

6 Application Effects of Probiotics in Environmental Regulation of Grass Carp Aquaculture

6.1 Effects of probiotics on improving physicochemical properties of aquaculture water

Probiotics can improve the physicochemical properties of grass carp culture water, especially by reducing nitrogenous wastes that drive stress and eutrophication. In grass carp culture, complex probiotics lowered ammonia nitrogen, nitrite nitrogen, and total nitrogen throughout the experimental period, and nitrate nitrogen fell by 54.49% on day 18. A broader freshwater synthesis found that probiotics reduced ammonia by an average of 50.7% across studies, indicating that nitrogen control is one of the most reproducible environmental effects of probiotic application (Nathanailides et al., 2021).

Mechanistically, these effects appear to arise from microbial restructuring and enhanced nitrogen cycling rather than from simple dilution of pollutants. Metagenomic analysis of pond water showed that adding probiotics reduced $\text{NH}_4^+\text{-N}$, $\text{NO}_2^-\text{-N}$, and total nitrogen while increasing nitrification genes such as *amoC_B* and *hao* and denitrification genes such as *nirS* and *nosZ* (Mang et al., 2024). Mixed *Bacillus* systems also improved water quality by reducing $\text{NH}_4^+\text{-N}$, $\text{NO}_2^-\text{-N}$, $\text{NO}_3^-\text{-N}$, and total phosphorus by 46.3%, 76.3%, 35.6%, and 80.3%, respectively, while enriching bacterial groups associated with nitrogen and phosphorus removal.

6.2 pathogen inhibition

Probiotics suppress harmful microorganisms in aquaculture water through several direct and indirect mechanisms, including organic acid production, antimicrobial metabolites, nutrient competition, and exclusion of pathogen colonization. Reviews of disease control in aquaculture show that probiotics can inhibit pathogenic bacteria by lowering pH after organic acid production and by secreting bactericidal compounds such as short-chain fatty acids, peroxide, and bactericidal proteins. Classical probiotic theory in aquaculture also identifies competition for nutrients, energy, and adhesion sites as core mechanisms by which beneficial microbes suppress harmful species in the rearing environment (Verschuere et al., 2000).

In grass carp systems, these antimicrobial effects are supported by strain-specific evidence. *Bacillus methylotrophicus* WM-1, isolated from grass carp culture systems, showed strong antagonism against *Aeromonas hydrophila* and was considered applicable to aquaculture production because it combined pathogen inhibition with environmental safety. More broadly, quorum-quenching probiotics appear especially promising because they reduce bacterial virulence by disrupting quorum sensing rather than by killing pathogens outright, which makes them a plausible non-antibiotic strategy for controlling disease pressure in sustainable aquaculture (Lubis et al., 2024).

6.3 Ecological aquaculture applications

The main value of probiotics in ecological aquaculture is that they can couple production support with environmental remediation. Reviews focused on sustainable aquaculture consistently describe probiotics as feed additives or water supplements that improve water quality, reduce antibiotic dependence, and support environmentally friendly production. In freshwater fish farming, the environmental benefits can outweigh the environmental cost of probiotic production, especially because lower ammonia and improved feed conversion directly reduce the ecological footprint of pond systems (Nathanailides et al., 2021).

Grass-carp-relevant studies also suggest that probiotics fit well within integrated and low-pollution production models, but their use should be embedded in broader management rather than treated as a stand-alone solution. *Bacillus velezensis* LG37 degraded ammonia nitrogen and residual feed protein in grass carp culture wastewater by 55.5% and 73.6% within one week, and it also increased grass carp tolerance to ammonia toxicity. At the same time, recent cyprinid reviews emphasize that probiotic performance depends on environmental factors such as pH, temperature, and dissolved oxygen, and that sustainable aquaculture still requires integrated strategies including water-quality optimization, biosecurity, and preventive health management (Qu et al., 2025). In grass carp aquaculture, probiotics therefore appear most useful as ecological regulators that improve water quality, suppress harmful microbes, and support greener production systems. Their environmental value is strongest when strain selection, application method, and farm management are matched to the specific culture system.