

INTEGRATION OF A NEW PHOTOSYNTHETIC BIOFILM FILTER IN RECIRCULATING AQUACULTURE SYSTEMS AND DIRECT BIOMASS RECOVERY

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Introduction

The treatment of nitrogen compounds in recirculating aquaculture systems (RAS) is a rigorous task to ensure optimal water quality and fish production. In nature, the concentration of different species of nitrogen is controlled by photosynthetic organisms and by different microbial metabolisms, including nitrifying bacteria. The traditional treatment of RAS water is to separate the solid matter and the metabolic waste to avoid the decomposition of this material which increases the concentrations of total ammonia nitrogen (TAN). Even at low doses, these nitrogen species are toxic to fish. Despite this first treatment, a non-negligible fraction of TAN is found in water and requires a second treatment by nitrification. Ammonium will be oxidized to nitrite and nitrate. Nitrite is also toxic to fish and nitrate, although more stable, does not enter the fish diet but may cause growth inhibition beyond a certain concentration (vanRijn et al., 2006, Davidson et al. 2014). As a result, nitrate-rich waters are regularly renewed and are released into the environment, polluting lake and river ecosystems through eutrophication.

Nitrification is a widespread method for eliminating TAN because, thanks to the acidifying power on the medium, this process allows a good control by preventing the new formation of ammonia nitrogen and in particular volatile ammonia. However, the acidification due to the increase of CO₂ dissolved in the environment is very problematic because it affects the quality of water for fish. This CO₂ must be removed before recirculation in the fish pond by a fairly energy-consuming system requiring an oxygen supply. A TAN treatment system based on microalgae would be very advantageous because it directly assimilates ammonia nitrogen and CO₂ to transform it into biomass while producing oxygen. This biotechnology offers the possibility of directly exploiting the algal biomass produced, for example, by processing into a food packaging medium or as a feed for fish farming.

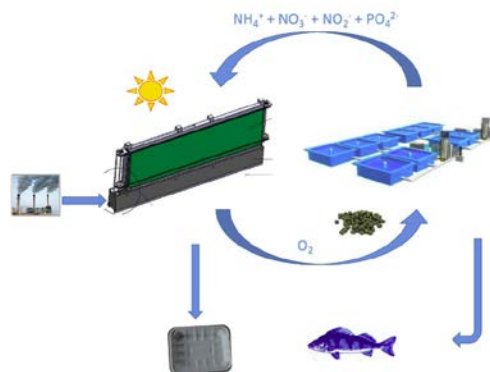


Fig. 1. System for water treatment from RAS by a photosynthetic biofilm culture reactor and generation of bioproducts based on algal biomass.

Methods

The research project starts with the assembly, the setting of parameters and finally the operation of the photosynthetic biofilm reactor to allow biofilm development. Then, it is intended to operate two tests: one for the treatment of the final effluent leaving the RAS

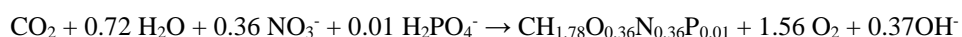
and the other, for the treatment of the RAS water simulating as much as possible the volume of water retained and the daily treatment of a biological filter.

Preliminary results

A previous project called AlgOnfilm allowed to validate under industrial conditions (Wastewater Treatment Plant of Yverdon-les-Bains) and for 6 months, the pilot biofilm photobioreactor system. The main goal was to treat the daily water volume attributable to 1 EH (equivalent-inhabitant) on a ground surface of 1 m². The most important results were a total N reduction around 60% while for P it was 100%. For ammonium the reduction was 100%. The concentration of heavy metals in water was also reduced on average (on all metals) by 20%. Another meaningful result was the production of a fairly homogeneous bioplastic resin by mixing 30% lyophilized algae and 70% biodegradable polyester.

Scenario analysis of nutrient removal from an industrial RAS facility:

The water analysis allows establishing the stoichiometric reaction of biomass production in relation to the reduction of nitrates and the production of oxygen. With a N: P ratio of 36:1 and considering that all the inorganic nitrogen is in the form of nitrate, it is predicted that photosynthetic activity assimilates N and P in this way:



Oxygen production based on the ground surface will be the result of the quantum yield (moles of O₂ released per mole of absorbed photons) multiplied by irradiance (which is the surface density of flux of light energy). The quantum yield is a hypothetical value based on a theoretical maximum efficiency of 0.1 and which takes into account several losses (reflection, respiration, photo-saturation or -inhibition), while the irradiance can be estimated for any location and for any period of the year. Oxygen production based on the ground surface for an installation in the Jura-Nord Vaudois District between the months of April and October = 2.08 moles m⁻² d⁻¹ (with a quantum yield of 0.06 and an average irradiance of 34.66). This O₂ production will therefore be accompanied by a production of 1.33 moles m⁻² d⁻¹ of algal biomass, which from the elementary recipe of algal biomass, means an estimated production of 33 g⁻² m⁻² d⁻¹.

According to this production, the NO₃⁻ consumption of the system can also be deduced. Following the elemental molar composition of the algal biomass (defined from these culture conditions), the fraction of nitrogen corresponds to 20% of the total biomass. Thus, the rate of nitrogen consumption will be 6.6 g m⁻² d⁻¹.

Expected impact

The project idea is to generate a synergistic approach for the integration of microalgae production in the aquaculture context in order to develop an economic model taking into account its transformation to a bioproduct. For modern aquaculture systems in particular, the technology offers the advantage of reducing the budget for water consumption (water renewal today is 33% while it could be 5%) as well as the power consumption costs when compared to filters based on nitrification which require constant aeration. Additional revenues can be expected from the recovery of algal biomass as a feed for fish farming or as a raw material for the production of bioplastic materials.

References

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