Comparative Growth Performance of Climbing Perch, *Anabas testudineus* (Bloch, 1792) under Two Different Low Cost and Advance Recirculatory Aquaculture System (RAS)

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ABSTRACT

Background: Recirculatory aquaculture system (RAS) is an intensive and sustainable aquaculture system that involves the reuse of water within a closed loop system minimizing water usage and reduces environmental impact. This study compares the growth performance of Climbing Perch (*Anabas testudineus*) in a low-cost recirculatory aquaculture system (RAS) versus an advanced RAS. The low-cost RAS aims to reduce economic burdens on fish farmers while maintaining sustainability through efficient water reuse.

Methods: Climbing perch fingerlings were cultured under Advance RAS, Low cost designed RAS and fiberglass reinforced plastic (FRP) (control) tanks in triplicate with meticulous monitoring of various growth parameters and water quality assessments following standard methods.

Result: The study reveals that *A. testudineus* grew better in advanced RAS, with higher weight and length compared to low-cost RAS and FRP tanks. However, the survival rate was highest in the low-cost RAS (100%) versus advanced RAS (97.61%) and FRP tanks (86.77%). Weight gain, specific growth rate, PER and FCR were statistically similar in both RAS systems. Advanced RAS had a higher temperature (29.02°C) and lower pH (7.56) than the low-cost RAS (28.66°C, 7.82) and FRP tanks (28.46°C, 8.25). The low-cost RAS outperformed in dissolved oxygen levels, lower ammonia, nitrite and nitrate content Low-cost RAS demonstrated superior efficiency in controlling total suspended solids (20.00 mg/l) compared to advanced RAS (58.21 mg/l) and FRP tanks (158.74 mg/l) and superior control of total suspended solids. The low-cost RAS offers comparable performance to advanced RAS, with proper filtration maintenance enhancing fish survival and quality.

Key words: Dissolved oxygen, Growth analysis, Survival rate, Total dissolved solids.

INTRODUCTION

Aquaculture, the world's fastest-growing food production sector, experienced a remarkable 5.3% annual growth rate from 2001-2018 and a production surge of over 600% since 1990 (FAO, 2020). Asia leads, accounting for 89% of global aquaculture output (FAO, 2020), which significantly boosts food security, surpassing population (Allison, 2011; Béné *et al.,* 2016). However, the challenge of feeding a projected 9.7 billion people by 2050 persist (United Nations, 2019; Berners-Lee *et al.,* 2018; Ehrlich and Harte, 2015). With stagnant capture fisheries and environmental threats like climate change (Brander, 2007; De Silva and Soto, 2009), the industry must meet future targets of 109 million tons by 2030 (FAO, 2020) and 140 million tons by 2050 (Waite *et al.,* 2014). Recirculatory aquaculture system (RAS) present a promising strategy to address these challenges and sustain aquaculture growth. The utilization of advanced culture systems like recirculating aquaculture system (RAS), IMTA and biofloc proves to be very advantageous with a combination of maximum production capacities (Ezhilmathi *et al.,* 2022).

Recirculating aquaculture systems (RAS) are land-based, indoor tanks known for exceptional water reuse efficiency and water quality maintenance. They eliminate the need for external irrigation, prevent contamination (Sri-uam *et al.,* 2016) and enhance hygiene and disease management (Summerfelt *et al.,* 2009; Tal *et al.,* 2009). RAS enables superior growth performance, higher productivity per area and worker and controlled growth rates with predictable harvests (Ebeling and Timmons, 2012). Despite its benefits, RAS faces high operational and startup costs (Lazur, 2003). Efforts to make RAS more cost-effective include innovations like inexpensive systems for Nile tilapia (Soto-Zarazúa *et al.,* 2010) and economical setups for

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marine fish broodstocks using FRP systems with advanced filtration and temperature control (Anil *et al.,* 2019). Advances like denitrification reactors and sludge thickening have further reduced water consumption and waste (Martins *et al.,* 2010), making RAS a sustainable option for farmers seeking high yields and reduced environmental impact.

The climbing perch (*Anabas testudineus*), locally known as Vietnam koi, is a significant air-breathing fish native to India, valued for its broad distribution and environmental tolerance, making it a promising species for aquaculture. Though omnivorous, it prefers a high-protein, carnivorous diet (Palinggi *et al.,* 2002). Rich in fat, protein, fatty acids, essential amino acids and vitamins, it also contains iron and copper necessary for hemoglobin synthesis (Saha, 1971). *A. testudineus* is highly regarded for its nutritional value and commands a higher market price, particularly in West Bengal (Paul *et al.,* 2017). This study evaluates its growth performance in low-cost and advanced Recirculatory aquaculture systems (RAS).

MATERIALS AND METHODS

Experiments on low-cost RAS and FRP tanks were conducted at the Aquaculture Lab, College of Fisheries Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana located in the subtropical zone at 215.2 m above sea level. Advanced RAS experiments were carried out in collaboration with Swastik Aqua RAS Farm in Ambala, Haryana, with the farmer's consent. The low-cost RAS (Fig 1) developed by Singh (2022) uses 1,000-liter FRP tanks for production and four waste plastic drums as filtration units, including a drum filter, protein skimmer, MBBR biofilter and UV disinfectant. This system, with a filtration rate of 50,000 liters/hour, costs approximately INR 1,24,000 and is currently under patenting. It was compared with an advanced RAS and conventional FRP tanks.

The experiment used sanitized canal water, with no water changes in the low-cost RAS and a 10% exchange in the advanced RAS. Conventional FRP tanks required 40% water replacement every four days due to increased turbidity. A total of 1,000 *A. testudineus* fingerlings were procured from certified Malik Fish Seed Supplier, Rohtak, Haryana and acclimatized in 1,000-liter FRP tanks for 8-10 days. Each tank low-cost RAS, advanced RAS and FRP (control) received 100 fingerlings, averaging 2.15 g, 1.95 g, 1.52 g in weight and 5.23 cm, 5.03 cm, 4.50 cm in length, respectively. The fish were fed New Hope feed (34% crude protein, 1.2 mm) thrice daily at 8% (1-30 DOC), 6% (31-60 DOC) and 4% (61-90 DOC) of body weight over 90 days. The experiment was conducted from May to September, 2022 in triplicate for all systems.

Growth performance analysis and water quality parameters

Every 15 days, 50 experimental fingerlings/fish from each tank (low-cost RAS, advanced RAS and FRP tanks) were weighed and measured for length (Fig 2). Daily feed consumption was recorded. The data was used to calculate percent weight and length gain, survival rate, daily weight gain (ADG); specific growth rate (SGR); protein efficiency ratio (PER) and feed conversion ratio (FCR) using standard formulas. Weekly water quality was assessed in triplicate for each tank. Parameters measured included temperature, pH, alkalinity, dissolved oxygen, ammonia, nitrite, nitrate, total suspended solids (TSS), total dissolved solids, salinity and conductivity, following APHA (2012) guidelines and using standard kits and meters. The growth performance of *A. testudineus* across three systems was analyzed using a completely randomized block design, with

Fig 1: Development of low-cost RAS.

Fig 2: Weight and length measurement of fingerling.

critical difference (CD) calculated *via* ANOVA. Two-factor ANOVA was applied to assess twelve water quality parameters over different durations.

RESULTS AND DISCUSSION

Comparison of growth and survival rates of *A. testudineus* across different RAS systems

In the comparison of *A. testudineus* across three systems, the advanced RAS showed significantly higher weight (22.34 g) compared to the low-cost RAS (18.63 g) and FRP tanks (9.11 g) (Table 1). Weight in the advanced RAS increased markedly from 1.95 g to 60 g (Fig 3). Similarly, fish length was greater in the advanced RAS (9.38 cm) than in the low-cost RAS (9.12 cm) and FRP tanks (7.25 cm) (Table 1). Studies have shown similar trends, with higher growth rates in larger RAS than in small size RAS for Nile tilapia (330.82 g vs. 138.84 g) (Martins *et al.,* 2009) and increased length in semi-intensive systems (Chakraborty, 2016). In a related study, Vietnamese koi had greater final length (14.40 cm) compared to Thai koi (13.50 cm) in Bangladesh (Nabi *et al*., 2020).

In the study, the advanced RAS system showed the highest per cent increment in *A. testudineus* weight (78.68%), followed by the low-cost RAS (70.35%), both of which were statistically comparable. The FRP tanks had the lowest weight increase (59.73%). Similarly, the highest per cent increment in length (19.24%) was observed in the advanced RAS, with decreases to 18.14% in the low-cost RAS and 16.51% in the FRP tanks. Patra (1994) also found that a 40% protein diet led to the highest weight gain in *A. testudineus*, with a negative correlation to FCR and PER. Survival rates for *A. testudenius* varied significantly by tank type: 100% in low-cost RAS, 97.61% in advanced RAS and

Fig 3: Fish weight and length at DOC90.

Table 1: Growth parameters of climbing perch, *Anabas testudineus* under FRP tanks, Low cost RAS and Advance RAS.

Days of culture	FRP tanks (Control)	Low cost RAS	Advance RAS
	0-90	0-90	0-90
Mean weight (g)	9.11	18.63	22.34
CD (p=0.05)= 0.65; SE (m)= 0.24			
Mean length (cm)	7.25	9.12	9.38
CD (p=0.05)= 0.21; SE (m)= 0.07			
Mean % increment in weight	59.73	70.34[a]	78.68[a]
CD (p=0.05) = 8.99; SE (m)= 3.12			
Mean % increment in length	16.51	18.14	19.24
CD (p=0.05) = N/A; SE (m)= 0.91			
Mean survival rate (%)	86.77	100.00	97.61
CD (p=0.05)= 1.37; SE (m)= 0.47			
Mean daily weight gain (g)	0.24	0.56	0.69
CD (p=0.05)= 0.03; SE (m)= 0.01			
Mean SGR (%)	3.17	3.74[b]	4.08[b]
CD (p=0.05) = 0.38; SE (m)= 0.13			
Mean PER	1.88	2.50[c]	2.70[c]
CD (p=0.05)= 0.60; SE (m)= 0.21			
Mean FCR	2.36	1.27[d]	1.09[d]
CD (p=0.05)= 0.24; SE (m)= 0.08			

Values with same superscript do not differ significantly.

86.77% in regular FRP tanks (control). Kohinoor *et al.* (2016) reported 89% survival for Vietnamese Koi versus 85% for Thai Koi. Martins *et al.* (2009) found 100% survival in *O. niloticus* in middle and high accumulation RAS systems.

Daily weight gain (ADG) and specific growth rate (SGR) in *A. testudenius*

The highest daily weight gain (0.69 g) in *A. testudineus* was observed in advanced RAS, followed by low-cost RAS (0.56 g) and FRP tanks (0.24 g). The specific growth rate (SGR) was significantly higher in advanced RAS (4.08%) compared to low-cost RAS (3.74%) and FRP tanks (3.17%) (CD=0.38; p=0.05) (Table 1). Mota *et al.* (2018) reported increased growth in turbot under high pH. Ridha and Cruz (2001) found higher weight gain and daily growth in *O. niloticus* with media block biofilters (267.4 g, 1.18 g/day) compared to biofilter chips (264.1 g, 1.16 g/day). Chakraborty (2016) observed higher average daily growth (1.77 g) and SGR (5.18%) in semi-intensive systems compared to control systems (1.20 g, 4.79%). Kristan *et al.* (2018) noted a higher SGR for *Ctenopharyngodon idella* in RAS (0.49%) versus ponds (0.12%). Szczepkowski *et al.* (2011) found that pikeperch in larger fish groups had the highest body length (34 mm) but the lowest SGR (9.2% /day), while smaller fish groups had the highest SGR (10.1% /day). In a fresh water-based RAS, Moses *et al.* (2024) reported a maximum weight gain and SGR in Asian seabass when supplemented with Vitamin C at 0.8% inclusion.

Protein efficiency ratio (PER) in different systems and feed conversion ratio (FCR) by *A. testudenius*

A study on the effect of different systems on PER found that FRP tanks had a significantly lower PER (1.88) compared to low-cost RAS (2.50) and advanced RAS (2.70), with the latter two being statistically similar (Table 1). Advanced RAS also showed the lowest FCR (1.09), which was statistically similar to low-cost RAS (1.27), while FRP tanks had a significantly higher FCR (2.36) for *A. testudenius* (Table 1). Watanabe *et al.* (1993) found that the highest daily weight gain of juvenile *O. niloticus* occurred at 18-32°C (0.30 g/day) and the lowest FCR (1.27) at 32°C. Kohinoor *et al.* (2016) reported that Vietnamese koi exhibited higher weight (138.91 g), specific growth rate (SGR) (4.06%) and lower FCR (1.58) compared to Thai Koi (89 g, 3.70%, 1.60).

Water quality parameters in different systems

Temperature, pH and dissolved oxygen

The study found that water temperature was highest in advanced RAS (29.02°C), followed by low-cost RAS (28.66°C) and FRP tanks (28.46°C), aligning with Nabi *et al.* (2020), who reported a suitable temperature range (29.11-30.88°C) for Vietnamese Koi growth. Optimal temperatures

Table 2: Water quality parameters of climbing perch, *Anabas testudineus* under FRP tanks, Low cost RAS and advance RAS.

Sampling weeks	FRP tanks (Control)	Low cost RAS	Advance RAS
	0-12	0-12	0-12
Mean temperature (°C)	28.46	28.66	29.02
CD (p=0.05)= 0.16; SE (m)= 0.05			
Mean pH	8.25	7.82	7.56
CD (p=0.05)= 0.02; SE (m)= 0.01			
Mean dissolved oxygen (mg/l)	5.10	5.92	5.60
CD (p=0.05)= 0.12; SE (m)= 0.04			
Mean total alkalinity (mg/l)	179.05	92.36	87.59
CD (p=0.05)= 2.05; SE (m)= 0.72			
Mean total hardness (mg/l)	118.31	121.28	123.72
CD (p=0.05)= 0.76; SE (m)= 0.27			
Mean ammonia (mg/l)	0.286	0.009	0.042
CD (p=0.05)= 0.006; SE (m)= 0.002			
Mean nitrite (mg/l)	0.134	0.008	0.067
CD (p=0.05)= 0.008; SE (m)= 0.003			
Mean nitrate (mg/l)	7.83	1.73	3.40
CD (p=0.05)= 0.29; SE (m)= 0.10			
Mean total suspended solids (mg/l)	158.74	20.00	58.21
CD (p=0.05)= 2.68; SE (m)= 0.95			
Mean total dissolved solids (TDS) (mg/l)	132.40	241.81	192.67
CD (p=0.05)= 1.03; SE (m)= 0.36			
Mean salinity (ppm)	241.84	552.67	331.40
CD (p=0.05)= 1.07; SE (m)= 0.38			
Mean conductivity (µS/cm)	385.87	602.74	499.69
CD (p=0.05)= 2.27; SE (m)= 0.80			

for red tilapia and juvenile yellowtail kingfish in RAS were 27°C (Watanabe *et al.,* 1993) and 26.5°C (Abbink *et al.,* 2012), respectively. FRP tanks had the highest pH (8.25), followed by low-cost RAS (7.82) and advanced RAS (7.56). Optimal pH for different species in RAS varied, with 7.90 for marine finfish (Gopalakrishnan *et al.,* 2018), 7.16-7.85 for yellowtail kingfish (Abbink *et al.,* 2012) and 7.39-7.75 for *A. testudenius* (Nabi *et al.,* 2020). Dissolved oxygen was lowest in FRP tanks (5.10 mg/l) and highest in low-cost RAS (5.92 mg/l), with optimal levels for other species ranging from 6.07-7.74 mg/l for yellowtail kingfish (Abbink *et al.,* 2012) to 4.72 mg/l for marine fish broodstocks (Gopalakrishnan *et al.,* 2018).

Total alkalinity and total hardness

The study showed that total alkalinity was lowest in advanced RAS (87.59 mg/l), followed by low-cost RAS (92.36 mg/l) and FRP tanks (179.05 mg/l). Although no specific data on alkalinity's effect on *A. testudenius* are available, climbing perch showed better growth in systems with water hardness between 117.14 and 127.11 mg/l (Chakraborty and Haque, 2014). Martins *et al.* (2009) reported alkalinity levels of 72.4, 46.15 and 130.75 mg/l for *O. niloticus* in high, middle and low water exchange RAS systems. Summerfelt *et al.* (2015) found that varying alkalinity levels (10, 70 and 200 mg/l as $CaCO_3$) affected Atlantic salmon health in recirculating systems, with low alkalinity (10 mg/l) leading to CO_2-related health issues. The optimal alkalinity in a low-cost RAS for marine finfish broodstock development was 108.75 mg/l (Gopalakrishnan *et al.,* 2018). Water hardness was lowest in FRP tanks (118.31 mg/l) compared to low-cost RAS (121.28 mg/l) and advanced RAS (123.72 mg/l). Davidson *et al.* (2017) observed water hardness levels of 289 and 306 mg/l for post-smolt Atlantic salmon under different NO_3-N treatments in freshwater RAS.

Ammonia, nitrite and nitrate content

The study found that ammonia levels were significantly lower in low-cost RAS (0.009 mg/l) compared to advanced RAS (0.042 mg/l) and FRP tanks (0.286 mg/l), with ANOVA revealing lower ranges in low-cost (0 to 0.100 mg/l) and advanced RAS (0 to 0.267 mg/l) than in FRP tanks (0 to 0.9 mg/l). For *O. niloticus* in RAS, ammonia levels varied from 0.07 to 0.36 mg/l (Martins *et al.,* 2009), 2.93 mg/l (Soto-Zarazua *et al.,* 2010) and 0.089 to 0.094 mg/l (Davidson *et al.,* 2017). Gopalakrishnan *et al.* (2018) found unionized ammonia at 0.001 mg/l in low-cost RAS. Nitrite content was also lowest in low-cost RAS (0.008 mg/l), followed by advanced RAS (0.067 mg/l) and FRP tanks (0.134 mg/l), ranging from 0 to 0.156 mg/l. Reported nitrite levels were 0.59 to 0.72 mg/l in simple recirculating systems with *O. niloticus* (Ridha and Cruz, 2001) and 0.007 mg/l in low-cost RAS for marine fish broodstock (Gopalakrishnan *et al.,* 2018). Nitrate levels were lowest in low-cost RAS (1.73 mg/l) compared to advanced RAS (3.40 mg/l) and FRP tanks (7.83 mg/l). Nitrate ranged from 0.11 to 5.8 mg/l (Soto-Zarazua *et al.,* 2010) to 63.02 mg/l (Martins *et al.,* 2009), with a maximum of 1.38 mg/l in semi-intensive systems for *A. testudineus* (Chakraborty, 2016) and 90 to 125.9 mg/l for turbot in RAS (Mota *et al.,* 2018).

Total suspended solids and total dissolved solids

The study found that low-cost RAS was most efficient in removing total suspended solids (TSS) at 20.00 mg/l, followed by advanced RAS (58.21 mg/l), while FRP tanks were least effective (158.74 mg/l) (Table 2). This trend was consistent across all sampling weeks. In comparison, Zhang *et al.* (2011) reported TSS levels of 68.40 mg/l in a primary biological pond, 53.20 mg/l at the inlet and 9.30 mg/l at the outlet of a filtration system in an integrated recirculating aquaculture setup. Total dissolved solids (TDS) were lowest in FRP tanks (132.40 ppm), followed by advanced RAS (192.67 ppm) and highest in low-cost RAS (241.81 ppm), with significant interactions between sampling weeks and systems. During the culture of post-smolt Atlantic salmon, Davidson *et al.* (2017) reported a maximum TSS level of 1.23 mg/l in freshwater RAS.

Salinity and conductivity

The study showed that salinity levels were significantly lower in FRP tanks (241.84 ppm) compared to low-cost RAS (552.67 ppm) and advanced RAS (331.40 ppm) (Table 2). Mota *et al.* (2018) reported stable salinity levels in recirculating aquaculture systems, while Mojer *et al.* (2021) observed salinity ranging from 3.2-8.2 PSU in earthen ponds and 0.60-0.67 PSU in plastic RAS tanks. Conductivity followed a similar trend, with FRP tanks showing the lowest levels (385.87 µS/cm), followed by advanced RAS (499.69 µS/cm) and low-cost RAS (602.74 µS/cm) (Table 2). Martins *et al.* (2009) found the highest conductivity in high water exchange RAS (1404.88 µS/cm) and the lowest in low water exchange systems (744.21 µS/cm). Davidson *et al.* (2017) recorded a maximum conductivity of 1322 µS/cm in freshwater RAS during the culture of post-smolt Atlantic salmon.

CONCLUSION

The study found that the advanced RAS system significantly promoted *A. testudineus* growth, with better weight and length increments than low-cost RAS and FRP tanks. Low-cost RAS achieved a 100% survival rate and effectively maintained dissolved oxygen levels and controlled total suspended solids. As a cost-effective alternative, low-cost RAS offers farmers a practical way to enhance productivity and access advanced aquaculture techniques, supporting sustainable practices.

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Informed consent statement

The fish used in this study were not subjected to any harm. All experimental procedures were conducted ethically, focusing solely on assessing growth performance and feed utilization. The well-being of the fish was maintained throughout the study, adhering to established animal welfare guidelines.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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