

feed, indicating that quantitative scheduling can maintain stable production when ration size is matched to animal demand (Figure 1).

Evidence also shows that the optimal quantitative ration depends on production stage and culture system rather than increasing linearly with feed supply. In fattening with raw fish, increasing ration from 4% to 16% significantly improved absolute weight gain and specific growth rate, although survival and FCR did not differ significantly among treatments, suggesting that growth is more sensitive than efficiency to ration adjustment. By contrast, in a recirculating aquaculture system, changing feeding frequency from once to three times daily did not significantly affect growth or survival, although feeding once daily at night produced the best mean growth values, implying that timing can be optimized without necessarily increasing meal frequency (Mayzuri et al., 2025).

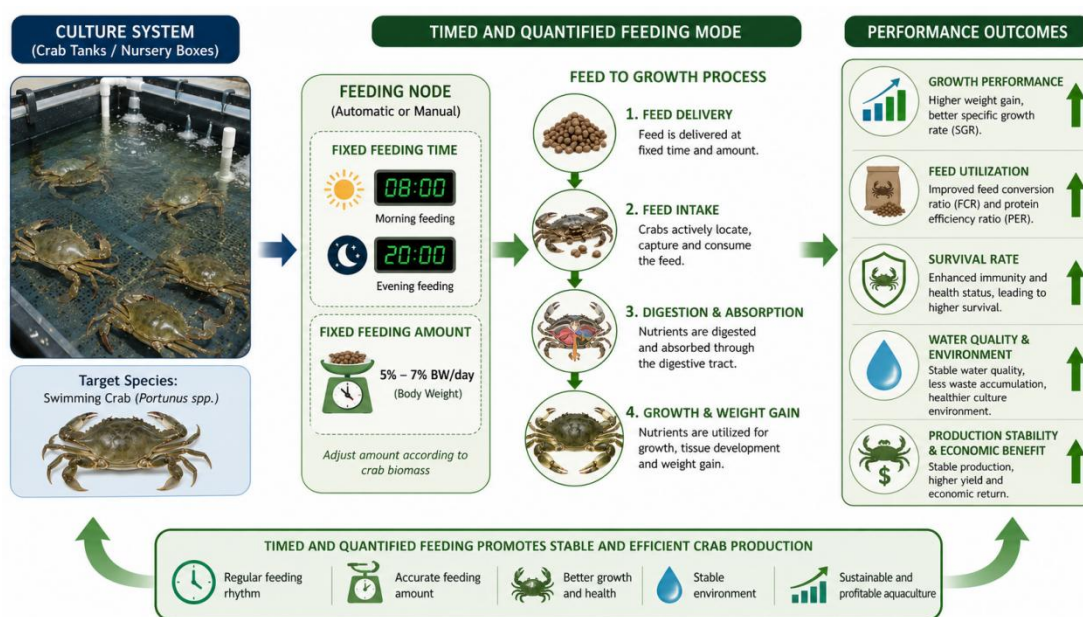


Figure 1 Conceptual framework of scheduled and quantitative feeding management in mud crab aquaculture

3.2 Satiation feeding and restricted feeding modes

Satiation feeding aims to supply feed until intake demand is met, whereas restricted feeding intentionally provides less than that level to improve feed use efficiency or reduce waste. In juvenile *Scylla paramamosain*, reducing ration from optimal to suboptimal and low levels prolonged intermolt duration, increased molting desynchrony, and decreased carapace size and body weight, showing that restriction can directly suppress growth-related processes even when animals still molt successfully (Gong et al., 2022). Starvation was clearly detrimental, because unfed juveniles died without molting, while even low-ration crabs maintained molting success above 95%, indicating that mud crabs tolerate moderate feed limitation better than complete deprivation.

A broader crustacean literature suggests a trade-off between growth maximization under higher feeding allowance and better feed efficiency under restricted rations. In *Penaeus vannamei*, feeding at 80% of apparent satiation improved FCR relative to 100% satiation, but this occurred alongside lower weight gain, demonstrating that restriction can enhance efficiency at the expense of biomass accumulation (Espinoza-Ortega et al., 2026). Similarly, juvenile *Penaeus monodon* showed feed-efficiency benefits under restricted ration and growth benefits from higher feeding frequency, with a significant interaction between frequency and ration size. For mud crab production, these findings support using moderate restriction only when feed cost or water quality control is prioritized over maximum growth.

3.3 Automated and intelligent feeding modes

Automated and intelligent feeding modes extend beyond fixed timers by using behavioral or environmental feedback to decide when to continue, slow, or stop feeding. Conventional automatic feeders generally deliver feed