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Bio-filters: The need for an new comprehensive approach

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Abstract

The aquaculture industry struggles to profit in light of low product prices, increasing costs of inputs and constrains due to environmental, water and land limitations.

Intensive aquaculture systems are relevant to efficiently produce fish and shrimp. The two important limiting factors of intensive aquaculture systems are water quality and economy. An intrinsic problem of these systems is the rapid accumulation of feed residues, organic matter and toxic inorganic nitrogen species. This cannot be avoided, since fish assimilate only 20–30% of feed nutrients. The rest is excreted and typically accumulates in the water. Often, the culture water is recycled through a series of special devices (mostly biofilters of different types), investing energy and maintenance to degrade the residues. The result is that adding to the expenses of purchasing feed, significant additional expenses are devoted to degrade and remove 2/3 of it.

There is a vital need to change this vicious cycle. One example of an alternative approach is active suspension ponds (ASP), where the water treatment is based upon developing and controlling heterotrophic bacteria within the culture component. Feed nutrients are recycled, doubling the utilization of protein and raising feed utilization. Other alternatives, mostly based upon the operation of a water treatment/feed recycling component within the culture unit are discussed.

The present paper was presented in the biofilter workshop held in Honolulu, 8–11 November 2004. The main purpose of this paper was to raise new ideas and new options toward the planning and operation of intensive fish/shrimp ponds.

Keywords: Intensive aquaculture; Active suspension ponds; Microbial control

There is a common desire to achieve higher and higher yields. However, achieving very high yields and getting listed in the Guinness book of records is not the goal of the aquaculture business. The justification for intensification stems in specific culture, environment and economy reasons. Several reasons listed here have different priorities under different conditions.

1. Environmental regulation prohibiting or limiting water disposal.
2. Bio-security concerns limiting water intake.
3. Water scarcity and/or cost. Conventional aquaculture consumes 2–10 m^3 water to produce 1 kg fish. In Israel, for example, water cost is rising to ca US$ 0.4/m^3, i.e. 0.8–4 $/kg fish.

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Table 1
Schematic presentation of pond intensity levels, approximate annual fish yields and limiting factors

Pond type	Intervention	Approximate yields (kg/ha year)	Limiting factors
Minimal feed	Minimal feeding with grains, farm and home residues	<2000	Limits of primary production, food chain efficiency
Fed ponds	Feeding by complete diet pellets	2000–4000	Early morning oxygen
Night time aeration	Night time or emergency aerators, ~1–5 hp/ha	4000–10,000	Sludge accumulation, anaerobic pond bottom
Intensive mixed aerated ponds	24 h aeration >20 hp/ha, completely mixed	20,000–100,000	Water quality control

4. There is a demand for quality control and transparency, that are difficult to achieve in extensive systems.
5. Feed utilization may be higher than in conventional systems. This may be an important point.
6. In cases where production is close to the market, space limitation is also of concern.
7. Intensification enables easier temperature control.
8. Intensification and automation may save labor.

However, intensification cost money in both capital investment and operational costs and is not always the recommended mode of development.

The evolution of pond intensification can be better seen in perspective by looking at the whole spectrum of pond intensity, as given in Table 1.

Feed, at large does not limit fish growth once fed ponds were introduced. The limiting factor in fed ponds is usually the very low early morning oxygen concentration. Introducing aeration, though partial and not covering the whole pond area and volume, provides enough oxygen to some parts of pond and it is assumed that oxygen is not a limiting factor any more. The next limitation becomes the high rate of organic matter accumulation on the bottom of the pond, development of anaerobic conditions and production of toxic metabolites (Avnimelech and Ritvo, 2003), retarding further intensification. This was overcome by thoroughly mixing the pond and aerating it 24 h/day, enabling to raise yields to levels not imagined before.

Fish (and shrimp) can be grown at very high density in aerated–mixed ponds. However, with the increased biomass, water quality becomes the limiting factor, due to the accumulation of toxic metabolites, the most notorious of which are ammonia and nitrite. To utilize the potentials of aerated–mixed ponds, water quality has to be controlled.

Three different approaches were used to control water quality:

(a) Replace pond water with fresh water, usually at high exchange rates of over five times a day. This option, though, is in contrast to environmental constrains, bio-security and water scarcity considerations.
(b) Recycle the water through an external unit (“biofilter”) that treat and purify the water.
(c) Treat water quality within the pond system, using algae (partitioned aquaculture ponds) or bacterial communities (e.g. active suspension ponds, ASP).

The use of external bio-filters was practiced successfully for years, in hatcheries, nurseries, ornamental fish culturing and to some extent in culturing of commodity fish. These systems are operative, well tested, proven and can be obtained commercially. However, they are quite costly, both in investment and in operation. As a demonstration, we can compare municipal waste water treatment plants to required bio-filters. Assuming average COD in raw municipal waste water to be 600 mg/l and waste water production of 300 l/cap day, we get a COD release of 180 g/cap day. A town of 10,000 inhabitant has to treat 1800 kg COD/day. In fish farms, feed application is about 20 kg feed day per ton fish. More than half of it is released to the water, i.e. at least 10 kg COD/ton day. A fish farm holding 180 ton of fish emit about the same load as the 10,000 inhabitant town. Moreover, the standards and demands for fish water treatment systems are higher than those for waste water treatment. The last ones releases treated water