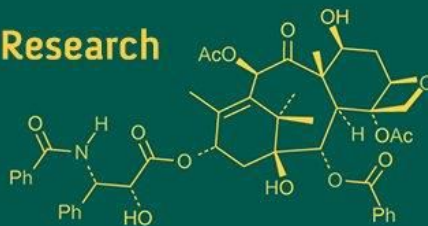
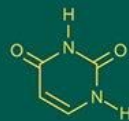
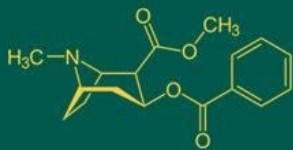


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Evaluation of water quality, growth performance, feed efficiency and survival of *Labeo rohita* (Rohu) and *Carassius auratus* (Gold fish) in a recirculating aquaponics system

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Abstract

In the face of limited resources, a growing global population, climate change, and an increasing demand for organic food, sustainable agricultural practices have become imperative. Aquaponics, an integrated system combining aquaculture and hydroponics, holds promise as a potential solution to address these challenges. This study involved a 60-day experiment conducted within a recirculatory aquaponics system (RAS), allowing for the efficient reuse of water and nutrients. In this study two species of fish were studied, the ornamental goldfish (*Carassius auratus*) and the popular food fish, rohu (*Labeo rohita*). The results revealed significant enhancements in the growth and clarity of the water when goldfish were incorporated into the treatment groups, as compared to the control. On the other hand, rohu fish showed promising growth in the treatment systems compared to control. Additionally, the study evaluated the water quality parameters in the fish rearing tanks, which continually provide optimum conditions for the growth of plants and fish. The findings highlight the potential of aquaponics as a resource-efficient and environmentally friendly method for producing a variety of foods.

Keywords: Recirculating aquaponics system, growth performance, *Carassius auratus*, *Labeo rohita*, water quality

1. Introduction

Rapid growth in the human population has created numerous environmental challenges, including water scarcity, degradation of arable land, rapid climate change, and land salinization (Dijkgraaf *et al.*, 2019; Goddek *et al.*, 2019a; Yang and Kim, 2020) [3, 8, 29]. To eliminate the disparity between available resources and expanding demand for food, there is a need to change from a growth-dependent, cost-effective model to one that prioritizes environmentally friendly food production systems in a balanced manner, assuring nutritional security (Goddek *et al.*, 2019a) [8]. Pisciculture as a rapidly expanding sector, offers a viable solution to achieve both food security and the growth of entrepreneurship. However, traditional aquaculture technologies such as ponds and open-water systems pose significant environmental problems, including eutrophication and habitat degradation. Therefore, addressing these problems requires implementing a more intensive, cost-effective, and ecologically friendly food production approach (Dijkgraaf *et al.*, 2019) [3].

As a zero water exchange technology, aquaponics offers a potential solution by improving the recycling of nutrients and culture water, hence reducing the negative discharge from aquaculture sites. This system has a 95-99% water reuse rate and effectively uses scarce land and water resources. Furthermore, it offers numerous financial advantages through the sustainable production of plants and fish (Nuwansi *et al.*, 2015) [18]. Aquaponics represents a biologically-integrated model which improves the availability of nutritious foods, aligns with United Nations Sustainable Development Goals (Goal 2: Zero Hunger and Goal 14: Life Below Water), and fulfils the needs of a growing global population (Goddek *et al.*, 2019a; Ani *et al.*, 2022) [8].

The technique combines recirculating aquaculture and hydroponics, using nutrient-rich culture water effluent from fish tanks with waste and uneaten feed as the principal fertilizer supply for plants. Filtered water is recirculated to fish tanks.

Aquaponics reduces the need for nutrient supplementation in hydroponics and improves waste-water purification in the RAS. This results in excess nutrient exclusion and increased profitability by producing two marketable crops concurrently (Hu *et al.*, 2015; Nuwansi *et al.*, 2015) [13, 18].

The primary aim of this study was to determine the growth performance of food fish and ornamental fish with selected horticultural plants in an aquaponics system. Furthermore, it also demonstrates the potential of aquaponics as a sustainable strategy for integrating aquaculture and horticulture to increase production.

2. Materials and Methods

2.1 Experimental Site

The present research work was carried out at the polyhouse of the College of Fisheries Science (COF), Kamdhenu University at Rajpur (Nava) Himmatnagar.

2.2 Experimental Fish

The healthy and non-infected advance fry of *Labeo rohita* and *Carassius auratus* (Family: Cyprinidae and order: Cypriniformes) were used for *in vivo* experiment. The stock of fish was obtained from the State Fisheries Department-Ukai, Gujarat. The average weight of the rohu fish (1.36 ± 0.026) g and gold fish was (1.34 ± 0.02) g. The prophylactic treatment following the standard protocol of bath treatment in 0.05% potassium permanganate solution was given to fish before placing them in an acclimatization tank. Fish was reared one month under laboratory conditions for proper acclimatization under the optimal condition, before taking them for in-vivo experiment. Commercial feed was used to feed the fish.

2.3 Experimental design

The experiment was carried out in pretreated (2ppm KMNO₄, fully washed 3-4 times and sun dried) 1000 Liter capacity circular FRP tanks and filled with pre-quality tested borewell water in each circular tank. The experimental design was CRD, and the tanks were set up in triplicates for treatment and control group. The experimental fish *Labeo rohita* (Rohu) and *Carassius auratus* (Gold fish) were stocked at a rate of 1gm/l of water. After acclimatization period, fish fry with an average initial body weight of rohu (1.36 ± 0.026) g and (1.34 ± 0.02) g of gold fish were randomly distributed in replications. 10-15% Water refilled to compensate the evaporation loss. The fish fry were fed at the rate of 10% of body weight in split dosed twice a day for first 30 days and 8% for subsequent time. Growth parameters of fishes and plants were monitored fortnightly. The experiment lasted for 60 days.

2.4 Preparation of Aquaponics System

The aquaponic system has been expanded with recirculation in two sections. The Floating Raft Aquaponic System was created utilizing thermocol sheets. To create the floating raft, we used thermocol sheets that were 1 meter long, 0.5 meter wide, and 0.03 meter thick. The aquaponic structure consisted of six thermocol sheets with implanted plant seeds. Six sets of Floating Raft Aquaponic Systems were set up,

with seedlings securely fixed in 2-inch diameter planting pots and placed 6 inches apart on floating sheets. Each floating raft could hold 16 seedlings from four distinct plant varieties.

The second phase was to construct the aquaponic system's media bed, which included four crates for each replicate, resulting a total of 12 crates over three replication units. The rectangular plastic crates had a capacity of 160 liters and measures 0.77 meters in length, 0.53 meters in width, and 0.40 meters in depth. The crates were pre-filled with pebbles of various sizes to provide a homogeneous media bed thickness of 11.3 cm meters. Plant seedlings were then placed on top of the medium bed. The media bed aquaponic assembly was placed after the main tanks and goldfish tank in a duplicate configuration, while the floating bed aquaponics assembly floated on the FRP (rohu and goldfish tanks, respectively).

2.5 Water quality parameters

Water quality parameters such as temperature, pH, TDS and electrical conductivity were determined in the biochemistry lab by HANA multiparameter bench meter (HI 5522, USA).

2.6 Growth parameters of experimental fish

Growth parameters such as Percentage Weight Gain (gm), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER) and Lipid Efficiency Ratio (LER) were calculated. The growth performance assessed at 15 days intervals by randomly sampling 15 fish from each tank in all experimental replicates.

The following formulas were used to measure the growth parameters of fish.

Mean Weight gain = Final Weight-Initial Weight

Survival

Survival (%) = total no. of fish h at the end of the experiment/total no. of fish at the beginning of the experiment x100

Specific growth rate (SGR)

SGR (%) = $\frac{\ln \text{ Final Weight} - \ln \text{ Initial Weight}}{\text{Number of Days}} \times 100$

Feed conversion ratio (FCR)

FCR = Feed given (dry weight)/Body weight gain (wet weight)

Feed conversion efficiency (FCE)

FCE = Weight gain/Feed given

Protein efficiency ratio (PER)

PER (%) = Weight gain/protein intake

Lipid efficiency ratio (LER)

LER (%) = Weight gain/lipid intake

2.7 Statistical Analysis

The results of the present study were statistically analysed using completely randomized design (CRD) and one-way analysis (ANOVA) using IBM® SPSS® version 26.00 software and significant differences ($p < 0.05$) among treatment means were compared using Duncan multiple range test (DMRT).

3. Results and Discussion

3.1 Water quality parameters

The water quality parameters observed during the experimental period are presented in Table 1. The water temperature ranged from 27.72 ± 0.09 °C to 29.90 ± 0.00 °C, while the pH ranged from 7.93 ± 0.08 to 8.64 ± 0.15 , which is ideal for fish, plants, and nitrifying bacteria growth. The optimal pH range for nitrification is 7.0 to 9.0 (Chen *et al.*, 2006) [2]. Medina *et al.* (2016) [16] reported 8.3 pH in a recirculating aquaponics system. The obtained result of present study were well within the optimal range and in agreement with the findings of Santhosh and Singh (2007) [23] and Chen *et al.* (2006) [2]. The electrical conductivity measured in this study varied from 900 to 925 $\mu\text{S cm}^{-1}$ in the control and 873 to 934 $\mu\text{S cm}^{-1}$ in the aquaponics system. Stone and Thomforde (2004) [26] state that water with an electrical conductivity between 100 and 2000 $\mu\text{S cm}^{-1}$ is preferred and suitable for fish culture. According to FAO (2014) [7] and Grabet and Junge (2009) [10], these values are well within the suggested EC range for aquaponics systems (300-1100 $\mu\text{S cm}^{-1}$), which is considered optimal for maintaining nutrient availability for plants while preventing osmotic stress in fish. The total dissolved solid concentration in this investigation ranged from 511.33 ± 19.09 to 572.96 ± 26.24 mg/l. The observed TDS values are within the recommended limits for aquaponics systems (300-800 mg/l) which is considered for adequate nutrient availability for plants while maintaining osmotic balance and fish health (Rahman *et al.*, 2015; Rajkumar *et al.* 2018) [20, 21].

3.2 Growth performance of *Labeo rohita* and *Carassius auratus*

This experiment was conducted to determine the influence of a recirculating aquaponics system on the growth and survival of *Labeo rohita* and goldfish fry over a 60-day period. The findings of growth metrics, including mean weight increase and specific growth rate, are shown in the table 2. During the experimental period observed body weight gain (%) of Rohu ranged from 16.95 ± 2.45 to 36.96 ± 2.82 in control group and from 18.08 ± 1.95 to 48.92 ± 4.82 in treatment group. Similarly, Gold fish demonstrated body weight gain (%) values from 22.78 ± 5.32 to 62.00 ± 3.95 in control and from 19.11 ± 0.50 to 91.06 ± 1.15 in treatment group. The results agreed with the findings of Rakocy *et al.*, (2006) [22] and Goddek *et al.*, (2019) [8] revealing higher weight gain of rohu and Gold fish reared in aquaponics system. Improved water quality through efficient nutrient removal may be the reason for higher growth in aquaponic systems, lowering physiological stress and increasing feed conversion ratio (Rakocy *et al.*, 2006; Endut *et al.*, 2010) [22]. Furthermore, continuous water recirculation ensures consistent nutrition supply and maintains steady physicochemical conditions that support optimal metabolic activity and fish growth performance. The SGR of Rohu varied from 1.04 ± 0.13 to 2.64 ± 0.21 in control

and from 1.40 ± 0.08 to 2.04 ± 0.21 in treatment, whereas gold fish ranged from 1.35 ± 0.28 to 4.21 ± 0.16 and 1.16 ± 0.02 to 3.31 ± 0.04 in control and treatment, respectively. Hazarika *et al.* (2023a) [11] discovered comparable SGR in rohu in a recirculating aquaculture system. Ujjania *et al.* (2023) [28] found 1.37 SGR in *Labeo rohita* in an aquaponics system, emphasizing the need of nutrient recycling and steady water quality for fish growth.

3.3 Feed Utilization

This experiment was conducted to determine the feed conversion efficiency under a recirculating aquaponics system by assessing the utilization of feed and its conversion into biomass. The findings of feed conversion ratio (FCR), protein efficiency ratio (PER) and lipid efficiency ratio (LER) obtained in the present study shown in table 2. The FCR in *Labeo rohita* varied from 2.80 to 6.23 in control and from 2.20 to 4.39 in treatment while in *Carassius auratus* it ranged from 1.97 to 4.45 in control and 1.57 to 3.18 in treatment. Priadi *et al.* (2019) [19] reported a similar observation, having FCR values ranging from 2.5 to 3.7 in combined aquaculture-hydroponic production systems. The treatment groups had lower and more efficient FCR ranges, which improved environmental conditions and increased feed intake, digestive efficacy, and overall feed utilization. The PER and LER measurements indicated an upward trend. In Rohu, the PER was 0.78 ± 0.01 and 0.94 ± 0.01 in control and treatment, whereas the LER was 5.48 ± 0.09 and 6.60 ± 0.13 in control and treatment, respectively. Similarly, the PER in gold fish was 0.98 ± 0.02 and 1.07 ± 0.01 respectively in control and treatment, while the LER in gold fish was 6.85 ± 0.14 and 7.50 ± 0.11 respectively.

3.4 Survival Rate

The survival rate of *Labeo rohita* and *Carassius auratus* in the different treatments is shown in the table 2. Survival was discovered at the end of the experiment. In Rohu, survival rates in the control and treatment groups were 95.23 ± 0.06 and 97.50 ± 0.96 respectively. Similarly, the goldfish in both the control and treatment groups survived the experiment completely. Hussain *et al.* (2022) [24] and Shete *et al.* (2013; 2016) [24, 25] found high survival rates in aquaponic systems. In the RAS system, rohu larvae survived at rates ranging from 80 to 93%. Shete *et al.* (2013) [24] found that all treatments and controls resulted in a 100% survival rate in gold fish.

Table 1: Range of water quality parameters during the experimental period

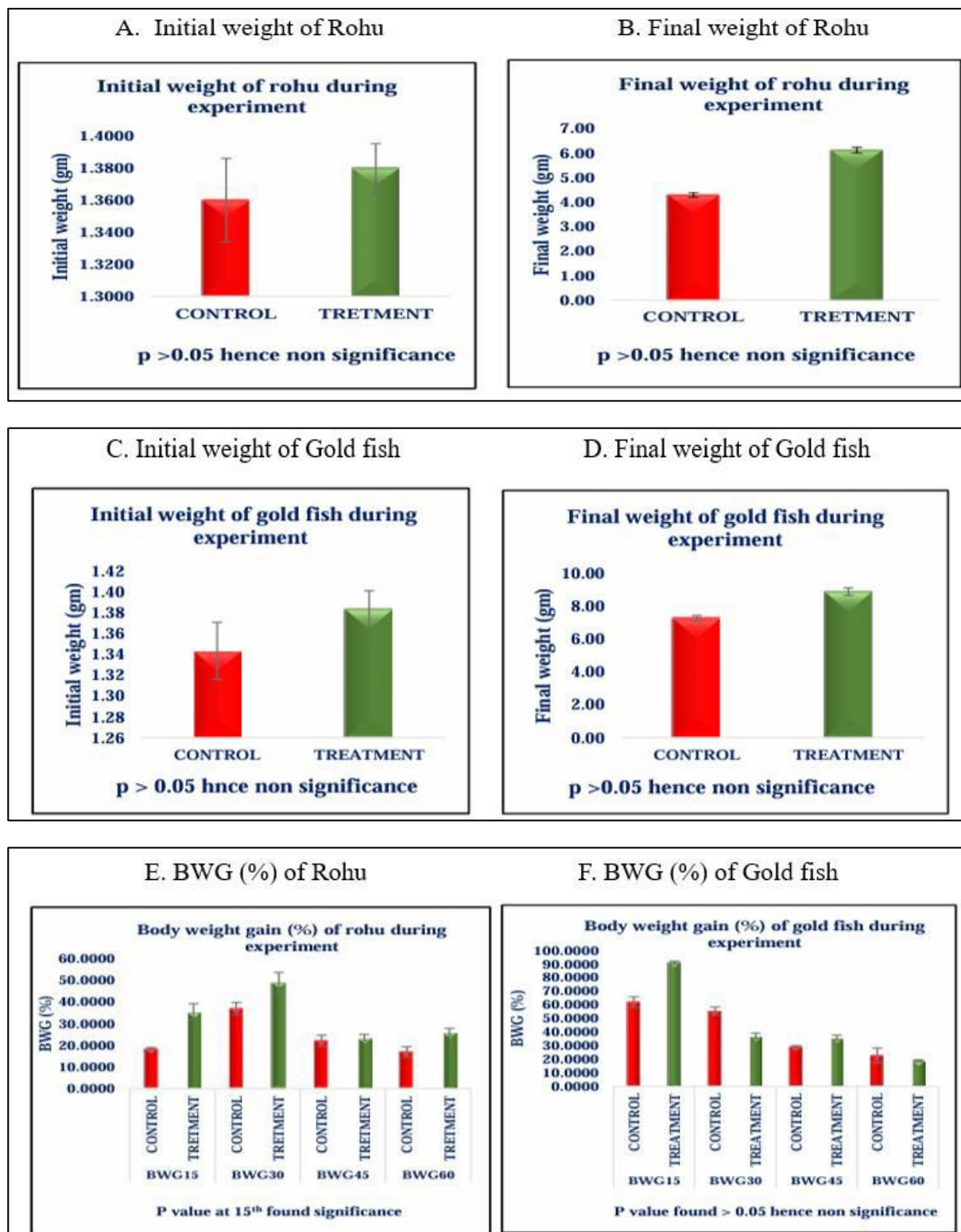
Water quality parameters	Control	Treatment
Temperature (°C)	27.72-29.63	28.06-29.90
pH	7.96-8.64	7.93-8.26
Conductivity ($\mu\text{S/cm}$)	900.01-925.33	873.66-934.66
Total dissolved solid (mg/l)	511.33±554.13	551.16-572.96

Note: Values given are mean $\pm$ standard deviation.

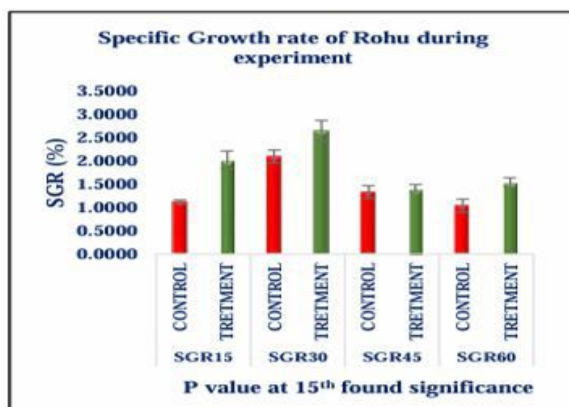
Table 2: Performance of *Cirrhinus mrigala* during culture period

Growth parameters	Growth performance of Rohu		Growth performance of Gold fish	
	Control	Treatment	Control	Treatment
Initial body weight (g)	1.36±0.026	1.38±0.015	1.34±0.02	1.38±0.017
Final body weight (g)	4.30±0.09	6.12±0.11	7.23±0.17	8.85±0.22
Body weight gain (%)	36.96±2.82	48.92±4.82	62.00±3.95	91.06±1.15
Specific growth rate	2.64±0.21	2.04±0.21	4.21±0.16	3.31±0.04
Survival rate (%)	95.23±0.06	97.50±0.96	100±0.00	100±0.00
Feed conversion ratio	6.23±1.16	4.39±0.32	4.45±0.89	3.18±0.68
Protein efficiency ratio	0.78±0.01	0.94±0.01	0.98±0.02	1.07±0.01
Lipid efficiency ratio	5.48±0.09	6.60±0.13	6.85±0.14	7.50 ±0.11

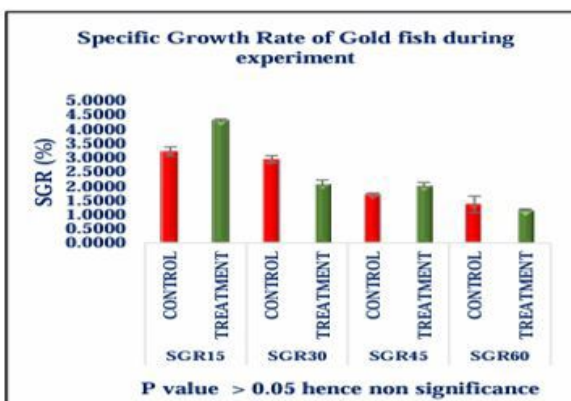
Note: Values given are mean ± standard deviation.



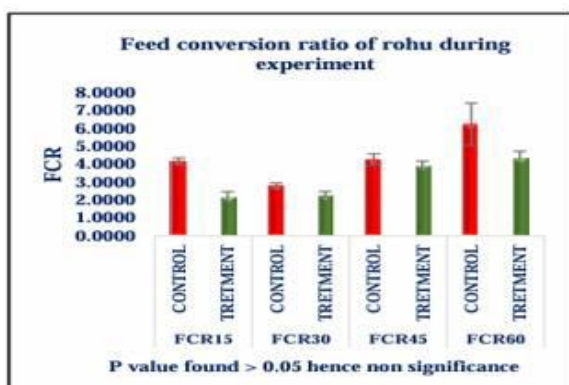
G. SGR of Rohu



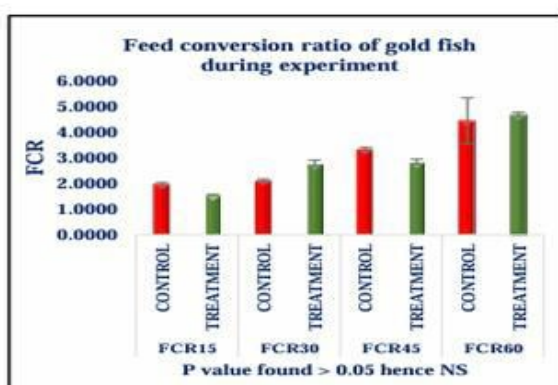
H. SGR of Gold fish



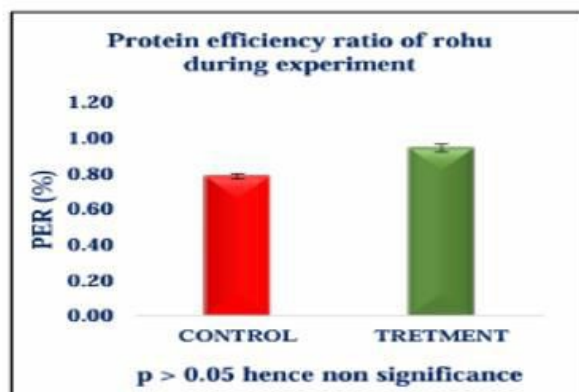
I. FCR of Rohu



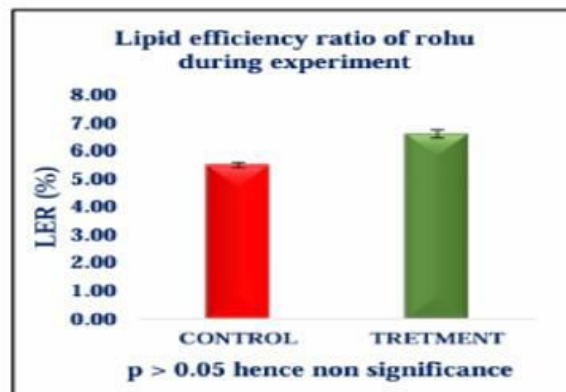
J. FCR of Gold fish



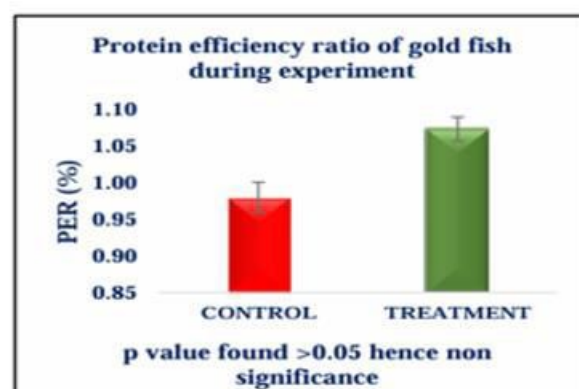
K. PER of Rohu



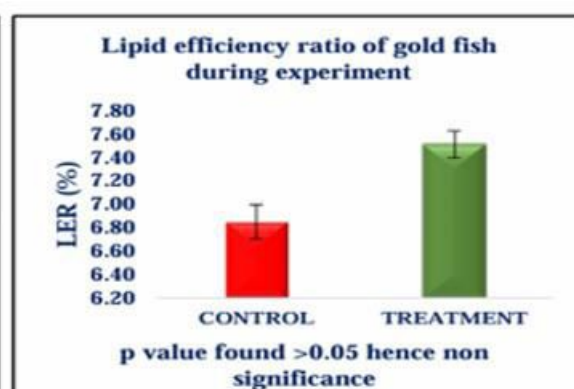
L. LER of Rohu



M. PER of Gold fish



N. LER of Gold fish



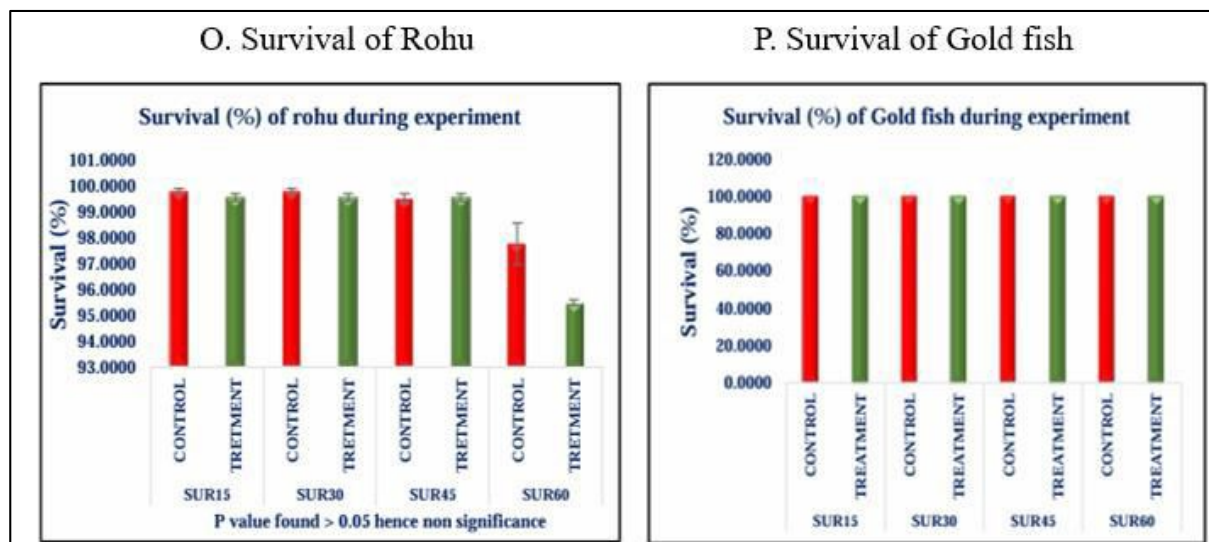


Fig 1: A-P (A) initial weight of rohu (g), (B) Final weight of rohu (g), (C) initial weight of gold fish (g), (D) Final weight of gold fish (g), (E) Body weight gain (%) of Rohu, (F) Body weight gain (%) of gold fish, (G) Specific growth rate (SGR) of rohu, (H) Specific growth rate (SGR) of gold fish, (I) Feed conversion ratio (FCR) of rohu, (J) Feed conversion ratio (FCR) of gold fish, (K) Protein efficiency ratio (PER) of rohu (L) Lipid efficiency ratio (LER) of rohu, (M) Protein efficiency ratio (PER) of gold fish, (N) Lipid efficiency ratio (LER) of gold fish, (O) Survival rate (%) of rohu and (P) Survival rate (%) of gold fish recorded in different treatments during the culture period.

4. Conclusion

The present 60 days study conducted in a recirculating aquaponics system clearly shows that aquaponics can efficiently improve fish growth performance while improving overall water quality. The combination of decorative ornamental fish *Carassius auratus* (Gold fish) and feeding fish *Labeo rohita* (Rohu) produced better growth outcomes in treatment system compared to the control. Additionally, Goldfish integration significantly enhanced water clarity, indicating efficient nutrient recycling within the system, whereas rohu grew consistently and promisingly under aquaponic conditions. During the experiment, the initial mean weights of rohu and goldfish (1.34 g and 1.38 g, respectively) increased significantly to the final weights of 6.12 g and 8.85 g. These findings show recirculatory aquaponics promise as an environmentally friendly and resource-efficient method of diversifying fish production while improving growth performance and water quality control.

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