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Microbial flocs for aquaculture

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Natural treatment method supports fresh-water, marine species in recirculating systems

In recent years, the suspended microbial floc process has gained attention and worldwide use, primarily for farming marine shrimp in intensive, closed-cycle ponds. But few people are aware of its history and potential for culture of a variety of fresh-water and marine fish. The author has used microbial floc treatments over 30 years for water treatment, natural food production, nutrient recycling, and disease prevention for varied species in recirculating tanks and raceway systems.

The microbial floc on the right is dominated by bacteria, zooplankton, detritus, and brown algae, while the thin floc on the left is dominated by green algae.

ODAS, microbial floc processes

Many names have been used for suspended microbial floc treatments. ODAS, short for organic detrital algae soup, was used in projects developed by the author, but “microbial floc” appears to be the term upon which most users have agreed.

Microbial flocs consist of a wide variety of beneficial nitrifying bacteria, fungi, protozoans, ciliates, rotifers, brown and green microalgae, grazing microinvertebrates and detritus. They are continuously mixed and suspended, treating and bioconverting via autotrophic, heterotrophic, and filter-feeding/grazing microorganisms both dissolved and particulate wastes into microbial biomass.

These flocs are essentially the same as the suspended flocs, detritus, and planktonic organisms in nutrient-rich marine estuaries, which are among the world’s most productive ecosystems and nursery habitats for a wide variety of marine fish, shellfish, and shrimp.

Advantages of microbial flocs

The microbial floc treatment method is not for everyone. It requires completely different thinking than conventional biofilter systems. Instead of trying to clarify and sterilize water by removing and disposing of as much particulate waste as possible, microbial flocs bioconvert both dissolved and particulate wastes for use in several beneficial ways.

The particulate wastes create a suspended detrital substrate for microorganisms, eliminating the need for expensive

Tilapia were raised in high-density tanks with microbial floc as the sole treatment system at Solar AquaFarms in California, USA.

artificial biosubstrates and associated support equipment. The microbial floc bioconverts most wastes into natural food organisms for filter-feeding species like tilapia and marine shrimp, reducing feed and waste disposal costs.

Microbial flocs function directly within fish tanks, reducing the size and cost of piping, pumps, and controls for a separate biofilter system, and allowing closed-cycle operation of individual tanks when desired. Probiotic bacteria in the microbial floc continuously surround the fish or shrimp and provide natural disease prevention and control.

Floc projects

Marine shrimp in intensive tanks

A suspended microbial treatment process developed by the author was originally tested for intensive culture of *Penaeus vannamei* shrimp in closed-cycle, aerated, greenhouse-covered tank systems in Encinitas, California, USA, in 1978. The method eliminated expensive water filtration components and bioconverted wastes into natural food for the shrimp, reducing feed costs.

Chopped straw in baskets was used as an organic carbon source for heterotrophs and to stimulate the food chain. Although the method proved successful, it was too difficult to raise funds for scale-up because the system was too radical a concept at the time.

The tilapia fingerling production raceways at Solar AquaFarms used microbial flocs for both water treatment and natural food.

Tilapia in treated distillery effluent

In 1980, the ODAS process was used to treat and bioconvert alcohol distillery effluents into microbial protein for tilapia. A wide variety of microbial floc organisms, including microalgae, was adapted for the extremely high strength and toxicity of the effluent, which was about 100 times stronger than raw sewage.

With a 1:1 dilution with fresh water and the addition of bacteria from a polluted local lagoon that thrived on the distillery waste, the effluent was finally made safe for the tilapia, which thrived in the treated effluent and microbial floc. Twenty hectares of bioconversion and grow-out raceways were eventually constructed.

Production from the aerated raceways averaged about 22 metric tons (MT) per hectare per year, for a total of about 450 MT per year of tilapia. Supplemental feed was provided, since the natural foods were insufficient to support that density of fish production. Final effluent was used for rice farming.

Solar Aqua Farms tilapia

During the 1980s, the author developed a large commercial-scale tilapia farm in southern California, USA, for the production of high-quality fillets. A closed-cycle treatment process was required due to the shortage of fresh water, environmental restrictions, and need to prevent tilapia escape. Microbial flocs were used to reduce water treatment capital and operating costs, feed costs, and final waste disposal.

There were 7.3 ha of circular 29.3-meter-diameter tanks and 18.3 x 146.3-m raceways covered by greenhouses for hatchery and grow-out. Yield rates averaged 65 to 70 kilograms per cubic meter annually. The total farm production capacity was 2,270 MT per year.

Extensive research was done to develop low-cost, low-protein diets, and to increase the nutritional value of the detrital soup to the tilapia. The ODAS process was remarkably stable over many years, maintaining ammonia and nitrite levels under 0.6 ppm. The lower-protein feeds improved carbon:nitrogen ratios for more heterotrophic uptake of ammonia. Because no extra carbon was added to fish tanks, both autotrophic and heterotrophic bacteria were active, so nitrate accumulated.

Denitrification was accomplished as a side stream in separate "biofilter" tanks with the same ODAS organisms through the addition of organic carbon (molasses or corn syrup) and lowering oxygen levels to under 1.0 ppm. Instead of the 10 to 30 percent water exchange rates common in most intensive recirculating culture systems, the daily water input rate at Solar AquaFarms was only 0.5 percent of system volume, which was supplied from an on-site well. There was no off-site discharge, and final excess solids were digested in a settling lagoon/marsh for eventual land application.

A similar tilapia farm was developed during the 1990s in Jordan using technology provided by Solar AquaFarms. The farm is still operating profitably, selling whole tilapia to local markets.

Marine fish culture

Hybrid sturgeons were raised in microbial floc systems in Florida, USA. The fish grazed the floc and biofilm off the sides and bottoms of tanks.

From 1996 to 2001, the author directed the aquaculture project at Mote Marine Laboratory in Florida, USA, to culture snook for stock enhancement, as well as pompano, permit, and several snapper species in low-salinity recirculating tank systems. Even though these species can not utilize microbial protein directly, there were other reasons for using a microbial floc process.

For snook stock enhancement, it was essential to produce juveniles using entirely natural methods that would expose the fish to the full range of natural bacteria and organisms in the wild. A diverse microbial community was created using local organisms supplemented with cultures of probiotic bacteria for larval, fry, and fingerling culture. The probiotic floc worked very well, for no disease problems occurred over a five-year period.

The microbial floc process also worked well for water treatment and disease prevention with the other marine fish species. For parasite control, salinities below 10 ppt and hydrogen peroxide dips were sufficient. Tilapia were raised in "biofilter" tanks downstream of the marine fish to harvest the microbial floc and uneaten feed.

The two drawbacks for the microbial floc process for marine fish were related to staff and visitors, not the fish. People naturally prefer clear-water systems to see the fish, and in research projects with a variety of species and frequent visitors, the low visibility with microbial floc process may not be appropriate.

A second problem was the frequent tendency of new technicians, interns, and volunteers to drain the "dirty" water and refill tanks with "clean" water, not realizing they had thrown away the biofilter. To avoid disrupting experiments with the resultant ammonia spikes, conventional biofilters were added to each system to back up the microbial floc, which simply passed continuously through the biofilters.

Sturgeon culture

At Mote Marine Laboratory during the same period described above, six species of sturgeon were hatched and raised to determine the feasibility of sturgeon culture in recirculating systems in Florida. Most were Caspian Sea/Russian species.

The flocs and brackish water simulated the natural Caspian Sea and Volga/Danube River environments, and provided probiotic disease control and the lower light preferred by the sturgeons. In addition, the sturgeons appeared to consume the settled floc.

A second sturgeon project using microbial flocs was developed by the author for a commercial farm in eastern Canada that raised shortnose sturgeon in recirculating greenhouse tank systems. Even though conventional biofilters were installed to share the nitrification load, the colder water greatly reduced nitrification rates. The microbial floc heterotrophs proved highly beneficial, because the addition of organic carbon to the culture water as needed rapidly dropped ammonia and nitrite levels, often within only a few hours.

Design, management

Although the above projects using microbial flocs represent a wide variety of species, salinities, and climates, many common issues and management techniques have emerged.

Autotrophs Vs. Heterotrophs

There is a broad misunderstanding in the biofilter community about autotrophs versus heterotrophs. Endless publications state that heterotrophs are “bad” and particulate/organic wastes must be removed in order to eliminate heterotrophs and allow biofilters to function properly. In fact, few scientists can truly identify autotrophs and heterotrophs, and when they do, many bacteria show the capacity to switch back and forth depending on the availability of organic carbon.

All biofilters and floc systems have both heterotrophs and autotrophs. The issue is, do you want to pass the ammonia through the autotrophic pathway, ending up with nitrate accumulation, or pass it through the heterotrophic pathway and end up with microbial protein (nitrogen immobilized within microbial biomass). This is easily done by adding, or not adding, organic carbon on a steady hourly or daily basis. Big advantages of heterotrophs are their extremely rapid growth and ammonia uptake compared to autotrophs, solving ammonia problems in hours instead of weeks.

Carbon Issues, Lower-Protein Feeds

Critics of the heterotrophic microbial floc method say the need for daily organic carbon addition or low-protein feeds with high carbon:nitrogen ratios is an extra expense and task. But in recirculating systems with low or zero discharge, an autotrophic nitrification process quickly produces toxic levels of nitrate, and denitrification by adding carbon to an anaerobic stage is the most common solution.

The carbon required for either process is about the same, so the real issue is do you want to produce and/or harvest a microbial biomass, or operate an anaerobic denitrification system with the carbon? If the species raised can utilize the microbial floc, or a second, filter-feeding species is added downstream, then going the microbial floc route makes economic sense. Otherwise, it’s probably an even trade-off.

Flavor: Nonissue

Another major misunderstanding about microbial floc systems is the assumption that water with high suspended solids and/or algae causes off-flavor. Not so. The author has used microbial floc systems for over 20 years with a variety of species and salinities, including commercial “finishing” systems managed specifically for flavor optimization, with ODAS the sole treatment method.

Designers and owners of “clear-water” recirculation system are often shocked to discover their fish are badly off flavor. The causes of off-flavor are beyond the scope of this brief article, but are related to the anaerobic breakdown of organic matter, not aerobic, suspended microbial floc or algae. A few rare species of blue-green algae can add off-flavor in stagnant pond systems, but they do not survive in suspended microbial floc systems.

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