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Problems and Prospects of Crustacean Cultivation in Recirculating Aquaculture Systems

Abstract

Recirculating Aquaculture Systems (RAS) are gaining recognition as an environmentally friendly and efficient approach for the cultivation of crustaceans, with a particular focus on *Macrobrachium rosenbergii*. This species stands out for its remarkable nutritional profile, beneficial biochemical composition, and strong market potential. Due to its adaptability to controlled rearing conditions and rapid groüth performance,M.rosenbergii is considered a valuable candidate for intensive aquaculture operations. Nevertheless, certain technological and biological limitations continue to constrain large-scale RAS production. Major challenges include optimizing feed strategies to enhance conversion efficiency, maintaining genetic variability to ensure stock resilience, mitigating cannibalistic interactions that lead to yield losses, and improving biofiltration processes to stabilize water parameters. Current research highlights that formulating high-quality, species-specific diets and adopting modern system designs such as automated environmental monitoring, advanced recirculation mechanisms, and integrated biological filtration can significantly increase production outcomes. By overcoming these barriers, RAS-based *M. rosenbergii* aquaculture can evolve into a more profitable, sustainable, and ecologically responsible production model, supporting the long-term development of the global aquaculture industry.

Keywords: *Recirculating Aquaculture System (RAS), Macrobrachium rosenbergii, crustaceans, aquaculture, feed, cannibalism*

Introduction

The cultivation of arthropods (crustaceans, prawns, and other related species) in recirculating aquaculture systems (RAS) is considered one of the most promising directions of commercial aquaculture. Among them, the giant freshwater prawn *Macrobrachium rosenbergii*, the largest species within its genus, is gradually becoming an economically significant aquaculture organism. Studies have revealed that for all decapod crustaceans, including *M. rosenbergii*, the main challenges are the lack of nutritionally balanced and high-quality formulated feeds, as well as the reduced genetic diversity in captive populations, which makes seed production more difficult and expensive. For Russia, the cultivation of *M. rosenbergii* in closed water supply systems could be economically feasible; however, to maximize productivity, the development of optimized artificial feeds specifically designed for crustaceans is essential. The giant freshwater prawn, reaching a body length of up to 320 mm, is the largest species in its group and therefore of high commercial value. Its native range includes the islands of Oceania and northern Australia, and extends across South and Southeast Asia from India to China (Boyd, & Tucker, 2014). *M. rosenbergii* typically inhabits the lower reaches of rivers and estuarine areas. Despite its broad distribution, it is a tropical species. The optimal temperature range for its growth is between 28–30 °C; at 20 °C feeding ceases, and temperatures below 14–15 °C are lethal. Thus, temperature sensitivity restricts its natural distribution and imposes specific environmental requirements during cultivation.

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In Asian countries, freshwater prawn (*M. rosenbergii*) aquaculture is one of the most rapidly developing sectors of the fisheries industry. Its biochemical composition reflects excellent meat quality; the muscle tissue contains high levels of free amino acids (1756–1725 mg/100 g), predominantly arginine, proline, glycine, glutamic acid, lysine, and alanine (FAO, 2018; Gao, Chen, & Li, 2016). Additionally, no urea has been detected in meat samples, which contributes to its superior flavor (Table 1).

However, harvesting freshwater prawns from their natural habitats has become increasingly difficult. Rapid population growth and anthropogenic factors have placed significant pressure on freshwater ecosystems. Discharges from households, industries, and farms enter water bodies, increasing the risk of contamination by unknown and unhygienic pollutants. The recent surge in the production of synthetic chemicals has further exacerbated this problem.

To ensure food safety and improve production efficiency, various pond-based farming techniques have been developed for freshwater prawn aquaculture. These technologies are widely practiced in tropical countries. The United Nations' 2014 goal—to promote aquaculture production over extractive fishing—has been largely implemented through decapod crustaceans, particularly prawns. In 2018, the global commercial production of crustaceans in inland waters reached 9.4 million tons, corresponding to a market value of 69.3 billion USD. Although the production volume of crustaceans is smaller than that of finfish or bivalve mollusks, their unit price remains considerably higher. For comparison, mollusk aquaculture, with almost double the production volume (17.7 million tons), generated only about half the revenue (34.6 billion USD). The production of *M. rosenbergii* increased from 217 million tons in 2010 to 234.4 million tons in 2018, representing approximately 2.5 % of global aquaculture output, although productivity still remains lower than that of other crustacean species (Israni, & Levy, 2015). Thus, *M. rosenbergii* is regarded as a high-quality, flavorful, and highly profitable aquaculture product. Although its commercial production is still developing, it presents an opportunity to fill the gap in Russia's seafood market. Nevertheless, in most Russian climatic zones, large-scale production is only feasible during the summer months when water temperatures exceed 20 °C. Even under these conditions, prawns must be kept and reared indoors, which makes RAS facilities the most suitable solution. Unlike finfish, crustaceans possess unique biological characteristics that require specialized RAS configurations. Such systems are typically more compact and easier to maintain. A standard crustacean RAS unit includes circulation pumps, culture tanks, mechanical filtration, a biofilter, aeration devices, thermostats, and UV sterilizers (Jelkic, Popadic & Milanovic, 2012). These facilities are often adapted from existing fish farms. The schematic layout of an RAS designed for *M. rosenbergii* is shown in Figure 2. This adaptation is mainly due to the limited availability of specialized crustacean farming systems; the main differences lie in the water circulation setup. Compared to fish ponds, prawn ponds produce 100–200 times less biomass per cycle, resulting in lower pollution and oxygen demand. Consequently, smaller water volumes and compact filtration and aeration units can be used efficiently. Cannibalism in *M. rosenbergii* arises primarily during intensive molting periods, posing a major challenge during rearing. According to studies by the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), lower stocking densities increase cannibalism risk, while higher densities reduce aggression only marginally. Researchers have noted that cannibalism is associated with more frequent physical interactions among individuals, especially between molting and non-molting prawns (Hernández & Lee, 2017). To reduce cannibalism in pond culture, various shelter systems have been introduced. Israeli researchers designed shelters made of inert material bundles that provide both refuge and a bioactive surface layer, where microorganisms decompose nitrogen compounds. With low stocking densities, a RAS can even operate without a biofilter, as biofilms form directly on the shelter surfaces and serve as an additional food source. Experiments have shown that consumption of biofouling material enhances prawn growth (Kumar & Engle, 2016). However, biofouling can also lead to sediment accumulation; thus, even water distribution and shelter arrangement are crucial.

For efficient space use in RAS prawn farming, tanks with a large surface area and shallow depth are recommended. These tanks can be arranged in multi-tier systems using vertical water circulation.

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Oxygen is supplied from a centralized compressed-air system through diffusers to maintain proper aeration (RFRIFO (Russian Federal Research Institute of Fisheries and Oceanography), 2019). Several methods have been tested to enhance *M. rosenbergii* reproduction: stimulating gonadal maturation, shortening the interval between gonadal development and spawning through special feed formulations, hormone injections, and eyestalk ablation—all aimed at accelerating seed production and reducing production costs (Ende, Henjes, Spiller, Elshobary, Hanelt & Abomohra, 2024; Musayev, 2018). The main limitation in RAS crustacean farming remains the insufficient level of technological advancement, which presents financial risks in commercial-scale operations. Nonetheless, one of the critical challenges in *M. rosenbergii* farming is the development and production of high-quality, balanced feeds specifically tailored for decapods. As the industry is still emerging in Russia, *M.rosenbergii* aquaculture could fill a major gap in the national seafood market, offering a high-value and profitable product. Currently, Russian producers lack access to specialized crustacean feeds. As a result, many farms empirically combine available ingredients based on general assumptions about crustacean nutrition. This approach increases costs and uncertainty in production. To determine the optimal feed composition, an experimental trial was conducted, correlating feed formulations with average body weight and survival rate. The experiment aimed to identify the most suitable base substrate for prawn diets (Smith & Nguyen, 2020).

Diseases and Biosecurity

One of the most serious issues in RAS crustacean farming is disease outbreaks. High stocking densities promote bacterial (e.g., *Vibrio* spp.), viral (white spot syndrome, yellow head virus), and fungal infections, which can rapidly spread and cause substantial economic losses. Although RAS reduce external contamination compared to open ponds, high density, oxygen deficiency, and poor water quality favor pathogen development. Therefore, strict biosecurity measures are necessary. Preventive strategies include UV sterilization, ozonation, and advanced filtration. Adding probiotics to feed helps stabilize intestinal microflora and boost immunity. The use of antibiotics has been restricted due to their negative impact on product quality; thus, biological treatments and immunostimulants are considered more sustainable alternatives. Feed quality remains another critical factor in *M. rosenbergii* farming. Most current diets rely on fishmeal and fish oil, which are expensive and unsustainable in the long term. Hence, numerous studies are investigating alternative protein sources such as algal meal, soybean protein, and insect-based feeds, particularly the black soldier fly (*Hermetia illucens*) larvae meal. These ingredients are cost-effective and environmentally friendly. Moreover, probiotic and prebiotic additives have been shown to enhance growth and immunity. Proper balance between protein, lipid, and carbohydrate content plays a decisive role in productivity. Therefore, the use of alternative feed sources and specially formulated diets for *M. rosenbergii* could significantly improve the economic efficiency of RAS farming systems. Overall, the cultivation of the giant freshwater prawn holds significant economic potential both regionally and globally. While the industry is already well-developed in Asia, it remains underdeveloped in Russia, where there is a substantial market gap. Establishing RAS-based prawn farms could reduce import dependency and create export opportunities. Despite relatively high production costs, strong consumer demand and premium market prices make this sector profitable. Furthermore, expansion of *M. rosenbergii* production can create new employment opportunities and stimulate regional economic growth. Thus, giant freshwater prawn aquaculture not only diversifies aquaculture production but also contributes to national economic development (Huseyn, 2020).

Research

In this study, the giant freshwater prawn (*Macrobrachium rosenbergii*) was cultured under intensive conditions in a Recirculating Aquaculture System (RAS). The experiment lasted for six weeks and evaluated the effects of three different feed formulations on the average weight, survival rate, and growth performance of the prawns. Each tank contained 50 individuals per group, with shelters and biofilm layers provided. Water temperature was maintained between 28–30 °C, dissolved oxygen levels at 5–6 mg/L, and pH between 7.2–7.6. The weight of the prawns was measured weekly, and survival percentages were calculated accordingly.

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Conclusion

The study demonstrates that *Macrobrachium rosenbergii* is a commercially valuable aquaculture species with high nutritional and sensory qualities. Recirculating Aquaculture Systems (RAS) provide favorable conditions for its culture under controlled environments; however, factors such as high stocking density, limited feed resources, and cannibalism still restrict production efficiency. Observations and experimental results indicate that the use of specially formulated balanced feeds, improvement of biofiltration technologies, and proper placement of shelter systems enhance survival rates and optimize growth performance. Therefore, the culture of giant freshwater prawns in RAS conditions holds significant economic and ecological potential to meet the growing demand in both local and international markets.

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