprehensive ammonia, CO_2 and fine particles removal, where both MIB and Geosmin can be efficiently decomposed using the system's electro-chemical reactor, even at single pass.



BioFishency ELX Process

BioFishency ELX is powered by an advanced controller with a highly-intuitive graphic UI that conveniently fits into existing control rooms. The system continuously monitors the water's pH, temperature, O_2, ORP, Cl_2 and NH_4 levels that results in optimal water quality for the fish, via sustainable, cost-effective ammonia removal and disinfection. **The results – consistently clean water, zero ammonia, fully disinfected, and no off-flavors.**

A cloud-based solution, BioFishency ELX enables real-time data collection and management via an intuitive dashboard. Remote monitoring and operation are facilitated by an easy-to-use mobile app, accessible from any location, at any time, via any mobile device or tablet. Intelligent process adaptation using Machine Learning technologies, are planned for future versions.

BioFishency ELX offers value-added benefits to both investors and fish farmers, by eliminating the purging process, supporting sustainability with a small carbon footprint, requiring considerably less space, and is highly cost-effective, with system deployment resulting in significant CAPEX and OPEX savings.

BioFishency ELX supports sustainability – Small carbon footprint, requires considerably less space, resulting in significant CAPEX & OPEX savings

BioFishency ELX includes complementary applications: **Live Seafood Holding** – Easy-to-use holding systems for supermarkets and hotels; **Live Seafood Transportation** – Facilitates land transport instead of costly air shipment, and **Well Boats** – Zero discharge water treatment for sea transport.

Proprietary and patented, BioFishency ELX was developed and commercialized in collaboration with the Department of Civil Engineering, Environmental & Water Resources, Technion – Israel Institute of Technology, Haifa, Israel.

BioFishency ELX™ Use Case: Live Testing of Barramundi

A recent live experiment was conducted in Tel Aviv, Israel, whereby BioFishency presented Barramundi, commonly referred to as Asian Sea Bass, to a team of award-winning chefs at leading Tel Aviv restaurants.

The Barramundi used in this live experiment exhibited off-flavors, and as such, were not suitable for harvesting and sales. Barramundi were subjected to a full RAS purging process, with 2% feeding per day. The fish, weighing 1Kg (prior to harvesting), were maintained in a $5m^3$ tank, at temperatures of 28-30^{o} C, with a salinity of 20ppt, at a c density of $12Kg/m^3$. A portion of the fish were sampled after 5 and 10 days.

Results: After 5 days purging while feeding, resulted in some residual off-flavors, however, **after 10 days purging while feeding, the Barramundi presented with no residual off-flavors.**

After 10 days purging while feeding, the Barramundi presented with no residual off-flavors

This critically important use case, exhibits live, for the first time, how BioFishency ELX demonstrates its unique ability to purge fish while feeding, and fully eliminate off-flavors. It is important to note that the BioFishency ELX system is fully-operational, and independent of water temperature, whereby the purging process can effectively handle both hot and cold-water species.

Further, BioFishency ELX successfully handles the purging process under full feeding conditions, with zero water discharge, while other purging processes are performed under starvation conditions, yielding an intensive water exchange.

This live experience represents a significant milestone, showing, in real-time, how, implementing BioFishency ELX in the purging process yields unparalleled results – no off-flavors.

This is a testament to the system's highly-efficient operation, how it outperforms comparable market solutions, and proves its ability to deliver formidable results based on BioFishency's innovative technologies that are redefining the future of aquaculture.

MIB and Geosmin Removal Using an Electro-Chemical Reactor

Research Study and Test Results: How BioFishency ELX™ effectively eliminates MIB and Geosmin

Overview

A mature RAS, which is based on biofilters, can potentially contain MIB and Geosmin at concentrations of up to 1000 ng/L in dedicated fish rearing water. Both compounds are absorbed into the flesh of the fish, resulting in off-flavors, producing an adverse effect on fish quality, potential inability to take to market, and severe economic losses.

At the end of the production period of Atlantic Salmon in RAS, MIB and Geosmin are absorbed in the fish flesh at concentrations of 400-1000 ng/kg fish. In the conventional process, the fish are depurated prior to sale by exposing them to clean water (saline or freshwater) that is void of off-flavor agents.

As the desorption of MIB and Geosmin is a result of a negative concentration gradient between the water and the fish tissue, any means that would result in maintaining their concentration in the water at near to nil (<5 ng/L), would lead to a similar purging effect. Although some conditions, such as low-salinity water and reducing the fish's fat content, enhance the depuration procedure, this can lead to further economic losses, namely spoilage of the fish taste and/or a significant loss of biomass.

The key challenge is that the major source of MIB, Geosmin and other off-flavor agents, is the *biofilter,* the heart of the RAS water treatment cycle. Consequently, all currently deployed depuration methods include holding the fish under starvation in a flowthrough unit, without a viable water treatment process that supports ammonia removal.

Aimed at the RAS industry, BioFishency ELX provides all the required water treatment components for operation at near zero discharge RAS conditions (e.g., ammonia and fine particles removal, CO2 stripping, water disinfection, pH control, oxygen enrichment, and more). Based on ammonia removal via electro-chemical oxidation as an Advanced Oxidation Process (AOP), BioFishency ELX results in highly-efficient water disinfection, also capable of degrading and removing persistent compounds, such as MIB and Geosmin.

By applying BioFishency ELX as a purging application to fish tainted with MIB and Geosmin, the concentrations of both MIB and Geosmin in the water decrease to near to nil in just a few days. Further, MIB and Geosmin adsorbed in the fish flesh will spontaneously desorb in the water, and decompose via the electrooxidation process. This, in parallel, oxidizes ammonia excreted by the fish, disinfecting the water from other pathogenic microorganisms.

Finally, BioFishency ELX enables the ability to maintain a regular feeding regime, and exceptionally low water discharge during depuration of the fish from the off-flavor agents. The preliminary testing process detailed below, was to demonstrate BioFishency ELX technology for the decomposition of MIB and Geosmin.

BioFishency ELX enables the ability to maintain a regular feeding regime, and exceptionally low water discharge during depuration of the fish from the off-flavor agents

Testing Setup

Two tests for MIB and Geosmin decomposition using an electro-chemical cell were conducted at lab scale: the first, to evaluate the effect of a single pass on off-flavor agents, and the second, to yield results under conditions that simulate BioFishency ELX deployment.

To simulate BioFishency ELX system design, the first testing setup consisted of two tanks, a pump, and an electrolyzer. The water from Tank 1 was pumped through the electrolyzer, in single pass mode. The initial MIB and Geosmin concentrations in the treated water was 450 ng/L. The procedure was repeated twice, the first time, with ammonia in the water, and a second time, without ammonia.

The water used in both tests was Mediterranean seawater. A control experiment was designed to examine the decomposition rate of MIB and Geosmin by dosing a Cl_2 rich solution (made via electrolysis of seawater) to a MIB and Geosmin seawater-containing solution. Cl_2 was added, resulting in two different concentrations: 250 and 750 mgCl_2/L, at contact times of 6 and 18 min, respectively.

These two concentrations were selected, as they were the calculated Cl2 concentrations achieved after HRT of 16 and 50 s in the electrolyzer (in the absence of ammonia). In Test 2, Tank 1, which contained 50 L of seawater with TAN concentration of 30 mgN/L, was recirculated through the electro-chemical reactor, until ten minutes after the ammonia had been fully electrooxidized.

Proportions between the electrolysis tank and the electrolyzer volumes and the flow rate through the electrolyzer, were derived from the BioFishency ELX design. Prior to operating the electro-chemical reactor, the pH value was reduced to below pH 4.

MIB and Geosmin analysis was performed in a service lab at Tel Aviv University, Tel Aviv, Israel.

Test Results

Table 1: Control. 250 and 750 mgCl_2/L represents the equivalent chlorine generated after HRT of 16 and 50 s, respectively. MIB and Geosmin concentrations at t=0 was 461 and 429 ng/L, respectively, as illustrated in the table below.

			Removal Rate (%)	
TAN t=0	**Dose**	**Contact time**	**MIB**	**Geosmin**
mgN/L	mgCl_2/L	min	%	%
0	250	6	1%	0%
0	750	18	93%	3%
400	250	6	0%	0%
400	750	18	82%	0%

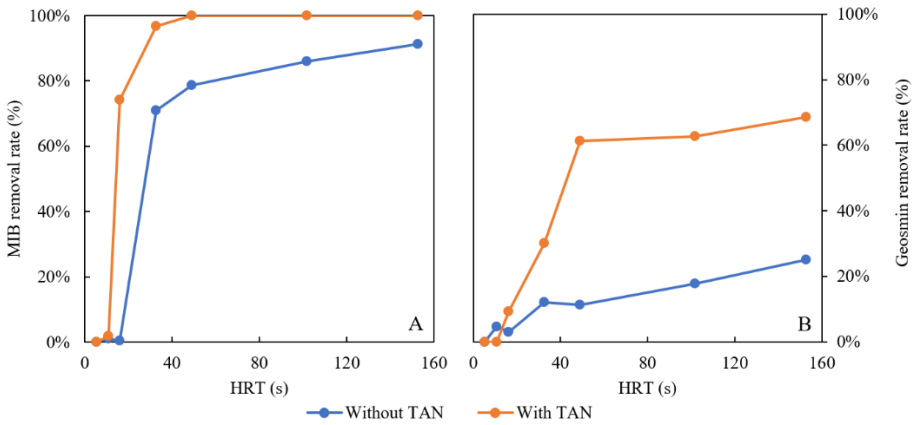


Fig. 1: *Test 1 – MIB (A) and Geosmin (B) removal rates in a single pass through the electrolyzer, with (red) and without (blue) TAN background, at different HRT in the electrolyzer*

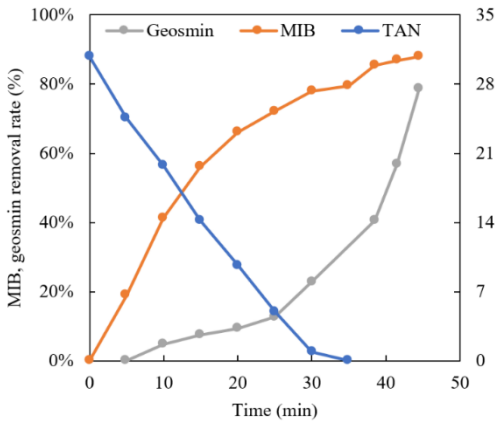


Fig. 2: *Test 2 – MIB (red) and Geosmin (grey) removal rates in a recirculating mode through the electrolyzer, and TAN concentration (blue). MIB and Geosmin concentrations at t=0 was 104 and 116 ng/L, respectively.*

Conclusions

Extensive testing yielded measurable results, showing BioFishency ELX's unique ability to address MIB and Geosmin by significantly decomposing both compounds, and eliminating them. Further, MIB and Geosmin can be efficiently decomposed using the applied electro-chemical reactor, even at single pass, while in BioFishency ELX's purging solution, the system's water volume passes tens of times per day through the electrolyzer.

Extensive testing yielded measurable results, showing BioFishency ELX's unique ability to address MIB and Geosmin by significantly decomposing both compounds, and eliminating them.

Testing also confirmed that by deploying BioFishency ELX, MIB was efficiently decomposed along the electrolysis batch reaction, with a removal rate of ~80% at the time that TAN was completely removed. Geosmin demonstrated low removal efficiency up to the TAN termination point (~30%), while a significant improvement was achieved beyond the point where TAN was completely oxidized. Further, Geosmin is not oxidized by chlorine alone, while MIB showed efficient removal only at a high Cl_2 concentration of 750 mg/L.

By testing BioFishency ELX's ability to efficiently break down and eliminate extensive levels of MIB and Geosmin and remove off-flavors in RAS-raised fish, BioFishency ELX has the potential to yield formidable results for other cold and warm water species, such as shrimp and trout. BioFishency ELX presents unlimited possibilities to further support the global RAS industry, and its quest for sustainable, cost-effective solutions to produce healthier fish. To that end, testing clearly indicated that deployment of BioFishency ELX in the purging process fully eliminates today's costly water discharge in both the fish feeding and growing processes.

BioFishency ELX is a new breed of disruptive RAS water treatment solutions developed by BioFishency, to not only reduce water consumption with full parameter monitoring and control, but to **enhance efficiency and productivity, year-round harvest of high-quality fish, and fully eliminate off-flavors.** BioFishency ELX presents a true revolution in the aquaculture industry, to help combat overfishing, lower the carbon footprint in urban areas, yield significant water and energy savings, and reduce greenhouse gas emissions. In turn, BioFishency ELX helps industry investors and fish farmers reduce operational costs, save valuable resources and the space required for efficient indoor fish farming, and eliminate the need for costly third-party systems.

About BioFishency

Founded in Israel in 2013, and part of The Trendlines Group, BioFishency Ltd. develops, manufactures and markets disruptive aquaculture water treatment solutions for Recirculated Aquaculture Systems (RAS). The company's patented technologies enable the production of healthier seafood products, while lowering the carbon footprint, and yielding cost and resource savings for its customers around the globe. BioFishency brings together expertise from the aquaculture, agriculture, engineering, and business development sectors, backed by a skilled and professional management team. With offices and production facilities in Israel and China, and a global install base, BioFishency solutions have been successfully deployed in China, Nigeria, Congo, Bangladesh, India, and Israel.

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