Understanding biofloc in aquaculture production systems

By Stephen G. Newman

Since 2009, protein from aquaculture production has surpassed that of fisheries for the first time in history. Aquaculture is simply a water-based agriculture with a long history. It is an essential source of nutrition, as well as a source of income for large number of communities. Aquaculture is here to stay, despite opposition to aquaculture from segments of the NGO community and commercial fisher folk. It is also certain to play an ever increasingly important role in feeding the Earth's burgeoning population.

However, as aquaculture practices intensify, environmental concerns and economic pressures oblige companies to conform to what are being termed best aquaculture practices or best management practices. These approaches to management are an attempt to bring consistency and ensure sustainability to the myriad of diverse practices world-wide. Control of waste streams and minimising environmental impacts at all levels are critical.

Recycling waste products

Aside from protein for consumption and by-products of processing (offal), the major by-product of the production process from the various culture systems is sludge. This sludge is rich in nutrients, typically nitrogen and phosphorous, as well as a host of macro and micronutrients. After each crop, it must be disposed off properly, in a manner that is consistent with avoiding nutrient enrichment (i.e. pollution) of the surrounding water environment. There are a number of different ways to get rid of this material including in-situ digestion with bacteria (conceptually confused with probiotics). Many microbial based products in the market today being sold as 'probiotics' function by digesting accumulated waste organic matter.

In sedimentation ponds, there is bioflocculation and direct disposal into receiving waters or burial into pits, etc. Flocculation refers to changes in the nature of suspended particulate materials that allow them to form aggregates or small clumps. In many waste treatment systems, this is done using chemicals such as alum, chitosan or other similar materials that impact the electrical charge of the particulates. It can also be done as well by the use of microbes and/or their metabolites (bioflocculation). These processes allow for handling of excess nutrients for easier disposal and are commonly used in the treatment of high organic content waste materials produced in human sewage treatment plants.

Biofloc

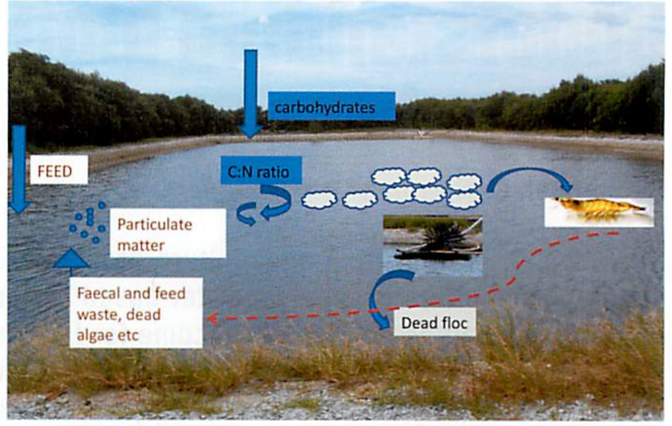
In aquaculture, this flocculation process is being exploited in a modified form in fish and shrimp culture ponds. The term biofloc has been coined to apply to these particulate materials when they are generated in very low or zero exchange water systems principally through the action of bacteria and other microorganisms. Actually, the concept is not new as it has been used for a long time in sewage treatment plants. It is only within the last two decades, that this concept is widely applied in aquaculture.

In pond environments, this is recycling in the truest sense of the word. Almost 30 years ago, Steve Serfling discovered the potential of biofloc in the production of tilapia. Considerable research has been done since then and biofloc systems are often found in intensive shrimp and fish farming systems globally.

Explaining biofloc

The term biofloc is synonymous with many others, including microbial floc, organic detrital soup, intensive microbial reuse systems, etc. Usually there is never a consistency in terms of composition between farms (and even ponds within a farm). These particulate suspensions of organic matter are composed of a wide variety of living organic and in many cases inorganic matter as well. The typical composition can include a myriad of different species of bacteria, fungi, algae, protozoa, nematodes and other microscopic organisms. This is a complex ecosystem and is in some aspects related to biofilms that typically colonise surfaces.

The generation of biofloc depends on high levels of organic matter in the ponds, usually the common by-products of culture such as faecal material, uneaten feed, dead algae and other plant and animal materials and a proper balance between carbon and nitrogen levels. As with all ecosystems, there is a succession of stages and the process will eventually result in a stable floc.



Stages of biofloc formation. A stable floc produced from the particulate suspensions of high levels of organic matter needs a balance of C:N ratio, aided by carbohydrate inputs such as molasses. The suspension requires high aeration to keep particles suspended. Fish/shrimp consume the highly nutritious biofloc and additional inputs include less costly feeds. Ammonia nitrogen is broken down into nitrates.

Why biofloc

The primary advantage of these systems is with high density production systems. Here there is limited or no water exchange, resulting in economic, environmental and production advantages. This means savings is in electrical costs with a reduction in pumping water. However, the risk is that high levels of aeration for oxygenation and water agitation is essential to ensure that the particles remain suspended in the water column. Some of the reported benefits are:

- A low or zero exchange system will have a decreased reliance on water during the production cycle. In turn, with a concomitant increase in biosecurity, the closed system decreases the risk of introducing pathogens or potential pathogens that may be present in the incoming water.
- There is a significant decrease in the amount of water resources required to produce the crop. Many of these systems require no water exchange during the cycle and typically, any incoming water is to make up for evaporation.
- The reuse of the pond water translates to a very small environmental footprint, both from the standpoint of water usage and the potential for impact from effluent that is discharged during harvest, etc.
- Reusing water is a component of sustainability. Furthermore, effluents, which are largely free of nutrients, will reduce the environmental footprint.
- The system allows for in-situ nutrient recycling. In conventional open culture systems, most of the nutrients that are not consumed and the rich nutrient content of faecal material and the huge biomass that exists in ponds are wasted. In biofloc systems this is not the case. This applies to nitrogenous nutrients particularly protein and carbohydrates as well. Micronutrients are also recycled in this manner.
- There is less reliance on external sources of feed for growth. Bioflocs are highly nutritious and are readily consumed by many species of fish and shrimp. Less costly feeds containing lower levels of nitrogen (protein) with concomitant lower feed conversion ratios can be used as supplementaryfeed.
- The cost of production is reduced and also lessens the potential environmental impact of these operations by allowing production of animals that require less fish meal and fish oils to produce.

Positive impacts on animal health include immunity and nutritional status. The biofloc system supports denitrification by the breakdown of ammonia nitrogen into biologically benign forms of nitrogen such as nitrates.

A tool and not a solution

It should be noted that biofloc system is a tool. It is not a solution and is not a substitute for progressive management strategies that encompass proper biosecurity protocols, appropriate feeding regimes and feed management strategies, monitoring for water quality parameters, that can negatively impact animals, proper disposal of excess accumulated sludge at harvest time, etc. There is not a single universal set of guidelines that can be followed, i.e. a recipe, for the production of biofloc. There are, however, some consistent features of these systems and understanding what they are and ensuring that the system is conducive to the formation of these particulate materials will go a long way towards ensuring that a degree of reproducibility is achieved.

- High biomass. High animal densities result in higher nitrogen levels from faecal material and feed waste that diffuse into the water from the feed prior to it being consumed. Particularly in the case of shrimp, these are added to the water column because of the way the shrimp feeds.
- Aeration. Vigorous aeration is required to keep the particles in suspension and to encourage their formation.
- Ratio of carbon to nitrogen. These range from about 10:1 to 20:1. The ratio has to be determined experimentally for each operation. Flocs do not form immediately and typically, the addition of molasses or other soluble carbon sources is needed to optimise conditions for biofloc formation.
- Consumption by fish/shrimp. The ability of the organisms being produced in these systems to consume the particulates. In order to prevent the accumulation of these materials from becoming rate limiting they must be removed from the system. Clearly the solution that makes the most sense is when they are eaten by shrimp (*Litopenaeus vannamei* or other omnivorous benthic grazing species) and fish (Tilapia species, some catfish species, etc.). Any other method for removal would add costs that might not be acceptable.
- Diet reformulation. Sources of sulphur in the diets and diet formulations that are not consistent with the buildup of toxic levels of micronutrients. In any system, that is largely if not completely closed, it is critical that diet formulations take this into account or the system can crash from the accumulation of metals and other potential inhibitory materials.

Useful but....

In conclusion, the production of suspended particulate biofloc in aquatic production systems is a very useful tool for improving profitability, biosecurity and lessening the environmental footprint of aquaculture. It enhances sustainability and the eco-friendly nature of aquaculture.

Not all systems lend themselves to this approach. For those that do, generation of these high nutritious and water chemistry moderating amalgams of organisms and nutrients are an essential element of a responsible and consistent production system.

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