Rethinking phytoplankton production: How cell density and biosecurity drive hatchery success

Reliable production of high-quality live microalgae remains a critical – and often labor-intensive – part of hatchery operations. French manufacturer Synoxis algae has spent the past decade developing automated photobioreactors (PBRs) designed to simplify microalgae production while improving consistency and biosecurity. Drawing on more than 20 years of experience in PBR design and manufacturing, including early scientific collaborations with IFREMER and the University of Nantes, the company now has more than 170 installations worldwide.

In this Q&A, Hugo Vuillemin, Business Manager at Synoxis algae, discusses why cell density, automation and modular production can help hatcheries rethink the way they produce live microalgae.

HFM: Today, live microalgae production remains one of the most significant operational bottlenecks and cost drivers in modern hatcheries. Why is it still so challenging today to secure and automate this critical step?

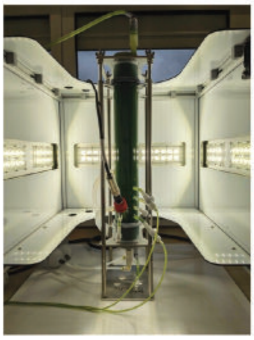
HV: This is a challenge we see among hatcheries worldwide, as phytoplankton cultures are essential for feeding animals and ensuring the overall viability of hatcheries.

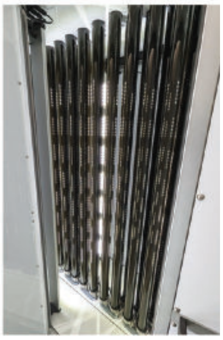
The challenge isn't simply growing algae; it's consistently producing the right quality while minimizing the risk of a culture crash. Hatcheries rely on specific strains for their nutritional value, such as *Isochrysis, Rhodomonas or Thalassiosira*, depending on the species being fed, and these are highly sensitive biological organisms.

Traditional production methods such as bags, ponds or carboys can be highly labor-intensive, requiring up to 20 hours of manual work per person each week. They can also increase biosecurity risks. Culture parameters may fluctuate throughout the year with changes in temperature and ambient light, while manual handling introduces another source of variability.

Labor is another challenge. Fewer workers are willing to take on physically demanding tasks, and handling large volumes of water at relatively low algal densities can place additional strain on operators.

At the same time, transitioning to a new production system can be a significant decision for hatchery managers. They need to see clear evidence that a





system will perform reliably before committing capital and operational resources. This is the feedback we hear repeatedly from hatcheries worldwide.

This feedback has shaped the way we design our photobioreactors. We believe automation, ease of use and robustness should serve both the biology and the operator. For example, an operator typically spends around two hours per week managing a PBR such as our JUMBO system. The objective is to move from labor-intensive, high-volume production toward more controlled, high-density cultivation.

HFM: Photobioreactor capacity is often discussed in terms of volume. Why do you argue that cell density is a more meaningful measure of production efficiency for hatcheries?

HV: Whenever this comes up, the question we get almost every time is: *"What is the production volume of your system?"* But the real question a hatchery should ask is: *"What algal density do we actually need per day?"* Ultimately, density and volume need to be considered together.

Focusing solely on tank volume highlights a fundamental misunderstanding of what a hatchery actually needs. Larvae require microalgal cells, not simply a volume of culture water. When production is based primarily on large volumes at relatively low cell concentrations, hatcheries also have to pump, heat, cool, filter and treat more water. That increases both the physical footprint and resource requirements of the system.

Our approach is therefore to prioritize high cell density. Our SALT (Spiral AirLift Tubular) technology has a high surface-to-volume (S/V) ratio – the relationship between illuminated surface area and useful culture volume – which helps optimize light availability to the microalgae.

In commercial use, our systems have achieved concentrations of up to 130 million cells/mL in batch production within one week and around 80 million cells/mL in continuous mode with strains such as T-*Isochrysis*. Productivities are even higher for some users depending on the strain.

At these densities, which can be 10 to 15 times higher than those achieved in conventional systems, according to our operating data, a 280-L JUMBO can produce a comparable amount of usable biomass to much larger, lower-density systems. JUMBO occupies approximately 4 m^2 of floor space. Reducing the volume of water that needs to be treated, heated, cooled and filtered can lower utility costs (OPEX) while also reducing potential pathways for contamination. Smaller production volumes can also make cultures easier to isolate and manage if a problem occurs.

There are practical benefits at harvesting as well. Operators can transfer smaller volumes of highly concentrated culture to achieve the required cell count. It also offers key biological advantages for the animals: it reduces water handling, allows feeding algae directly in the rearing tanks, limiting disturbance and stress, and reducing pH differences between the algae culture and the tanks.

HFM: Beyond cell density, the daily routine of a hatchery relies heavily on culture management. How does this high-density approach affect inoculation, scale-up and daily harvesting?

HV: Every manual culture transfer or adjustment introduces additional labor and a potential biosecurity risk. Traditional production methods can require several intermediate steps and relatively large volumes of starter inoculum before a production unit is running. For example, operators may need to start a carboy or bottle a week before harvesting a production tank, with an Erlenmeyer flask started a week before that. Each additional step requires time, resources, and energy.

High-density cultivation allows us to simplify that process. For inoculation, a single 100-mL inoculum from a flask can be used to start our 280-L JUMBO PBR. This reduces the volume of starter culture required and the number of transfers involved, helping limit both labor, space required in the starter room and exposure to external contaminants during transfer.

During scale-up, the high surface-to-volume ratio and optimized lighting help cultures reach exponential growth rapidly. Depending on the strain and operating conditions, a JUMBO 280-L can reach production density and be ready for harvesting in less than a week. Parameters can be predefined for the target strain, with the PBR automatically regulating the production environment. In our installations, a JUMBO 280-L can provide the biomass output that would otherwise require a conventional production line containing considerably larger culture volumes, more than 5,000 L in some configurations.

The same principle applies to daily harvesting. Operators can harvest smaller volumes of concentrated culture while still delivering the required number of cells to the larvae. That means less water transfer, less equipment use and less disruption to water parameters in the rearing tanks.

Cleaning is another important part of the workflow. Our photobioreactors incorporate an automated cleaning-in-place (CIP) process. When a culture change is required, the system can be automatically cleaned and disinfected before a new production cycle begins.

HFM: Looking at the complete picture, hatchery operators need operational reliability and the ability to scale. How do automation and modularity fit into that approach?

HV: Automation needs to simplify the operator's job without introducing unnecessary technical complexity or additional points of failure. Hatcheries are demanding environments, so operators need robust, real-time control that supports biological performance.

Our photobioreactors can, for example, be equipped with a bypass density sensor that continuously measures biomass concentration and contamination without requiring manual sampling. This helps operators monitor culture development while reducing the need to open or manipulate the system. It can also be used to automate harvesting when the target cell density is reached.

We also integrate alarms for critical production parameters. If a CO_2 bottle runs empty during pH regulation, for example, the operator receives an alert on the PBR screen and an email notification, allowing the issue to be addressed quickly.

The other part of risk management is scalability. Rather than concentrating production in one very large vessel, we favor a modular approach that distributes capacity across several units.

Our range extends from the 3-L NANO for strain selection and R&D to the 20-L LUCY for intermediate scale-up and the 280-L JUMBO for continuous production. Hatcheries can therefore configure multi-unit production lines according to their daily biomass requirements and the species they are producing. This modularity also provides redundancy: if one unit requires maintenance, other units can remain in operation. For hatcheries requiring a dedicated cultivation facility, the same systems can also be integrated into turnkey algae containers.

Ultimately, we see high-density production, automation and modularity as complementary tools. The goal is not simply to produce more algae, but to give hatcheries greater control over how that biomass is produced while reducing labor, water use and biosecurity risks.

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