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Water pH Impacts Sustainability of Recirculating Aquaponic Systems

By Richard Tyson, Ph.D., Extension Agent IV, Seminole County; Eric Simone, Associate Professor, and Danielle Treadwell, Assistant Professor, UF/IFAS Horticultural Sciences Department

Sustainable agriculture combines plant and animal production, integrates natural biological cycles, and makes the most use of non-renewable resources (Gold, 1999). Aquaponics is an integrated system linking hydroponics with aquaculture (Rakocy et al., 2006). The major system advantages are fish waste nitrogen removal by plants and reduced water usage and nutrient discharge to the environment for both systems. Intensively managed recirculating tilapia tanks linked with plant float systems supplied nearly all of the nutrients required by plants (with some supplementation) through the application and utilization of fish feed in the system (Rakocy et al., 1997). Aquaponic system biofiltration by nitrifying bacteria maintains water quality for the fish, by converting waste ammonia into nitrate nitrogen for plants (Timmons et al., 2002). The availability of nitrate nitrogen is dependant on this biological step called nitrification.

Plants take up nitrogen primarily in the nitrate nitrogen (NO_3^- -N) and ammonium nitrogen (NH_4^+ -N) forms (Marschner, 2003). In general, when nitrogen is supplied primarily in the ammonium form to terrestrial plants, reduction in dry matter and yields usually occur, especially in solution culture (Bialczyk et al., 2007; Silbur et al, 2005). A

good ratio for most terrestrial plants tends to be between 50:50 – 75:25, $\text{NO}_3^- - \text{N} : \text{NH}_4^+ - \text{N}$. Thus, if we want to rely on the aquaponic system to supply most or all of our plant nitrogen needs (minimizing the use of non-renewable energy resources required to produce nitrogen fertilizer), we must maximize the use of our biological nitrification subsystem in aquaponics. In order to do that, operating pH must be considered.

The optimum pH for hydroponic plant production is between pH 5.5 and 6.5 (Hochmuth, 2001). The optimum pH for the activity of nitrifying bacteria in aquaculture biofilters is between pH 7.5 and 9.0 (Hochheimer and Wheaton, 1998). Recent research utilizing a perlite trickling biofilter / root growth medium in recirculating culture with cucumber and tilapia (Fig. 1) resulted in significant differences in the quantity of waste ammonia converted to nitrate nitrogen based on operating pH (Tyson, 2007). Results from a subsystem trial using a trickling perlite biofilter indicated linear increases in ammonia biofiltration as pH increased from 5.5 to 8.5 (Fig. 2). In another trial, an aquaponic system operating pH of 8.0 had the highest ammonia biofiltration compared to pH 6.0 and 7.0. The perlite biofilter contributed significantly more to the removal of total ammonia nitrogen ($\text{TAN} = \text{NH}_4^+ - \text{N} + \text{NH}_3 - \text{N}$) from the system when compared to plants (Fig. 1). Therefore, operating pH should be carefully considered when managing these systems for maximum nitrogen utilization from fish feed inputs.

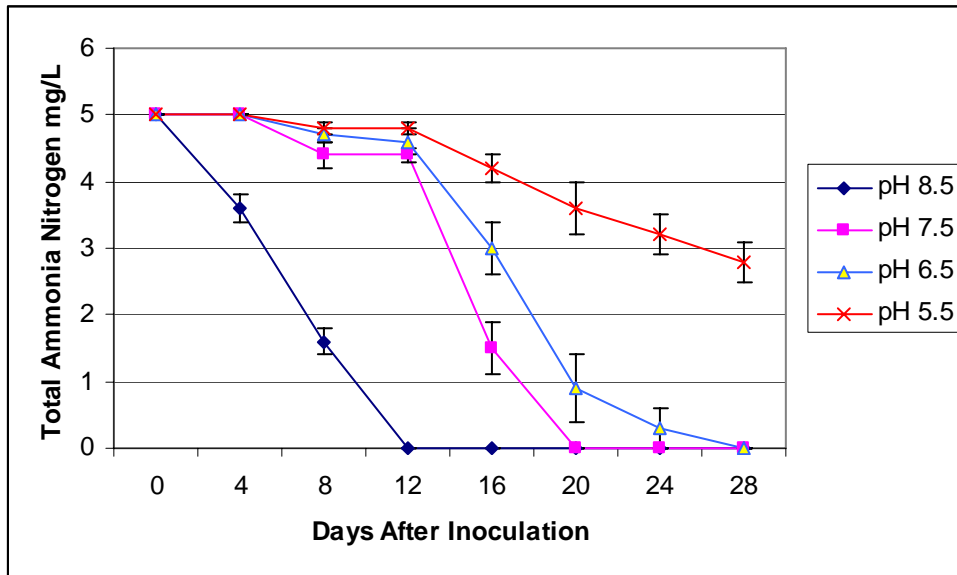
Results of these trials also showed that early cucumber yield increased linearly with an increased pH from 6.0 to 8.0 but total cucumber yield was unaffected by pH. More research work needs to be done on other plant/fish/system combinations to see if these results hold true before firm recommendations can be made. However, for the system under study here (cucumber/tilapia in recirculating culture with a trickling perlite biofilter), maintaining aquaponic system water at pH 8.0 will increase system ammonia biofiltration by nitrification, thereby allowing higher fish stocking densities, producing more plant nutrients from fish waste. This will conserve applied fertilizer and thereby improve aquaponic systems integration and sustainability.



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Figure 1. Aquaponic research utilizing a perlite trickling biofilter / root growth medium in recirculating culture with cucumber and tilapia.



Error bars represent \pm SE (n=8).

Figure 2. Affect of water pH on total ammonia nitrogen (TAN) loss from recirculating tanks using perlite medium trickling biofilters inoculated with nitrifying bacteria.