

levels in India showed that feed alone represented about 70% of variable costs in whiteleg shrimp farms, underlining that small changes in feed use or price translate into large changes in total production cost per hectare (Nisar et al., 2021).

Because feed is such a dominant cost, strategies that reduce ration without harming growth can markedly lower total and operating costs. In a synbiotic pond system, partial feed restriction cut FCR by roughly half and reduced effective operating costs by 21.8% and total operating costs by 20.2%, with feed volume being the only cost component differing between treatments (Gonçalves et al., 2024). Under semi-intensive pond conditions, modest feed reductions (to 90% or a staged 80%-90%-100% of standard tables) produced similar growth and economic returns to full rations, while slightly decreasing feed cost per kilogram of shrimp, indicating that careful ration control can improve cost efficiency without sacrificing performance.

7.2 Comparison of yield and economic returns

Feeding technologies and strategies that raise growth and yield generally increase gross revenue and shrimp value per hectare. In a 16-week pond trial comparing four feed-management techniques, timer feeders and acoustic demand feeding significantly increased final weights, and the AQ1 acoustic system more than doubled shrimp value to about US\$21,198/ha relative to standard twice-daily protocols (Ullman et al., 2019). A separate study with higher stocking density similarly found that AQ1 demand feeding raised yield to 7430 kg/ha and shrimp value to US\$65,587/ha, clearly outperforming timer and standard feeding while maintaining comparable FCR and survival (Ullman et al., 2018).

Diet formulation, when coupled with appropriate feeding management, can also shift revenues through changes in yield and size distribution. Under commercial conditions, a fishmeal- and fish-oil-free “F3” diet produced higher biomass, better FCR (1.03 vs. 1.15), and larger shrimp, leading to an 11.8% higher sales revenue compared with a commercial reference feed. On-demand feeding with different protein levels showed that although a 40% protein diet was more expensive, it did not improve biomass or economic outcomes relative to 30%-35% protein diets, indicating that overly rich diets may not yield proportional revenue gains when demand feeding is used (Strebel et al., 2023).

7.3 Evaluation of return on investment and economic sustainability

Economic analyses that integrate feed inputs, yields, and market prices show how feeding choices influence return on investment (ROI) and long-term financial viability. In a commercial pond trial comparing conventional and marine-resource-free feeds, the F3 diet yielded higher growth and revenue, resulting in ROI values of 89.8% versus 64.5% for the commercial diet, while all other non-feed costs remained similar between treatments (Tran et al., 2022). Business analyses from Indonesian farms likewise report R/C ratios above 1 and very short payback periods (around 0.5-2.9 years) for intensive *L. vannamei* operations, suggesting that when feed is managed efficiently the sector is highly profitable (Farkan et al., 2024).

Feeding and management strategies also interact with intensification to determine economic sustainability and resource use efficiency. Comparative studies across intensity clusters in India showed that more intensive *L. vannamei* farms achieved higher net returns (about US\$41,641/ha/year) and lower cost per ton, provided feed and other inputs were used efficiently. (Nisar et al., 2021). Multi-country analysis of intensification in Vietnam and Thailand further found that higher-intensity clusters had lower costs per metric ton and greater profitability, reinforcing that feeding strategies which support high yields while controlling feed costs are central to economically sustainable shrimp farming.

8 Case Study: Comparative Evaluation of Different Feeding Strategies in Pacific White Shrimp Farming

8.1 Performance analysis of traditional manual feeding practices

Traditional manual feeding remains a common baseline strategy in pond and tank culture, typically using standard feeding tables and two to four meals per day. Semi-intensive tank and pond trials applying a standard feeding