Tilapia production using biofloc technology, saving water, waste recycling improves economics

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These 0.1-ha intensive ponds contain tilapia in a biofloc environment at Pacific Aquaculture in California, USA.

Tilapia Production Using Biofloc Technology

Saving Water, Waste Recycling Improves Economics

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Summary:
Biofloc systems enable more intensive tilapia production. The fish adapt to the conditions within biofloc systems and grow well by utilizing the bioflocs as a feed source. The recycling of feed and minimization of water exchange are important contributions to the economy of tilapia production. Understanding the biofloc system, monitoring and fast response to negative developments are essential for successful culture.

Production of tilapia has risen tremendously in the last few decades. At about 3 mmt in 2010, the volume of worldwide tilapia production was second only to carps among fish. Current trends indicate a continuous growth of production and expanded penetration of tilapia in a variety of markets, from expensive restaurants to local households all around the world.

Although higher production levels are needed, increased aquaculture production is limited globally by the availability of suitable water and land. The most feasible and environmentally acceptable way to raise aquaculture production is by the use of intensive production systems.

Biofloc Technology

One of the systems that enable intensification at a relatively reasonable investment and operating cost is biofloc technology.

Biofloc technology is based upon pond management using minimal water exchange and subsequent development of dense microbial populations. The microbes are managed through the adjustment of the carbon:niotrogen (C:N) ratio to control inorganic nitrogen concentrations in the water.

The bacteria that form bioflocs assimilate total ammonia nitrogen (TAN), produce microbial proteins and enable recycling of unused feed protein. Biofloc systems are widely used for shrimp production.

Tilapia And Bioflocs

Tilapia are ideally adapted to biofloc systems. The filter-feeding herbivores adapt to the harvest of bioflocs suspended in the water, and the strong, stable fish grow and flourish in dense systems.

An essential feature of biofloc tilapia production systems, especially as compared to shrimp systems, is the very high biomass. In the author's experience, tilapia biomass can reach 200-300 mt/ha, as compared to shrimp biomass of about 20 mt/ha in well-managed ponds. This difference is a very significant feature for minimal water exchange. The high fish density, however, generates wastes at high rates.

TAN Control

The daily TAN release, if untreated and left in the water, is high enough to lead to fish mortality. Two microbial mediated processes act in biofloc systems to control TAN concentrations.

The first process is the assimilation of TAN by heterotrophic bacteria into microbial protein. In systems with higher levels of available carbon than nitrogen (C:N ratio above 15), bacteria utilize the carbon as a building block for new cell material. However, since microbial cells are made of protein, they need nitrogen and take up ammonium from the water. Both experience and theory demonstrate that when C:N is higher than 15, TAN concentrations are kept low.

The second microbial process is nitrification that converts the toxic ammonia and nitrite to nitrate. It is important to note that both processes can take place only if the proper microbial consortia are present in sufficient levels in the water. The heterotrophic consortia develop rather quickly following the build-up of organic matter in the water. The nitrifying community develops slowly and takes about four weeks to reach its capacity, unless a proper inoculum is applied.

Microbial assimilation of nitrogen is, as mentioned, a high-capacity mechanism that controls nitrogen and especially TAN levels in water. Microbial protein produced concomitantly can serve as a high-quality feed source for fish. In biofloc microbial systems, where bacterial density can reach 1 billion cells/mL, the bacteria stick together with other organisms and organic particles to form bioflocs whose particles range in size from 0.1 to a few millimeters. Such particles are easily harvested and assimilated by tilapia.

Suspended Solids

Total suspended solids (TSS) or biofloc volume quickly accumulate in ponds when fish biomass is high. The desired microbial community and reserves of feed should not be released carelessly, but excessive levels of TSS add to oxygen consumption and at very high levels can clog the gills of fish.

In addition, if water is not well mixed or TSS concentrations exceed the mixing capacity of the system, solid particles settle downward and can accumulate in anaerobic soil layers or pockets. Anaerobic sites in pond bottoms can lead to the production of toxic reduced compounds and eventually severely hamper fish growth.

TSS levels can be controlled by drainage of sludge, proper water mixing and good pond bottom design.

Protein In Bioflocs

The amounts of protein stored in bioflocs are very significant. If only 50% of the TAN excreted by tilapia is assimilated and available as a fish feed, this process can add an amount of protein equivalent to feeding with 30%-protein pellets at a daily ration of 150 g/m^3. Moreover, unlike the applied feed, bioflocs can be utilized by the fish continuously.

In comparing the feeding behavior of tilapia growing in a biofloc pond with tilapia in equivalent control ponds that received feed twice a day, fish in the control ponds were very hungry and rushed wildly to the floating feed pellets, while tilapia in the biofloc ponds ate quietly, showing they were not starved before feeding. It may be expected that the semi-continuous feeding available with bioflocs would help smaller fish compete with larger fish for food and thus achieve higher uniformity in size.

Feeding

Feeding is an important control in achieving the proper C:N ratios that promote the uptake of ammonium from the water. In addition, effective feed strategies enable fish to utilize the recycled microbial protein, reduce costs and minimize residues. There is a need for more research on optimized feed composition and ration.

The recommended C:N ratio can be obtained by feeding with pellets of low protein content or by augmenting the feed

High stocking density is a typical facet of biofloc systems.

pellets through the application of carbonaceous material such as molasses, cassava, wheat or other flours. The first option may save labor. However, the author's facility relies upon the passage and excretion of the added carbohydrates through the fish to be used by the bacteria. This assumption may not hold.

Feed rations can be lower than those used in conventional tilapia ponds. With shrimp in tanks, it was found that feed rations could be reduced 30% lower than the rates used in conventional systems. It was estimated, but not proven, that feed rations in biofloc tilapia systems can be lowered at least 20% from conventional system levels.

Molasses is readily soluble and its addition to ponds is rather simple. Adding flour demands more effort in dispersal. Using a mixer in a container outside the pond to create a suspension, rather than the dry flour that tends to cake in the pond, can assist the process.

Oxygen Management

Oxygen consumption in intensive biofloc tilapia culture is rather high due to the respiration of the high fish biomass as well as the microbial community that metabolizes the organic residues. Oxygen consumption has been estimated or modeled by several scientists.

Biofloc tilapia ponds tend to be rather small – 100 to 1,000 m^2 – mostly due to difficulties in thoroughly mixing the water within larger bodies. Most ponds are round or square with rounded corners. The pond floors usually slope toward the center to facilitate concentration and daily removal via a drain.

The range of required aeration is 10 to 20 hp for a pond of 0.1 ha. However, the exact aeration rate needed for a given pond should be adjusted following the daily determination of oxygen levels in the pond, with a normal minimal level of 4 mg oxygen/L. One should adjust aerator usage to the size of the fish and pond biomass. Farm operators can usually use lower aeration at the start of the production cycle, although it is recommended to utilize the capacity of the pond by stocking large numbers of fingerlings and maintaining a relatively constant biomass by appropriate transfers.

It was estimated that feed rations in biofloc tilapia systems can be lowered at least 20% from conventional systems levels.

Proper placement of aerators is very important. Most pond aeration is deployed to obtain a circular movement of water that concentrates settled particles as close as possible to the center drain, usually using paddlewheel aerators. However, there are conflicting demands in this matter.

We want to be able to effectively drain excess sludge, yet keep bioflocs suspended in the water. To prevent overly effective sedimentation of particles near the center drain, it is advisable to position an aspirator aerator or airlifts to resuspend particles near the pond center. By properly adjusting the location of these units, optimal resuspension of the less-dense bioflocs and sedimention of the heavier particles can be achieved.

A very important requirement is to have a sensitive and reliable monitoring and backup system. Aeration failure at high fish biomass can be critical if backup is not activated within an hour.

Monitoring

Although biofloc tilapia ponds are rather simple to operate, they demand careful monitoring and fast response to any problems detected. Since the ponds are so highly loaded, any fault not responded to can become critical. Normal aquaculture monitoring is certainly needed. Of special importance are the following parameters:

- **Oxygen.** If oxygen is high, you can reduce the number of applied aerators to save electricity. However, if oxygen levels are less than 4 mg/L, add aerators.
- **Total ammonia nitrogen.** TAN concentrations below 0.5 mg/L mean the system is working well. You may consider adding less carbon. If TAN increases, respond quickly with carbon supplementation.
- **Nitrite.** Nitrite can negatively affect tilapia, although its effects are limited in salty water. However, an increase in nitrite can indicate the build-up of anaerobic sites. In the case of an increase of nitrite, carefully check for sludge piles and, if found, change aerator deployment.
- **Floc volume.** Determination of floc volume using Imhoff cones is easy and cheap. Floc volume should be in the 5-50 mL/L range. If it is too low, add carbohydrates, and if it is higher than 50, increase sludge removal.

Aeration is essential, as oxygen consumption in intensive biofloc systems is high due to the respiration of the fish as well as the microbial community that metabolizes their organic residues.

International Coalition Breaks Cobia Fingerling Production Bottleneck

Rotifers are produced in an automated generator comprised of two 500-L culture tanks, a fluidized-bed biofilter and a protein skimmer.

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Summary:
Fingerling production has long been a bottleneck in the advancement of cobia culture. A coalition that integrated the ongoing work of Virginia Tech with the International Initiative for Sustainable and Biosecure Aquafarming has validated intensive cobia larviculture production systems and protocols that deliver 35% survival through weaning with an average production of 5.5 fingerlings/L in 25 days. The use of high-quality, biosecure live feeds is critical. A probiotic additive may further improve physiological development.

As with all commercially produced marine finfish species, a predictable and sustainable supply of high-quality juveniles is critical for the expansion of commercial production of cobia, *Rachycentron canadum*. While great strides have been made over the last two decades, resulting in global cobia production of approximately 30,000 mt by 2008, fingerling production had already been identified as a major bottleneck towards significant increases in production.

Since the 1990s, both academic and industrial entities have struggled with improving the survival rates of cobia fingerlings. In the early '90s, Asia adapted extensive production techniques used with other marine species and succeeded in consistent, low-density production of cobia fingerlings. This initial success enabled further development and expansion of cobia growout production techniques in Southeast Asia.

Around the turn of the century, significant interest in cobia culture expanded to the Americas. Specifically in North America, interest lay in more intensive and biosecure controlled production of specific pathogen-free fingerlings.

Cobia Coalition

Beginning in 2001, Virginia Tech integrated cobia into its marine finfish production program, focused at the Virginia Seafood Agricultural Research and Extension Center (VSAREC) in Hampton, Virginia, USA. In 2005, Virginia Tech mariculture programming integrated with the International Initiative for Sustainable and Biosecure Aquafarming (IISBA), which was formed after an international cobia summit held in the European Union.

Since 2005, this coalition has focused primarily on the fingerling production bottleneck for cobia, which was defined by an inability to consistently produce an average survival rate of 25% or greater, and a final production of 5 fingerlings/L. While every year since 2005 resulted in improved production techniques, protocols, systems and biosecurity measures, this production bottleneck persisted until 2009.

In 2009 and again in 2010 with even better results, this coalition validated intensive cobia larviculture production systems and protocols that finally broke the fingerling production bottleneck. With these refinements, survival rates of over 35% from stocking sac fry through weaning, with an average production of 5.5 fingerlings/L in 25 days were achieved. In addition, these were high-health juveniles produced in biosecure systems, a requirement for sustainable industrial expansion of intensive cobia growout.

These new production protocols and procedures represent the combined inputs and efforts from numerous individuals, academic institutions and industry partners, all aligned under the IISBA umbrella.

Live Feeds Production

Critical to the larviculture production procedures is the use of high-quality, highly nutritious and biosecure live feeds. To accomplish this, strict protocols have been developed regarding the culture, enrichment, harvest and storage of rotifers and *Artemia*.

Rotifers are produced in an automated generator comprised of two 500-L culture tanks, a fluidized-bed biofilter and a protein skimmer. The system is operated with a single 0.1-h.p. magnetic