

Under integrated multi-trophic systems, survival outcomes can even improve under adjusted feeding regimes. In tanks co-culturing shrimp with the macroalga *Caulerpa lentillifera*, survival and yield at 75%-100% of the control feed ration were significantly higher than in monoculture controls over 45 days, despite reduced formulated feed inputs. Biofloc-based studies cutting feed by 25% also maintained good survival while shortening effective time to marketable size through higher SGR, implying that optimized feed reductions in enriched systems may sustain or improve survival while potentially reducing culture duration required to reach target weights (Kusmiatun et al., 2025).

4.3 Effects on size uniformity within shrimp populations

Feeding strategies influence how evenly feed is distributed among individuals, thereby affecting size uniformity. Experiments manipulating pellet (diet) size showed that larger pellets prompted more aggressive feeding behavior, with some shrimp obstructing others and monopolizing feed; this “selfish” behavior was suggested as a mechanism leading to considerable size variation and potentially higher mortality among smaller individuals as they grow to market size. Practical feeding recommendations from field observations similarly stress that even feed distribution in ponds is essential to promote proportional growth, indicating that unequal spatial delivery of feed can exacerbate within-cohort size differences (Andriani and Pratama, 2023).

Feeding frequency and access time also interact with social dynamics to influence size dispersion. Studies of stocking density and dominance in *L. vannamei* showed that density and social rank affect time spent feeding, with dominant individuals securing more feeding opportunities under certain conditions. Automatic or demand-based feeding systems that provide more continuous access to feed throughout the day can partially mitigate competitive exclusion by extending feeding windows, which likely contributes to the improved growth observed with acoustic demand feeders compared with limited twice-daily hand feeding in ponds (Ullman et al., 2018).

5 Effects of Different Feeding Strategies on Feed Utilization Efficiency

5.1 Effects on feed conversion ratio (FCR)

Feed conversion ratio is highly sensitive to how much and how often shrimp are fed, with both restrictive and excessive rations altering efficiency. In high-density biofloc systems, varying feed inputs from 30% to 150% of a standard rate showed that increasing feed above about 100% raised final weight but caused FCR to increase, indicating diminishing returns in growth relative to feed supplied. Regression analysis also identified an inflection near 101% of the standard rate where feed utilization declined rapidly, emphasizing that overfeeding directly worsens FCR even when growth continues to rise (Weldon et al., 2021).

Feed restriction and the use of natural productivity can conversely improve FCR when carefully managed. In a synbiotic pond system, partial feed restriction reduced FCR from 0.59 under full feeding to 0.30 under restricted feeding while still allowing total compensatory growth, showing that lower rations can markedly increase efficiency if environmental food is available. Similarly, in biofloc tanks, a 25%-50% reduction in feeding rate produced the lowest FCR values (0.90-0.71) compared with standard rations in clear water or biofloc, illustrating that biofloc-based strategies can substantially enhance FCR under reduced feed inputs (Kusmiatun et al., 2025).

5.2 Effects on dietary protein utilization efficiency

Feeding strategies that alter protein intake and ration size strongly affect protein retention and utilization. In a green-water recirculating system, combinations of 25%-40% dietary protein and two feeding rates produced significant differences in apparent net protein retention (49%-66%), with lower protein intake treatments achieving the highest retention despite slower growth (Araujo et al., 2025). This indicates that high feeding and protein levels favor growth but can dilute protein efficiency, whereas more modest protein supplies improve retention per unit intake.

Biofloc-based feeding reductions can simultaneously improve growth and protein utilization when natural food supplements the diet. In a 30-day biofloc trial, a 25% feed reduction produced the highest final protein content and protein retention (18.94%) compared with standard feeding in clear water or biofloc, demonstrating more effective