

IMPACT OF FEEDING STRATEGIES ON GROWTH PERFORMANCE AND WATER QUALITY IN RECIRCULATING AQUACULTURE SYSTEMS

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Annotation: *Feeding strategy is a determining factor in the biological and technological performance of recirculating aquaculture systems (RAS). This article analyzes the application of nutritionally optimized, high-digestibility compound feeds designed to enhance growth performance while minimizing nitrogen and phosphorus excretion, thereby reducing organic and inorganic loading on biofiltration units. Particular attention is given to high-frequency and automated feeding regimes as tools for improving feed utilization efficiency and lowering feed conversion ratios (FCR). The paper further examines the interactions between feeding rate, water quality parameters (dissolved oxygen, temperature, pH, and total ammonia nitrogen), and system stability. Management practices related to feed storage, ration adjustment, and waste control are discussed in the context of economic efficiency and environmental sustainability. The findings emphasize that precision feeding is essential for maintaining optimal water quality and achieving sustainable intensification of aquaculture production in RAS.*

Key words: *nitrogen and phosphorus excretion, high-frequency, detritus, oxygen, ammonia, nitrite, plankton, aquatic plants, fiber, nutritional value.*

INTRODUCTION

Feeding management in recirculating aquaculture systems (RAS) depends on the use of high-quality, purpose-formulated feeds that promote rapid growth while limiting nutrient losses, particularly nitrogen and phosphorus, which can negatively affect water quality. Effective feeding strategies emphasize regular, high-frequency feeding-preferably through automated systems operating continuously- to achieve lower Feed Conversion Ratios (FCR). Proper storage of feed, close observation of feeding activity, and accurate daily ration adjustments are essential to maintaining system balance and ensuring fish health.

Recirculating aquaculture systems (RAS), also referred to as closed water supply systems, represent an intensive approach to fish production in which water is continuously treated and reused. These systems are characterized by limited water exchange, high stocking densities, and strict regulation of water quality parameters, including dissolved oxygen, ammonia, nitrite, and pH. Due to the closed-loop nature of RAS, feeding

management plays a central role in determining fish growth performance, health status, and overall system stability. Feed-derived wastes are rapidly accumulated in RAS, making inappropriate feeding practices a major risk factor for biofilter overload and water quality deterioration. Therefore, the optimization of feed composition, feeding strategies, and monitoring practices is essential for efficient and sustainable RAS operation.

Materials and Methods

The RAS environment imposes specific constraints on feeding due to minimal water renewal, high sensitivity to nutrient loading, and reliance on mechanical and biological filtration. Feeding strategies were designed to minimize waste generation while maintaining optimal growth under high-density culture conditions.

Feeds applied in RAS were formulated to meet strict nutritional and physical standards. Diets contained 30- 55% crude protein and 8- 20% lipids, depending on species and developmental stage, and were supplemented with balanced essential amino acids, vitamins, and minerals. High digestibility ingredients were prioritized to reduce indigestible fractions and fecal waste production. Pellets were required to exhibit high water stability with minimal fines and dust. Formulations were further optimized to reduce nitrogen and phosphorus excretion, thereby limiting biofilter loading.

Feed physical properties were selected according to fish feeding behavior. Extruded floating feeds were used for surface-feeding species such as tilapia, carp, and catfish to allow visual monitoring of feed intake. Slow-sinking feeds were applied for mid-water feeders, while sinking feeds were used for benthic species such as sturgeon. Pellet size ranged from micro-pellets (0.2- 1.0 mm) for fry to pellets $\geq 3-6$ mm for adult fish.

Feeding was conducted manually, using automatic timed or demand feeders, or through sensor-based systems employing camera or acoustic technologies. Feeding frequency varied with fish size and physiological requirements, with fry fed 6- 10 times per day, juveniles 3- 6 times per day, and adults 1- 3 times per day. Daily feeding rates ranged from 5- 10% of body weight for fry, 2- 5% for juveniles, and 0.5- 2% for adult fish.

Feeding rates were adjusted based on continuous observation of fish behavior and real-time monitoring of water quality parameters, including dissolved oxygen, temperature, ammonia ($\text{NH}_3/\text{NH}_4^+$), nitrite (NO_2^-), and nitrate (NO_3^-). Feed conversion ratio (FCR) was calculated as the ratio of feed supplied to fish biomass gain.

RESULTS

Implementation of high-digestibility diets and frequent, controlled feeding resulted in improved feed utilization and stable water quality conditions. Automated and sensor-based feeding systems ensured uniform feed distribution and reduced feed losses. Proper pellet stability minimized particulate waste accumulation, while optimized feeding rates prevented excessive ammonia release. Well-managed RAS achieved FCR values between 0.8 and 1.2, indicating efficient nutrient utilization. In contrast, overfeeding or poor-quality feeds led to increased organic solids, elevated ammonia concentrations, and increased stress on biofiltration units.

DISCUSSION

The findings confirm that feeding management is a critical operational component of RAS performance. High-frequency feeding in small portions enhances nutrient absorption and reduces metabolic waste output, thereby improving FCR and reducing environmental loading. The use of nutritionally dense, RAS-specific feeds with controlled phosphorus and stable lipid composition is essential for minimizing nitrogen accumulation and maintaining biofilter efficiency. Continuous monitoring of feeding behavior and water quality allows for adaptive ration adjustments, preventing system instability. Although specialized RAS feeds and automated feeding technologies involve higher initial costs, their adoption improves economic efficiency by enhancing growth rates, reducing maintenance demands, and supporting long-term sustainability. Overall, precision feeding emerges as a cornerstone of environmentally responsible and economically viable RAS-based aquaculture.

CONCLUSIONS

Efficient feeding management is a fundamental determinant of biological performance, water quality stability, and economic efficiency in recirculating aquaculture systems (RAS). The closed nature of these systems amplifies the impact of feed-derived wastes, making the use of high-digestibility, nutritionally balanced, and physically stable feeds essential. Optimized feeding strategies- characterized by high-frequency, precisely controlled feed delivery and supported by automated or sensor-based technologies- significantly improve feed conversion efficiency and reduce nitrogen and phosphorus loading on biofiltration units.

Continuous monitoring of fish feeding behavior and key water quality parameters enables timely ration adjustments and prevents system overload. Although specialized feeds and advanced feeding technologies may increase initial operational costs, their application enhances growth performance, minimizes filtration stress, and supports long-term economic and environmental sustainability. Overall, precision feeding represents a core component of sustainable intensification in RAS- based aquaculture production.

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