ELOXIRAS®: CASE STUDY

Introduction

APRIA Systems is a technology-based company, strongly focused on innovation to provide sustainable advanced solutions for the purification of industrial streams based on membrane and advanced oxidation technologies. APRIA Systems' experience has allowed the development of a novel water treatment process for recirculation aquaculture systems (RAS), ELOXIRAS®. This treatment is based on electrochemical oxidation processes, which generate a mixed oxidant without the addition of chemicals, only by applying an electrical potential between two electrodes in water. The developed technology achieves high removal rates of contaminants such as total ammonia nitrogen (TAN) and nitrite, also presenting a high disinfectant efficacy.

The novelty of the ELOXIRAS® system is its ability to increase the production of different marine species:

1. Allowing higher culture densities within the purification controlled limits.
2. Reducing new water intake consumption (and thus, proportional wastewater generation).
3. Removing whole key pollutants in an efficient way (>90%).
4. Increasing by a minimum of 30% the estimated potential benefit (€/year) of the overall process.

The technology.

ELOXIRAS® is a modular and versatile solution, which integrates three steps in the treatment process (figure 1): (i) pre-treatment by filtration of the water, (ii) main treatment by means of an oxidation reactor for the removal of pollutants and pathogens, and (iii) post-treatment for the removal of byproducts.

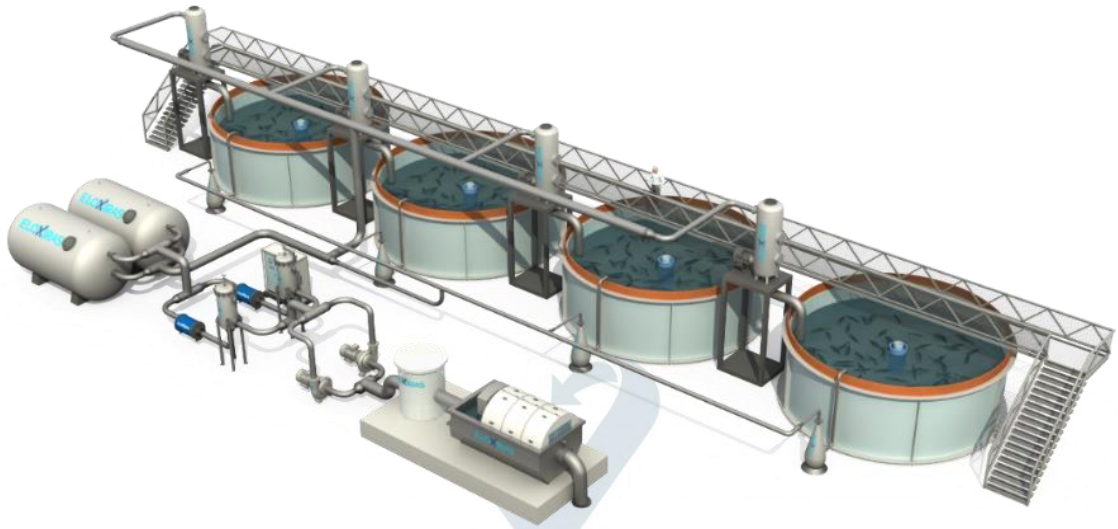


Figure 1. ELOXIRAS® integrated concept.

Due to the selective oxidation reactions promoted (figure 2), ELOXIRAS® allows attaining high removal rates of most concerning contaminants, such as TAN, nitrite and dissolved organic matter, also presenting high disinfectant efficacy.

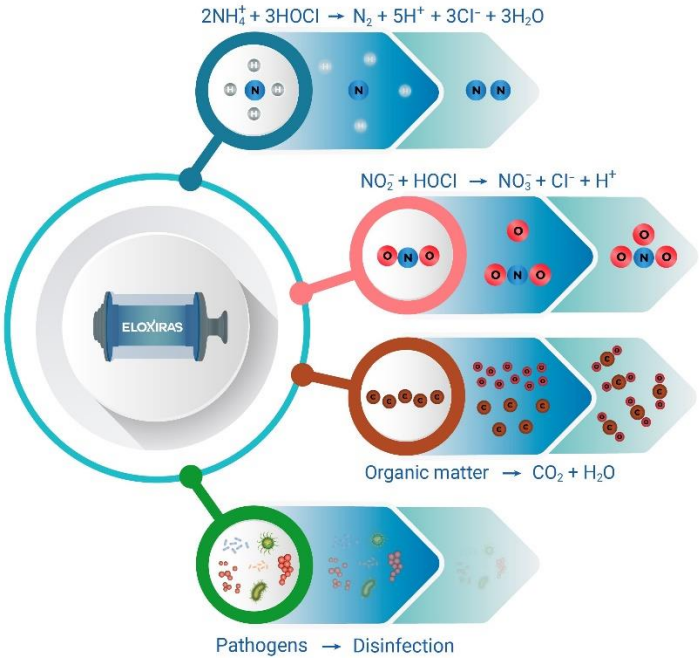


Figure 2. Main electrochemical reactions produced in ELOXIRAS®.

The ELOXIRAS® technology has been subjected to validation tests under real operating conditions in marine fish hatcheries and marine fish growing farms with the aim to corroborate the efficacy of the system in terms of pollutants remediation and to demonstrate its applicability to end-users.

ELOXIRAS® validation.

Figure 3. ELOXIRAS® treatment (model MINI-600-4.0).

The present case of study reports the performance of ELOXIRAS® in the most recent validation tests that were conducted under real operating conditions in an aquaculture facility in Spain (figure 3), which involved two different species of fingerlings: Gilthead sea bream and Sea bass. The target biomass density was between 20 and 50 kg/m^3 and a total rearing water volume of 20 m^3; further details regarding operating and culture conditions are summarized in table 1.

Table 1. Prototype specifications and culture conditions concerning validation tests.

Studied species	Capacity (m^3/h)	Culture conditions		
		Max. biomass density (kg/m^3)	$V_{culture}$ (m^3)	Recirculation rate (m^3/h)
Gilthead sea bream	Up to 50	49	20	26
Sea bass		44		

Main results.

In the first place, with regard to water quality, ELOXIRAS® showed a remarkable performance. The concentration values of the most concerning pollutants as well as other additional water quality indicators were intensively monitored in the fish tanks throughout the testing period. The observed values (table 2) evidence that the water treated by the ELOXIRAS® technology amply fulfills the quality requirements for RAS proposed in the literature.

Table 2. Averaged water quality parameters in ELOXIRAS® validation tests.

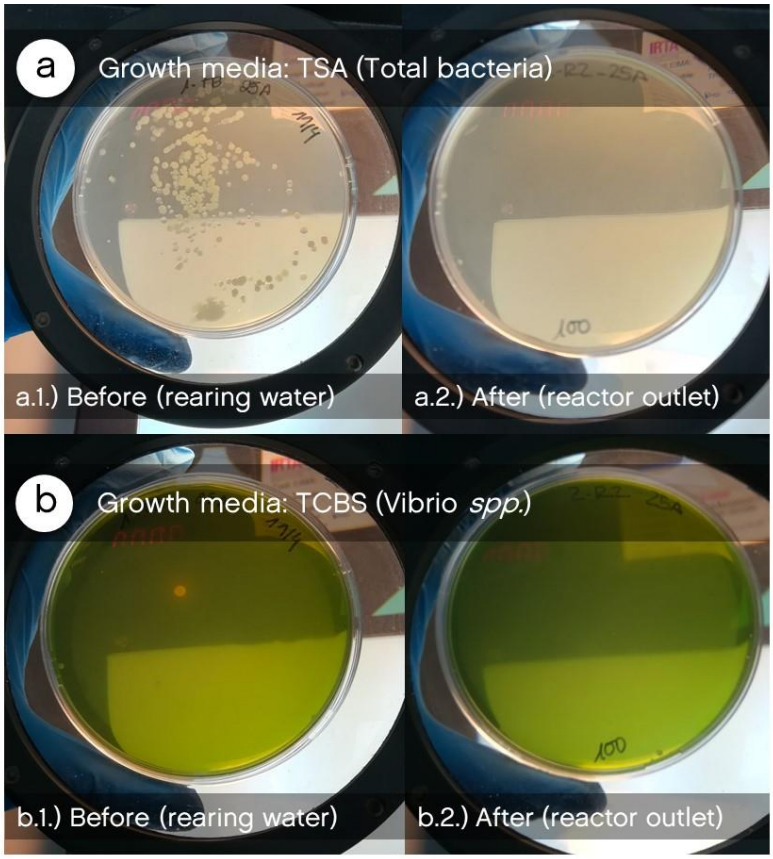
Parameter	Gilthead seabream	Sea bass	Quality criterion[a]	Water quality
pH	7.1 ± 0.2	7.2 ± 0.4	6.5 - 8.5	✓
Salinity (g/L)	35.8 ± 1.2	35.9 ± 1.2	-	✓
Temperature (°C)	23.6 ± 2.1	23.7 ± 1.6	-	✓
Dissolved oxygen (mg O_2/L)	8.4 ± 2.4	9.9 ± 2.1	> 5	✓
TAN (mg/L)	0.7 ± 0.5	0.7 ±0.5	< 3	✓
Nitrites (mg NO_2^-/L)	0.02 ± 0.01	0.01 ± 0.01	< 1	✓
Nitrates (mg N-NO_3^-/L)	1.0 ± 1.8	0.4 ± 0.5	0 - 90	✓
Chemical oxygen demand (mg O_2/L)	< 30	< 30	-	✓
Total suspended solids (mg/L)	24 ± 20	16 ± 3	10 - 80	✓
Oxidation-reduction potential (mV)	171.3 ± 90.0	171.5 ± 81.3	-	✓

[a]Quality criteria according to Timmons et al., 2009.

As seen in table 2, the rearing water quality was kept within optimal values. This is possible thanks to the high removal rates of concerned pollutants involved in RAS (figure 4) —namely, total ammonia nitrogen (TAN), its nitrification derivatives (nitrites and nitrates), and organic matter (expressed in terms of chemical oxygen demand or COD)—. There was also well-founded evidence to confirm the disinfection ability of ELOXIRAS® —with a pathogens removal efficacy greater or equal to 3 log CFU/mL (figure 5)—.

	Inlet	Outlet	Removal (%)
TAN (mg/L)	1.97	0.14	93
Nitrites (10^{-1} mg $N\text{-}NO_2^-$/L)	1.58	0.18	89
Nitrates (mg $N\text{-}NO_3^-$/L)	1.80	0.86	52
COD (10^{-1} mg O_2/L)	1.8	1.1	40

Figure 4. Experimental values of key pollutants at the inlet/outlet of the ELOXIRAS® system.



	Inlet	Outlet	Removal (%)
Total bacteria (CFU/mL)	207	n.d.	> 99.9 (> 3 log CFU/mL)
Vibrio spp. (CFU/mL)	3	n.d.	> 99.9 (> 3 log CFU/mL)

Figure 5. Plate count for the determination of the microbiological content at the inlet/outlet of the ELOXIRAS® system: a) total bacteria; b) *Vibrio spp.*. n.d.: not detected.

In the second place, for a proper evaluation of production quality and capacity, the validation tests of ELOXIRAS® were conducted in parallel analogous tests under a commercial conventional RAS system. As shown in figure 6, RAS operations based on ELOXIRAS® technology allows to obtain similar growth rates to those reported under similar culture conditions with a biofiltration-based RAS. Feeding and growth indices were well aligned with those expected for a RAS with high quality rearing water, evidencing the capability of ELOXIRAS® to contribute to an enhanced productivity. As an example, values of these indices obtained for Gilthead sea bream and Sea bass under different growth stages are summarized in tables 3 and 4, respectively.

Table 3. Feeding and growth performance for Gilthead sea bream.

	Pre-growing		Ongrowing	
Parameter	Expected values	ELOXIRAS®	Expected values	ELOXIRAS®
Biomass density (kg/m^3)	20	36	35	49
SGR (%/day)	3.8	5.1	0.56	2.0
SFR (%/day)	3-8	5.0	0.5-3.5	3.8
FCR (kg feed/ kg fish produced)	1.2-1.4	1.3	1.5-2	2.0

Table 4. Feeding and growth performance for Sea bass.

	Pre-growing		Ongrowing	
Parameter	Expected values	ELOXIRAS®	Expected values	ELOXIRAS®
Biomass density (kg/m^3)	20	39	23	44
SGR (%/day)	3.8	4.3	0.6	1.6
SFR (%/day)	3-8	5.2	0.5-3.0	3.7
FCR (kg feed/ kg fish produced)	1.1-1.4	1.4	1.5-2	2.5

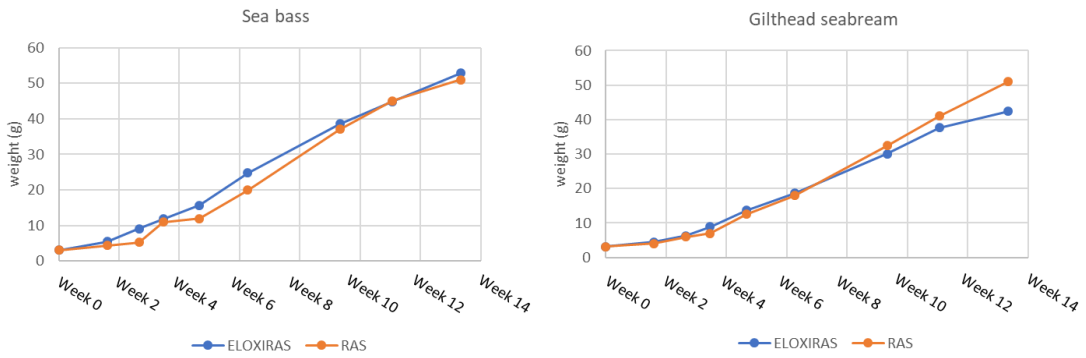


Figure 6. Evolution of mean weight for a comparison of the growth of the Sea bass and Gilthead sea bream specimens in a RAS under ELOXIRAS® (ELOXIRAS®) and a conventional technology (RAS).

In addition to a proper feed and growth performance, based on histopathologic studies conducted by internationally renowned veterinary professionals from Universitat Autònoma de Barcelona, the welfare of the fish is more than guaranteed. What is more, apart from the absence of significant injuries in the examined specimens, the experts pointed out the remarkable good condition of the fish. For further reference, please find below an extract of the results report, which briefly summarizes the outcome of the histopathologic study:

"*No macroscopic injuries were observed in the specimens, except for some occasional injuries in the fins, probably due to capture. The state of the fish was very good. The histologic study indicates the practical absence of significant anomalies or injuries in all the examined organs. In addition, the remarkable quality of the samples allowed a detailed analysis. In this regard, no signs of small alterations in gills, skin or kidney, which are very common in aquaculture fish, were found. The above suggests that the system (ELOXIRAS®) is providing a superior water quality in comparison with other systems. This better water quality leads to a better health of the fish*".

For illustrative purposes, the original and final look of the fish is shown in figure 7.

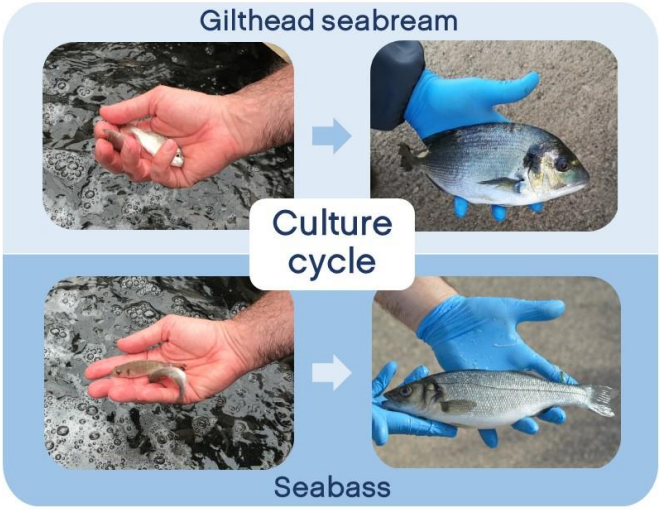


Figure 7. Depiction of the growth of fish farmed with an ELOXIRAS®-based RAS after one culture cycle.

Finally, with respect to resources consumption, an efficient use was made: i) the make-up water intake was reduced to just 200 – 300 L per kg of fish produced —becoming an intensive RAS—, and ii) low energy consumption was observed —e.g. 0.13 kWh/g TAN removed—.

In conclusion, the ELOXIRAS® technology is able to keep pollutant concentrations under suitable values with growth rates equal to those reported by the literature under similar culture conditions. This, together with competitive O&M costs, and affordable investment costs, make ELOXIRAS® technology a good candidate to contribute to enhance benefits and reduce environmental impacts of RAS facilities.

ELOXIRAS® technology benefits.

The remarkable performance of ELOXIRAS® allows a paramount intensification of marine RAS, enhancing its productivity and reducing the environmental impact. Specifically, based on the tests conducted:

- Integration of additional technologies for disinfection or even denitrification is not required, unlike many other conventional RAS based on biological filtration. Important savings on final water treatment processes before discharge to the media can be obtained.
- Production capacity can be increased by a minimum of a 30% in comparison with typical values, while maintaining the farming performance in relation to feeding and fish growth.
- Make-up water consumption at intensive RAS level is possible, which imply more than 50% reduction compared to biofilter-based RAS.

References.

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