Using molasses to control inorganic nitrogen and pH in aquaculture ponds

by Dan Willett and Catriona Morrison

The build up of toxic inorganic forms of nitrogen (especially ammonia - NH_3) is an inherent problem in aquaculture ponds. Even the best practices cannot avoid this since it has been shown that fish and crustaceans only assimilate between 20-30% of ingested food - the rest being excreted into the water column. It is generally accepted that approximately half of the nitrogen inputs into a pond (as feed protein) will eventually be converted into ammonia.

In a well managed pond, ammonia accumulation is controlled through uptake by algae. But algae itself is only a partial ammonia sink and in fed ponds stocked at current commercial densities, ammonia can accumulate at a greater rate than can be assimilated by algae. Surplus ammonia becomes available to nitrifying bacteria and this can sometimes lead to a build up of toxic nitrite – an intermediate by-product of nitrification. In addition, overgrowth of algae can lead to bloom crashes and subsequent release of ammonia. The most common way to alleviate this is by water exchange. However, with water conservation issues and nutrient discharge limits, flushing the pond is not always the most desirable solution. Inorganic nitrogen control, however, can be achieved by adding carbon.

Studies at the Bribie Island Aquaculture Research Centre are evaluating nitrogen waste control in aquaculture ponds using carbon addition. It is not a new concept and early experiments conducted in limited-exchange shrimp and tilapia production systems overseas have shown that adding carbon to the water promotes inorganic nitrogen uptake by heterotrophic bacteria.

So how does it work? In the simplest terms, heterotrophic bacteria utilise organic carbon as an energy source and in conjunction with nitrogen to synthesize protein for new cell material. In aquaculture wastewater there is a nitrogen surplus, but carbon is limiting. If we boost organic carbon levels, bacteria can metabolise more of the available nitrogen. In fact, bacteria will scavenge all bio-available sources of nitrogen - including ammonia and nitrite - if there is sufficient organic carbon available.

So exactly how much carbon is needed to remove inorganic nitrogen? This question remains difficult to answer even though it is not so hard to calculate a theoretical value. For instance, bacterial biomass has a C:N ratio of about 5:1 and carbon additions should aim to maintain this balance. However, in the same way shrimp and fish only assimilate a portion of the ingested feed, bacteria will assimilate only roughly 40% of the added carbon -meaning we need to compensate by adding organic carbon to achieve a C:N ratio of 12.5:1.

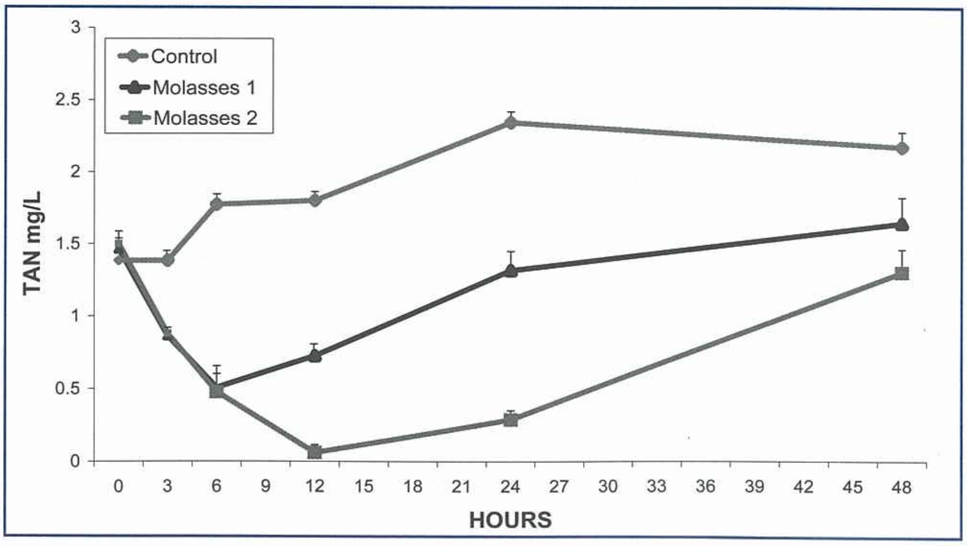
Molasses is an ideal form of organic carbon as it is cheap and largely carbohydrate with no additional nitrogen to complicate the equation. It can be easily added by simply mixing with water and splashing directly into the pond. Molasses is approximately 40% carbon which means we need to add about 32 g of molasses to account for every gram of bio-available nitrogen.

While these figures are only approximate values, an additional complication is that ammonia and nitrite are not the only form of bio-available nitrogen. Dissolved organic nitrogen (amino acids leached from feed) can constitute a varying but substantial portion of bio-available nitrogen, and bacteria may scavenge these before uptaking ammonia. Therefore molasses additions based only on the Total Ammonia Nitrogen (TAN) level may be under-dosing. Since dissolved organic nitrogen levels need to be determined in the laboratory it is difficult to get a real time (on-the-day) handle on how much carbon to add in order to remove the toxic forms of nitrogen.

DPI&F trials have looked to establish an appropriate dose rate of molasses to ensure thorough removal of ammonia. Daily in-the-field testing of ammonia is standard practice so trials looked at molasses dosing based solely on TAN concentration (32 g molasses/g TAN in the pond), plus doses based on double that amount to account for the extra 'unmeasured' bio-available nitrogen present (64 g/g TAN). Results of replicated experiments are summarised in the figure below.

Results show that with a single addition of molasses, over 65% of TAN is removed from the waterbody within six hours. However, the lower dose of molasses was consumed by the bacteria before complete ammonia assimilation was achieved. The higher dose allowed continued bacterial assimilation so that after 12 hours, ammonia was virtually eliminated. Due to bacterial senescence and excretion, TAN levels began to rise again as carbon was depleted, suggesting daily molasses additions are necessary for continued ammonia management. The 'un-dosed' control ponds showed only increasing ammonia levels during the trial.

This bacterial assimilation is an aerobic process which places an additional oxygen demand, so aeration is required both to maintain DO levels and ideally, keep organic particles suspended to provide better access by bacteria to the bio-available nitrogen. Bacteria will tend to flocculate around suspended particles, which themselves can become an addi-



Using molasses...continued...

tional food (protein) source for grazing cultured stock - and this forms the basis of zero-exchange bacterial-floc production systems such as the Belize shrimp facility. Of course, creating high volumes of flocculated organic matter in ponds can mean that periodic draining of concentrated sludge is required so that dissolved oxygen can be maintained.

In addition to nitrogen control, a useful side effect of molasses dosing is moderating pond pH. High pond pHs are usually a result of dense plankton blooms stripping carbon dioxide from the pond water for photosynthesis. The ability to increase bacterial numbers through molasses addition shifts the equilibrium that exists between photosynthetic and heterotrophic processes in the pond by allowing bacteria to compete more effectively with the phytoplankton, thereby moderating both the algal bloom and the pH. Regular daily, or twice daily, additions of molasses at a rate of approximately 30 litres per hectare provides a relatively safe, reliable and inexpensive means to reduce pond pH.

DPI&F trials have demonstrated that appropriate carbon dosing techniques can have broad application for controlling toxic forms of nitrogen in ponds and managing pH. Such treatments may form the basis for intensive zero-exchange suspended-growth production systems or may be utilised as part of an emergency response to adverse pond and water quality conditions.