Biofloc Technology Session
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Issues in BFT Systems
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James Ebeling – Three Pathways for N Removal

- Overview of the three typical N remediation pathways (heterotrophic, chemoautotrophic, photoautotrophic)
- Organisms that assimilate N package N that can be cropped and removed from system.
    - N goes into the biofloc
    - 1 g of ammonia-N produces about 8 g of VSS
    - Need plenty of available carbon
    - Depending on C:N the balance shifts between autotrophic and heterotrophic
    - In a heterotrophic system, NO_2 or NO_3 concentrations are negligible, shouldn't see TAN
    - Not hard to remove solids

David Brune – Algal – Bacterial Systems

- Green water shifts to brown with intensification
- Worked with catfish, tilapia, and shrimp
- Less than 100 mg/L VSS when tilapia were cropping floc in green water
- Algae run out of steam about 10-14 g of C/m^2 per day, then system transforms (for 2% BW feed per day, equivalent to 600-700 g biomass/m^{2-} YA)
    - Transforms to chemoautotrophic or heterotrophic depending on C:N
- Kendall Kirk (Clemson Ph.D. dissertation on biofloc systems):
    - Developed a color index, which is a numerical system to color code water as it "matures" from green to brown in response to feed loading increases.
    - When daily feeding rates exceed 300 lb/acre, equivalent to C fixation of 10-14 g C/m^2-d, photosynthesis declines precipitously in response to light limitation caused by elevated solids concentration. The color of the water is still green but photosynthesis is not occurring as the system shifts to bacterial dominance.
    - The system transitions to bacterial dominance at daily feed loading rates of 500-600 lb/acre; 1000 lb/acre is possible in bacterial systems.
    - Energy needs increase substantially when water shifts from green to brown. In greenwater systems, energy is needed primarily for aeration (10 hp/acre); in brownwater systems, power is needed primarily for mixing (60-80 hp/acre) to maintain solids in suspension.
- Performance of greenwater systems is subject to large perturbations from extended periods of cloudy weather.
- With a green water system, no alkalinity supplementation is needed.

John Leffler – Chemoautotrophic, Nitrifying Systems

- Intensive shrimp systems in greenhouses
- Systems are mixotrophic, with respect to presence of phototrophic algae, heterotrophic and chemautotrophic bacteria (nitrifiers)

- Biofloc system are generally heterotrophic using the ecological definition where oxygen consumption from overall respiration exceeds oxygen production from photosynthesis (P/R<1).
- The microbial community consumes approximately half the total oxygen in the system; shrimp biomass consumes the other half.
- Spikes of TAN and NO_2 occur when system is starting up and at other times during the production period, indicating the importance of nitrification.
- When water is reused in subsequent production cycles, there are not many spikes of TAN and NO_2
- Suggests that carbohydrates should be added only to manage through the spikes of ammonia and nitrite; otherwise supplemental carbohydrate additions are not needed.
    - Need to add 15.17 g per g of N to be removed (based on stoichiometry)
- Differences in stoichiometry of assimilation by heterotrophic bacteria and transformation by nitrifying bacteria have implications with respect to bacterial biomass produced, oxygen required, and alkalinity consumed.

Open Discussion

- If problems occur with ammonia and nitrite spikes during start-up, addition of simple carboyhydrate (e.g., sugar) can quickly resolve the problem
    - Robins McIntosh reported that this is now the management strategy of CP with their shrimp ponds; carbohydrate is not added beyond these initial additions during pond acclimation.
- Addition of carbohydrate during start up can rapidly produce biofloc.
- Forcing function of feed loading naturally pushes system toward nitrification; continuous carbohydrate addition is required to encourage development of biofloc; withdrawal of carbohydrate loading results in system reverting to nitrification as the main mechanism of ammonia transformation.
- Denitrification
    - probably occurring in the interior of bioflocs
    - may also be occurring aerobically through annamox
    - Brune uses a deep tank as an anoxic reactor to obtain denitrification
    - recovery of alkalinity possible with denitrification
    - some NO_3 (50 mg/L = suggested concentration) is considered desirable because it can poise redox potential at a level that prevents sulfate reduction that results in sulfide production and potential toxicity.
    - in the Oceanic Institute system, biofloc particles are small and <u>aerobic</u> denitrification is likely occurring; still have to add alkalinity
- biofloc is a good food item; when particles are removed, you have a new product, not a waste product; can be used as a feed ingredient
- Biofloc systems are integrated (fish, shrimp, nematodes, micorobes, etc.) and we need to look at it as a whole system
    - Are biofloc particles good??? We want to control them. Recent studies suggest that that we could use them for other things (e.g., feed ingredient)
- Do we want to maximize recovery of N in fish or encourage N loss processes?
    - It can be less expensive to get rid of N through denitrification rather than trying to recover it. Tilapia can consume biofloc and thereby recycle N.
- Seems to be some process instability at first

    - Sugar is effective and fast but once the system becomes dependent on sugar, it is difficult to cease additions without process instability
- Robins McIntosh commented that presently, he does not encourage bioflocs in CP ponds. Unlike Belize, he does not add carbohydrate beyond management of initial spikes of ammonia or nitrite. By feeding the shrimp with high protein feed, he gets intensive nitrification.

Andrew Ray – Solids Management
- fine particles are a problem – may want to use a foam fractionator to control
- What suspended solids concentration is "best"?
    - maintain 250 mg/L (Anderson)
    - 300-500 mg/L
    - Shrimp growth best at lower solids concentrations (100-300 mg/L) - Brunson
    - Brune approach: very high solids concentration in an external bioreactor; low concentrations in shrimp rearing tank;
    - high solids concentration in rearing tank = very short response time in the event of system failure
    - ideal level likely depends on intensity, species, management strategy, indoor (dark), outdoor (light)
- Pathogens (especially Vibrios) and biofloc concentration?
    - More solids may mean more competitive exclusion
    - Less solids may mean lower concentration of Vibrio?
- Bulking sludge and filamentous bacteria
    - Filamentous bacteria as an invasive species

TENTATIVE CONCLUSIONS
Biofloc pond systems are always mixotrophic, fluctuating among photo-autotrophy, chemautotrophy and heterotrophy according to feed loading (Brune), feed protein content (Mcintosh), or supplemental carbohydrate addition (Avnimelech).

In all closed intensive systems you have bioflocs. Control factors are solids removal and carbohydrate additions.

With time, if carbon is not added, the system tends to move toward nitrification as the primary mechanism of N transformation.

The system can be controlled through manipulation of the input C:N ratio.

Advantages and disadvantages of feeding high protein vs carbohydrate addition:

<u>High protein feeding</u>
Advantages
- encourages nitrification
- better animal health because TSS is lower (high TSS may affect shrimp/fish gills)
- somewhat lower oxygen consumption (see Ebling works on O_2 consumption for nitrification vs carbon respiration)
- lower shading enables some algal growth and photosynthesis (see Brune - limit of feeding for algal activity)

- less energy required to maintain solids in suspension

Disadvantages

- nitrification consumes alkalinity, necessitate addition of liming agents.
- alkalinity can be recovered by adding denitrification reactors, although this adds to costs.
- unless using heavy inoculum of biosolids or culture water from acclimated system, there may be insufficient nitrification during the first few weeks, necessitating addition of sugar in the beginning.
- nitrogen (protein) that is not utilized is wasted because it is ultimately transformed to nitrate, where it is difficult to recover in the form of bioflocs.

<u>Carbohydrate addition</u>

Advantages

- rapid potential inorganic nitrogen control
- has the potential to double protein utilization and enable the use of lower protein and cheaper feeds.
- increases feed utilization and enables decrease of feed rations (?)
- to some extent provides added values such as disease prevention and possible growth factors.
- possibly, though not straightforward, enables use of excessive bioflocs.
- lower alkalinity consumption

Disadvantages

- TSS may reach high too levels, leading to high oxygen consumption and danger of gills clogging.
- to avoid this, a need for solid removal tools.
- need for thorough mixing and the associated elevated energy requirements.
- addition of carbohydrate substrates may represent a significant cost addition (unless feed reduction can balance this)

There is a need to experimentally compare the two approaches in shrimp and tilapia systems and to quantify advantages and disadvantages in models such as presented by Ebeling and Brune.

Total suspended solids should be limited to a range of 250-350 mg/l in shrimp systems. There is no conclusive data on tilapia, yet 500 mg/l is a more likely upper limit.

Controlling TSS by sedimentation may lead to selection for fine bioflocs. Dissolved air flotation might be a better technology for solids control.