A mini review of bio-floc in aquaculture production systems

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Protein from aquaculture production surpassed that of fisheries for the first time in history last year (2008-2009). Aquaculture is simply water based agriculture and although it is several thousand years old in some of its forms it is in many respects the last wave in the shift from a hunting to agriculture paradigm and is an essential source of nutrition and income for large numbers of people. Despite opposition to aquaculture from segments of the NGO community and commercial fisher folk, aquaculture is here to stay and is certain to play an ever increasingly important role in feeding Earth's burgeoning population. 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 minimizing environmental impacts on all levels are critical to this.

Aside from protein for consumption and the by-products of processing (offal) the major by product of the production process on the farm is sludge. This sludge is rich in nutrients, typically nitrogen and phosphorous as well as a host of macro and micronutrients and must be disposed of in a manner that is consistent with avoiding nutrient enrichment (i.e. pollution) when disposed of. There are a number of different ways to get rid of this material including in-situ digestion with bacteria (conceptually confused with probiotics), sedimentation ponds, 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 by the use of 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. This process which is commonly used in the treatment of high organic content waste materials produced in human sewage treatment plants is being exploited in a modified form in the ponds that fish and shrimp are being produced in. The term bio-floc 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. The concept is not new having been used for a long time in sewage treatment plants and only within the last two decades has this concept begun to see wide spread application in aquaculture. In pond environments this is a 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 in widespread use in intensive shrimp and fish farming systems throughout the globe. The term biofloc is synonymous with many other terms, including microbial floc, organic detrital soup, intensive microbial reuse systems, etc. Never consistent 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. 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 likely in some respects related to biofilms that typically colonize surfaces. The generation of biofloc depends on high levels of organic matter in the ponds, typically normal by-products of production such as fecal 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 are successional stages and the process of floc formation likely goes through a series of stages which eventually result in a stable floc.

The primary advantage of these systems is that they allow for limited or no water exchange in high density production systems. This provides economic, environmental and production advantages though this is not without risk. Although limiting the need to pump water reduces electrical costs this is usually offset by the need for high levels of aeration for oxygenation and water agitation to ensure that the particles remain suspended in the water column.

Some of the reported benefits include:

1. The advantages of a low or zero exchange system including decreased reliance on water during the production cycle and thus decreased risk of introducing pathogens or potential pathogens that may be present in the incoming water with a concomitant increase in biosecurity.
2. A significant decrease in the amount of external water required to produce the crop. Many of these systems require no water exchange during the cycle and any water that is added is typically to make up for evaporation.
3. The potential for substantial reuse of the pond water allowing for 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 and ensuring that when effluents are discharged that they are largely free of nutrients that can cause eutrophication is a component of sustainability and reduces the environmental footprint.
4. Nutrient recycling in-situ. In open systems much of the nutrients that are not consumed and the rich nutrient content of fecal material and the huge biomass that exists in ponds in addition to fish 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.

5. Less reliance on external sources of feed for growth. Bioflocs are high nutritious and are readily consumed by many species of fish and shrimp. An end result is the need to utilize less costly feeds containing lower levels of nitrogen (protein) in them with concomitant lower feed conversion ratios. This drives the cost of production down 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.
6. Positive impacts on animal health include immunity and nutritional status.
7. Denitrification by the breakdown of ammonia nitrogen into biologically benign forms of nitrogen such as nitrates.

It should be noted that biofloc is a tool. It is not a solution and is not a substitute for enlightened 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 your system is conducive to the formation of these particulate materials will go a long way towards ensuring that one achieves a degree of reproducibility.

1. High biomass. High animal densities result in higher nitrogen levels from fecal material and feed components that diffuse into the water from the feed prior to it being consumed and particularly in the case of shrimp are added to the water column because of the manner in which shrimp feed.
2. Aeration. Vigorous aeration is required to keep the particles in suspension and to encourage their formation.
3. A proper ratio of Carbon to Nitrogen. These range from about 10:1 to 20:1 and likely should 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 optimize conditions for biofloc formation.
4. 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 in some manner. Clearly the solution that makes the most sense is that 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.
5. Sources of sulfur 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.

In conclusion, the production of suspended particulate biofloc in aquatic production systems is a very useful tool for improving profitability, biosecurity and lessening environmental footprints with impacts on sustainability and the perception of how eco-friendly these types of systems can be. Not all systems lend themselves to this approach but 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.