

conversion of ingested protein into body tissue under moderate restriction (Kusmiatun et al., 2025). Cyclical fasting-feeding regimes also improved protein efficiency ratio in juveniles, suggesting that intermittent restriction can enhance protein use while maintaining compensatory growth.

5.3 Effects on production efficiency and resource use

At the farm scale, FCR is closely tied to economic and environmental performance, so feeding strategies that lower FCR directly improve resource use. Nutrient-budget analysis on an intensive farm showed that feed contributed 80% of nitrogen inputs, with an overall FCR of 2.0; modeling a reduction to 1.8 FCR indicated the farm could cut 147 kg of feed, saving over US\$1000 per crop and reducing nitrogen and phosphorus loading to ponds and effluents. Global assessments of embodied resources in shrimp feeds further suggest that reducing FCR by 0.1 across major cultured species would save large amounts of energy, land, freshwater, and wild fish, underscoring the broader sustainability gains from efficient feeding.

Within biofloc and synbiotic systems, feed-restriction strategies can maintain or even improve production efficiency while lowering operational inputs. In synbiotic ponds, partial feed restriction halved FCR and reduced total operating costs by about 20%, yet both restricted and unrestricted treatments showed positive profitability, indicating that lower feed input strategies can be economically viable (Gonçalves et al., 2024). Complementary work in biofloc systems found that feeding according to minimum table values yielded better FCR, survival, and lower waste production than maximum table rates or FCR-based rationing, highlighting that conservative, well-calibrated feeding tables can improve both resource use and system cleanliness (Da Silva et al., 2023).

6 Effects of Different Feeding Strategies on Culture Environment and Health Management

6.1 Effects on water quality parameters

Feeding rate and delivery method directly affect nutrient loading and key water quality variables in shrimp culture systems. In semi-intensive ponds, increasing feed inputs raised nitrogen and phosphorus concentrations, elevating total ammonia nitrogen and nitrite, particularly when demand feeders allowed higher daily feed loads than hand feeding or timer-based protocols. In indoor recirculating systems, sharp increases in feed load led to spikes in total ammonia nitrogen up to 24.2 mg/L, coupled with oxygen depletion and large mortality events, underscoring how overfeeding can overwhelm biofiltration capacity and destabilize water quality (Mohammed et al., 2024).

Feeding strategy can also modify suspended solids and organic matter dynamics in pond water. Comparisons between ponds using feeding trays and mechanical feed blowers showed that tray feeding generated lower ammonia and particulate organic solids loads per kilogram of shrimp, even though total suspended solids were slightly higher, suggesting tighter control of uneaten feed. In biofloc and zero-exchange systems, adjusting feeding levels interacts with microbial floc to influence ammonia; for example, nursery tanks with lower feeding rates showed significantly reduced ammonia compared with higher-fed controls, reflecting the role of feed load management in maintaining acceptable nitrogen levels (Khanjani et al., 2016).

6.2 Effects on pond sediment conditions and organic loading

Uneaten feed and feces are major contributors to sediment organic loading, and their accumulation is closely linked to feed management intensity. Field analysis of different shrimp culture intensities showed that estimated organic waste (total suspended solids) derived from feed rose from about 488 kg TSS/ha in traditional plus systems to over 9,228 kg TSS/ha in intensive ponds, reflecting higher feed use at greater stocking densities (Mhr, 2022). Nitrogen budget studies in penaeid ponds, although not specific to *L. vannamei*, similarly indicate that up to 38.4% of nitrogen entering as feed and inflow may accumulate in sediments, with waste generation per kilogram of shrimp increasing strongly with stocking density and associated feed inputs.

Sedimentation rates of nutrients and particulates also respond to management history and feed loading intensity. In *L. vannamei* earthen ponds, treatments associated with higher initial inputs for dense greenhouse phases showed significantly elevated early sedimentation of nutrients and particulate matter, indicating rapid deposition of feed-derived solids. In polyculture ponds with tilapia and shrimp, ponds classified as high feed-loading exhibited