seedstock are widely regarded as a critical component of disease prevention. Strengthening quarantine measures, pathogen screening, and health assessments of broodstock and larvae can effectively reduce the introduction of major pathogens such as WSSV and AHPND at the source (Kumar et al., 2025).

During farming operations, appropriate stocking density remains a key factor in reducing disease incidence. Although high-density farming increases production per unit area, it also elevates contact frequency, water quality fluctuations, and chronic physiological stress, thereby facilitating pathogen transmission and disease outbreaks. Therefore, stocking density should be scientifically determined based on system carrying capacity, combined with adequate aeration, water exchange, and precision feeding management to maintain host health and reduce disease risks (Kumar et al., 2025). Water quality regulation is another critical component of ecological disease control. Maintaining parameters such as dissolved oxygen, pH, ammonia, and nitrite within optimal ranges helps alleviate physiological stress and suppress the proliferation of opportunistic pathogens such as Vibrio spp.

Sediment management also plays an important role in disease control. The accumulation of organic matter, including uneaten feed, feces, and dead algae, creates favorable conditions for pathogen proliferation, particularly benthic Vibrio and anaerobic metabolites that can negatively affect shrimp health. Measures such as pond sediment removal, the use of sediment conditioners, and the installation of settling systems can effectively reduce pathogen loads and improve system stability (Kumar et al., 2025). In recent years, ecological regulation has extended to the microbial level. Studies indicate that regulating water and gut microbiota composition can help maintain immune homeostasis and enhance disease resistance (Harpeni et al., 2024). In addition, comprehensive biosecurity practices—including water source disinfection, facility management, and personnel zoning—are essential for minimizing pathogen introduction and are integral to sustainable shrimp farming systems (Kumar et al., 2025).

5.2 Antibiotic alternatives and microbial regulation

Antibiotics have historically played a role in disease control in shrimp aquaculture; however, their overuse has led to increasing concerns regarding antimicrobial resistance, drug residues, and ecological risks. Consequently, antibiotic-free farming and alternative strategies have become major research and application priorities (Noman et al., 2024). In this context, environmentally friendly disease control approaches based on microbial regulation have rapidly developed, with probiotics, prebiotics, synbiotics, and biofloc technology emerging as key strategies.

Probiotic application is one of the most widely used microbial regulation methods. Beneficial microorganisms such as Bacillus, lactic acid bacteria, and Pseudomonas can be introduced into feed or water to inhibit pathogen colonization through competitive exclusion, competition for nutrients and adhesion sites, and the production of antimicrobial substances. Additionally, probiotics can modulate host immune responses and improve gut health (Tamilselvan and Raja, 2024). Studies have shown that probiotics enhance growth performance, survival rates, and stress resistance, thereby reducing reliance on antibiotics (Muthu et al., 2024). However, their effectiveness is influenced by factors such as strain selection, dosage, and environmental conditions, highlighting the need for standardized and optimized application strategies (Noman et al., 2024).

In addition to probiotics, prebiotics and synbiotics also play important roles in microbial regulation. Prebiotics promote the growth and colonization of beneficial microbiota, thereby enhancing gut microbial stability, while synbiotics combine the synergistic effects of probiotics and prebiotics to further improve host immunity and metabolic functions (Noman et al., 2024). Biofloc technology (BFT) represents a system-level application of microbial regulation. By adjusting the carbon-to-nitrogen ratio, BFT promotes the growth of heterotrophic microorganisms that convert nitrogenous wastes into microbial biomass, thereby improving water quality and reducing toxic compounds (Harpeni et al., 2024). The resulting bioflocs also serve as supplementary nutrition and help stabilize microbial communities, suppressing pathogen proliferation. Studies have demonstrated that microbial consortia derived from native microbiota can effectively reduce AHPND incidence and improve shrimp growth performance (Figure 3) (Guo et al., 2023). Microbial regulation strategies are shifting disease control approaches from pathogen suppression to ecological balance restoration.