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Article

Comparative Effect of Fish Feeds on the Initial Growth and Survival Rate of Juvenile Redbreast Tilapia (*Coptodon rendalli*) under Early Hatchery Conditions

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Abstract: This study compared the effects of three supplementary diets—egg yolk, Artemia, and commercial pellets with 48% crude protein—on the growth performance and survival rate of redbreast tilapia (*Coptodon rendalli*) under intensive culture conditions at the Kamutjonga Inland Fisheries Institute in the Kavango East region of Namibia. The study was conducted from December 2023 to January 2024 using a complete randomized design replicated thrice. Results showed that fish fed with commercial pellets exhibited the highest specific growth rate (1.39 ± 0.80%) compared to egg yolk (0.94 ± 0.54%) and Artemia (0.33 ± 0.19%). Commercial pellets also had the best survival rate (76.19 ± 43.099), compared to egg yolk and Artemia (70.47 ± 40.69; 33 ± 19.05), respectively. However, egg yolk had the best feed conversion ratio (0.20 ± 0.05) compared to the commercial pellets (0.22 ± 0.04) and Artemia (0.26 ± 0.07). Critical water quality parameters were maintained within acceptable survival ranges for *C. rendalli* across all treatments. These findings highlight the importance of dietary protein content in optimizing the growth and survival of *C. rendalli* under intensive culture conditions and provide insights for effective feeding strategies. However, commercial pellets are expensive and inaccessible to small-scale fish farmers. As an alternative, egg yolk emerged as a viable and affordable feed option, promoting fish growth and supporting the establishment of small-scale farming practices in the region.

Keywords: aquaculture; KIFI; brine shrimps Artemia; egg yolk; commercial pellets; integrated aquaculture

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1. Introduction

The aquaculture industry in Africa is experiencing significant growth, driven by the rising demand for fish as a protein source and the need for sustainable food production systems. However, one of the most pressing challenges faced by fish farmers across the continent is the high cost and limited availability of quality fish feeds [1]. Traditional fish feeds, primarily composed of fishmeal and oil, are becoming increasingly expensive and unsustainable due to overfishing and environmental concerns. Consequently, there is a growing interest in the utilization of alternative fish feeds that can provide a cost-effective and sustainable solution for aquaculture [2,3].

Research into alternative fish feeds has identified several promising sources including plant-based ingredients, agricultural by-products, and insect meals. Studies have shown that these alternatives can partially or wholly replace traditional fishmeal without compromising the growth performance and health of various fish species. For instance, a study by [4,5] highlighted the potential of plant proteins, such as soybean meal and corn gluten meal, as viable alternatives to fishmeal in aqua feeds. Similarly, research by [6] demonstrated that insect meal, particularly from black soldier fly larvae, could serve as a sustainable protein source for aquaculture.

Adopting alternative fish feeds is particularly critical due to the region's economic and environmental conditions in Africa [7]. Sub-Saharan Africa, in particular, faces challenges such as limited access to high-quality fishmeal, high feed costs, and the fluctuating availability of raw materials. As a result, fish farmers are increasingly turning to locally available resources to formulate and produce cost-effective feeds. For example, a study by [8] in Kenya evaluated agricultural by-products such as rice bran and cottonseed caked in tilapia diets, which effectively promote fish growth and reduced the feed costs.

Among the various aquatic species cultivated worldwide, tilapia has emerged as one of the most prominent culture target species due to its hardy nature, rapid growth, and widespread consumer acceptance. Among the various species cultivated [9], the redbreast tilapia (*C. rendalli*) holds significant potential due to its adaptability to different environmental conditions and its preference for local diets, particularly in Sub-Saharan Africa [10,11]. The cultivation of *C. rendalli* has gained attention in recent years as it offers a promising avenue for enhancing food security and livelihood opportunities in many developing regions [12]. This fish species is known for its resilience, tolerance to a wide range of water quality parameters, and ability to thrive in both fresh and brackish environments [9]. The growth and survival rate of aquaculture species such as *C. rendalli* can be significantly influenced by various factors, among which the type of feed plays a pivotal role [6,13].

Feed type affects the physiological and health status of the cultured fish and impacts the economic viability of aquaculture operations, given that feed costs represent a substantial portion of total production expenses [14]. Previous studies in Sub-Saharan Africa have investigated the effects of different feed types on tilapia species, revealing varied outcomes in terms of growth performance, feed conversion ratios, and overall health indicators [15]. However, research focusing specifically on *C. rendalli*, particularly within the Namibian context, remains limited [16]. Thus, this study aimed to explore the effect of various feed types on the growth and survival rate of *C. rendalli* under intensive culture. By examining the efficacy of locally available feed ingredients against commercial feeds, this research sought to identify cost-effective and sustainable fish feed that can enhance the productivity of *C. rendalli* and boost aquaculture in Namibia.

2. Materials and Methods

2.1. Study Site

The experiment was conducted at the Kamutjonga Inland Fisheries Institute (KIFI) in the Mukwe Constituency in the Kavango East region. As per the National Development Plan 2 (NDP 2), a decision was made to construct a freshwater research institute that would serve Namibia and the Southern African Development Community (SADC) as a whole. The institute serves as a research, training, and capacity-building institution for scholars, students, and aspiring freshwater aquaculture farmers.

The institute's reliable water supply, easy access to cultural facilities, and tilapia breeding habitat made it appropriate for the research. Poverty and limited access to resources are significant challenges for the inhabitants of Kavango East. These challenges are severe in rural areas, where most of the population resides [17]. Despite these challenges, the region is distinguished by its breathtaking scenery, which includes vast savannahs, wetlands, and the meandering Okavango River. The Okavango River and its associated ecosystem are critical to the livelihoods of the region's inhabitants. The river supports various flora and fauna including numerous fish species. Fish are crucial to the local economy and food security and provide income and nutrition to the riparian communities along the riverbank [18].

2.2. Experimental Design and Layout

A completely randomized block design (CRB) was employed for this study to evaluate the effects of three types of fish feed on the growth performance of *C. rendalli*. The experiment utilized three sets of treatment tanks, each corresponding to one fish feed under study: egg yolk, Artemia, and commercial pellets. Each feed type was replicated three times, resulting in nine replicated tanks of 200 cm × 50 cm × 50 cm. Specifically, three tanks were designated for feed type A (egg yolk), three for feed type B (Artemia), and three for feed type C (commercial pellets). This experimental setup ensured that each feed type was tested under identical conditions, thereby minimizing the impact of external variables and facilitating a robust comparison of the growth performance across the different feeds—treatment replication allowed for a more precise estimation of the treatment effects and better control of experimental errors.

2.3. Stocking of Fish

A batch of 315 individual *C. rendalli*, weighing 0.026 g and measuring 14.8 mm in total length on average, were sourced from an onsite hatchery and transferred into holding tanks for acclimation. After a week of acclimation, individual *C. rendalli* were randomly selected and stocked in experimental tanks A–C. Each experimental tank was stocked with 35 individual *C. rendalli* from the same cohort. A static recirculating system was used where 50% of the water was changed and renewed weekly with river water. All tanks were aerated and siphoned daily to remove fecal waste. Critical water parameters such as temperature, dissolved oxygen, pH, and ammonia were monitored throughout the experiment.

2.4. Feeding Trial Experiment

The experiment was conducted for 28 days, from November to December 2023. Experimental fish were fed three (3) times a day at 9 a.m., 2 p.m., and 5 p.m., respectively. The ingredients of each feed type are summarized in Table 1. These values serve as fundamental knowledge for evaluating the dietary impact on the growth and development of *C. rendalli* during the experiment.

Table 1. Proximate ingredient composition of egg yolk, Artemia, and commercial pellet diets under the feeding trial experiment for *C. rendalli*.

Parameters	Egg Yolk	Artemia	Commercial Pellets
Energy (KJ)	616	23.5	16
Protein (%)	16	23	48
Carbohydrates (%)	1	0.4	6
Total Fat (%)	8	0.3	6
Sodium (%)	3	21	11

Description of the Feeds Used in the Study

Artemia, often known as brine shrimps, are small crustaceans that are highly valued in the fields of aquaculture and research. These creatures flourish in habitats with extreme salinity such as salt ponds and lakes, where only a few other species can survive [19]. The feed contains abundant protein [4] content and essential fatty acids including DHA and EPA. These nutrients play a vital role in the growth and development of larval and juvenile fish and crustaceans [19]. In addition, they possess a variety of vitamins and minerals that enhance their nutritious composition. The lifespan of Artemia involves a period of dormancy called the cyst stage, during which its eggs can remain viable for an extended period. These eggs hatch into free-swimming nauplii when they are exposed to suitable conditions. This feature makes Artemia a handy and sustainable choice for feed in aquaculture [19]. We used Artemia as a feed option for juvenile redbreast tilapia fish. The feed was subsequently pulverized to ensure that the particles were sufficiently small for the juvenile fish to ingest efficiently. The Artemia were not subjected to enrichment or pellet formulation; they were merely crushed into powder-like fragments to aid in the fries' feeding.

Chicken egg yolk: The chicken eggs were obtained from nearby poultry farmers. The process entailed boiling the eggs and cooling them in cold water to make them easier to handle. The shells were extracted, and the yolks were carefully isolated from the egg whites (albumen). In order to make the yolk suitable for consumption by the juvenile fish, it was filtered through a small plastic mesh, resulting in small pellets that the fish could easily eat. This sieving process also helped maintain the yolk's consistency, preventing it from dissolving quickly in water. Drying the yolk pellets further reduced their chances of breaking down too quickly, thus minimizing water turbidity and ensuring the optimal tank conditions.

Commercial powder with 48% crude protein was obtained and imported from commercial dealers in Zambia. The feed is formulated as a fine powder that can easily remain suspended in water and subsequently dissolve over time.

In the hatchery, *C. rendalli* were fed with 10 g of each feed type per day at an interval of 3.3 g/feeding time of the day, which was based on 10% of their bodyweight.

2.5. Determination of Fish Growth Performance

The experiment was carried out over four consecutive weeks in four successive sampling periods from day 0, day 7, day 14, day 21, and day 28. On each sampling day, five (5) individual fish were randomly sampled from each tank, and the body length was measured in millimeters, and average wet weights were measured in grams. The weight (g) of each fish was measured using an analytical balance scale, while the total length (cm) was measured using a meter ruler. Mortality was visually assessed and recorded daily to monitor the survival rate of *C. rendalli* throughout the experimentation phase.

The growth performance parameters of *C. rendalli* were calculated as follows:

$$\text{Relative weight gain } (\%) = \frac{Final\ weight(g)}{initial\ weight(g)} \times 100$$

$$SGR\ (\%) = \frac{(\ln(Final\ weight) - \ln(Initial\ Weight))}{Time} \times 100$$

The food conversion ratio was calculated as follows $(\text{FCR}) = \frac{feed\ given\ to\ fish}{weight\ gain}$

The survival rate was calculated as follows:

$$\text{Survival rate } (\%) = number\ of\ fish\ harvested - number\ of\ fish\ stocked \times 100$$

2.6. Data Analysis and Presentation

Morphometric data on the weight and length were subjected to a normality test using the Shapiro–Wilk and constant variance tests using Levene's. With the confirmation of normal distribution and no violation of the homoskedasticity assumption, a parametric Fisher's one-way analysis of variance (ANOVA) was employed to assess the statistical differences in the growth rates of *C. rendalli* fed with three different feed types. A post hoc using the Tukey test was subsequently applied to identify the sources of variation and determine which feed types were significantly different from each other. Data computation and analysis were performed using R, following a completely randomized design with the specified statistical model:

$$Y_{ij} = \mu + \tau_i + \varepsilon ij$$

where Y_{ij} = *j*th replicate observation for the *i*th feed, μ = overall mean, τ_i = effect of *i*th feed effect, and εij = error associated with the *j*th replicate for the *i*th feed.

3. Results

3.1. Growth Performance of *C. rendalli* by Feed Type

The comparative analysis presented in Table 2 evaluated the growth performance, feed efficiency, and survival rates of *C. rendalli* fed with three different diets: egg yolk, Artemia, and commercial pellets. The analysis showed no significant differences in the initial weights across the three groups (p = 0.991), indicating that the fish started with similar baseline weights, allowing for a fair comparison of the subsequent growth and performance metrics.

Table 2. Comparative analysis of growth, feed efficiency and survival parameters for *C. rendalli* Fed with egg yolk, Artemia, and commercial pellets.

Parameters	Egg Yolk	Artemia	Commercial Pellets	p-Values
Initial weight (g)	0.037 ± 0.003 a	0.037 ± 0.003 a	0.037 ± 0.003 a	0.991
Specific growth rate (%)	0.941 ± 0.129 b	0.327 ± 0.049 a	1.394 ± 0.215 c	<0.001
Final weight (g)	0.301 ± 0.037 b	0.128 ± 0.014 a	0.427 ± 0.059 c	<0.001
Total weight gain (g)	0.264 ± 0.036 b	0.092 ± 0.014 a	0.390 ± 0.060 c	<0.001
Relative weight gain (g)	0.072 ± 0.005 b	0.045 ± 0.005 a	0.086 ± 0.006 b	<0.001
Food conversion ratio (FCR)	0.20 ± 0.05 a	0.26 ± 0.07 a	0.22 ± 0.04 a	0.567
Survival (%)	70.47 ± 40.69 a	33 ± 19.05 b	76.19 ± 43.099 a	0.02

The p-values reported in this table were based on Fisher's parametric analysis of variance (ANOVA). The letters following the mean ± standard error of the mean (SEM) indicate the results of post hoc comparisons performed using Fisher's protected least significant difference (LSD) method. Different letters within the same row denote statistically significant differences between treatments at the 0.05 level.

However, significant differences were observed in the specific growth rate (SGR), final weight, total weight gain, and relative weight gain among the different diets (p < 0.001 for all). Fish fed with commercial pellets exhibited the highest SGR (1.394 ± 0.215%), final weight (0.427 ± 0.059 g), and total weight gain (0.390 ± 0.060 g), significantly outperforming both the egg yolk and Artemia groups. The egg yolk diet resulted in intermediate growth performance, while the Artemia-fed group showed the lowest values for these growth parameters.

Interestingly, while the food conversion ratio (FCR), a measure of feed efficiency, did not differ significantly among the groups (p = 0.567), suggesting similar feed efficiency across the diets, the survival rates varied significantly. The Artemia group had a significantly lower survival rate (33% ± 19.05) compared to the other groups, particularly when contrasted with the commercial pellet group, which had the highest survival rate (76.1 ± 43.99%).

3.2. Growth Performance of *C. rendalli* by Sampling Week and Feed Type

The ANOVA results revealed significant differences in the average length and weight of *C. rendalli* across the different dietary treatments throughout the study (Table 3). In each week, the p-values were below 0.05, indicating that the type of feed had a statistically significant effect on the growth outcomes of the fish. In week 1, the average length (0.024) and weight (0.011) of *C. rendalli* showed significant differences among the dietary treatments. In week 2, the p-values for the average length and weight were 0.023 and 0.024, respectively, indicating that the dietary effects on these growth parameters continued during the second week of the experiment. Week 3 exhibited the most significant differences, with p-values of 0.005 for both length and weight, highlighting a strong influence of diet on the growth outcomes. In week 4, at the end of the study period, the p-values were 0.014 for length and 0.033 for weight, suggesting that dietary differences continued to significantly affect the growth parameters of the fish until the end of the experiment.

Table 3. Comparative effects of the different feed types on average length (mm) and average weight (g) of *C. rendalli* over the 4-week experimental period.

Source of Variation	DF	Week 1		Week 2		Week 3		Week 4	
		Average Length (mm)	Average Weight (g)	Average Length (mm)	Average Weight (g)	Average Length (mm)	Average Weight (g)	Average Length (mm)	Average Weight (g)
Feeds	2	18.72 **	0.004 **	40.880 **	0.021 **	47.567 ***	0.043 ***	0.136 **	120.596 **
Error	6	7.65	0.001	16.080	0.008	28.613	0.015	0.064	38.267
Total	8	26.38	0.005	56.960	0.0290	76.16	0.058	0.200	158.862
p-value		0.024	0.011	0.023	0.24	0.005	0.005	0.014	0.033

*** $p < 0.01$, and ** $p < 0.05$ based on the parametric Fisher's one-way analysis of variance.

The data presented in Table 4 and Figure 1 illustrate the growth rates of *C. rendalli* fed with three different feed types—Artemia, commercial pellets, and egg yolk—over four consecutive weeks. The growth rates, measured in grams, are reported for each feed type by week, with statistical significance indicated by different letters within each column.

Table 4. Comparative growth rates of *C. rendalli* by sampling week under the influence of different feed types.

Fish Feeds	Week 1	Week 2	Week 3	Week 4
Artemia	0.04 b	0.06 b	0.09 b	0.13 b
Powder 48% CP	0.08 a	0.17 a	0.24 a	0.43 a
Egg yolk	0.08 a	0.12 ab	0.14 b	0.30 ab

Means with the same letters in a column were not significantly different. The pairwise comparison was based on Fisher's protected least significance difference (LSD) method and was conducted for weight (g) only, as it is the key parameter for measuring growth.

In week 1, the growth rate of *C. rendalli* was significantly higher for fish fed with commercial pellets and egg yolk than those fed with Artemia, as shown by the different letters (a and b). Commercial pellets and egg yolk resulted in a similar growth rate of 0.08 g, while the growth rate for Artemia-fed fish was lower at 0.04 g. By Week 2, fish fed with commercial pellets exhibited a significant increase in growth rate to 0.17 g, which was higher than the growth rates for those fed with Artemia and egg yolk. The growth rate for fish fed with Artemia increased slightly to 0.06 g but remained significantly lower than that of commercial pellet-fed fish. The growth rate for egg yolk-fed fish was 0.12 g, which was not significantly different from Artemia but lower than that of commercial pellets. In week 3, the growth rate of *C. rendalli* continued to be highest for fish fed with commercial pellets at 0.24 g, significantly outpacing those fed with Artemia (0.09 g) and egg yolk (0.14 g). Fish fed with Artemia and egg yolk showed statistically similar growth rates, as the shared letter 'b' indicate. By week 4, the growth rate of fish fed with commercial pellets peaked at 0.43 g, significantly higher than those fed with Artemia (0.13 g) and egg yolk (0.30 g). The growth rate for fish fed with egg yolk was intermediate, showing no significant difference from Artemia or commercial pellets based on the shared letters 'ab'.

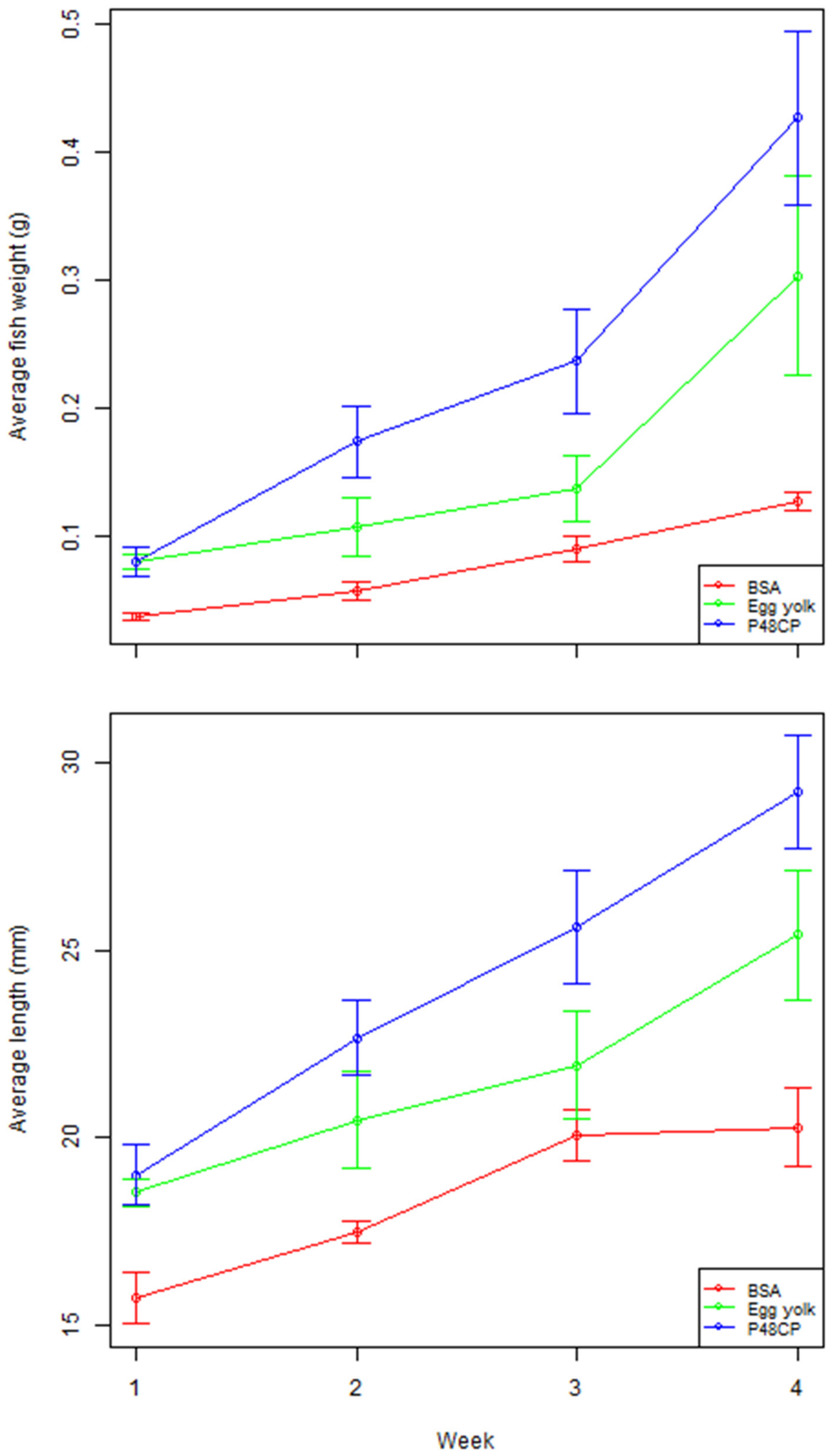

Figure 1. Weekly changes in average weight (g) and length (mm) of *C. rendalli* under the feed trial experiment. BSA refers to Artemia, P48CP—powder 48% protein commercial pellets.

3.3. Water Quality Parameters

The mean temperature ranged between 28.01 °C and 28.14 °C, with no substantial differences observed among the three supplementary diet treatments ($p > 0.05$) (Table 5). This condition implies that the experimental setup maintained a relatively stable temperature, which is important for the fish's physiological processes and overall well-being. Dissolved oxygen (DO) ranged from 8.08 mg/L to 8.59 mg/L, however, no statistical differences were detected ($p > 0.05$). Adequate DO concentrations are crucial for the survival and growth of fish, as they require oxygen for respiration. The recorded DO levels suggest that the tanks were adequately aerated, ensuring a favorable oxygen supply to support the metabolic needs of *C. rendalli*. The pH values ranged from 7.36 to 7.45 across the different diet treatments. However, these variations were not significant ($p > 0.05$). Water pH plays a vital role in maintaining proper physiological functions and the overall health of aquatic organisms. The recorded pH values indicate that the tanks provided a relatively neutral environment, generally considered suitable for *C. rendalli*. Ammonia levels were relatively low but maintained the same range ($p > 0.05$) among the three supplementary diet treatments (Table 5). High ammonia concentrations can harm fish health, as ammonia is toxic and can negatively impact their metabolism and overall well-being.

Table 5. Water quality parameters by feed type monitored during the feed trial experiment for *C. rendalli*.

Parameter	Egg Yolk	Brine Shrimp	Powder 48% Crude Protein
Temperature (°C)	28.14 ± 0.03	28.01 ± 0.01	28.11 ± 0.02
DO (mg/L)	8.59 ± 0.05	8.29 ± 0.02	8.08 ± 0.03
pH	7.45 ± 0.01	7.36 ± 0.01	7.38 ± 0.00
Ammonia (NH_3,/mg/L)	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01

4. Discussion

4.1. Water Parameters

Water quality is a fundamental aspect of successful aquaculture, significantly affecting fish growth, survival, and overall health. This study showed no variation in critical water parameters (i.e., temperature, oxygen, pH, and ammonia) among the three feed treatments. The consistency in water parameters ensured that any observed differences in growth rates were primarily attributable to the nutritional quality of the feeds rather than environmental factors. Thus, the plausible influence of water quality on fish growth performance was ruled out with confidence. For reporting purposes, the average temperature ranged from 28.01 °C to 28.14 °C, which was within the optimal temperature range between 27 °C and 30 °C, as reported by [20]. These stable temperature values ensured that the metabolic and physiological functions of the fish were not adversely affected by temperature, providing a conducive environment for growth in the broader context of aquaculture. This is mainly because any sudden changes in water temperature may result in thermal shock and subsequent mortalities.

The dissolved oxygen (DO) levels were within the recommended range for maintaining fish health and promoting efficient feed conversion, as reported by Hoseinifar et al. (2019) [21]. Low oxygen levels can lead to hypoxia, causing stress, reduced feed intake, and impaired growth. Maintaining high DO levels involves aeration systems essential in intensive aquaculture settings. Using an aerator ensures that oxygen levels remain sufficient to meet the demands of a high-density fish population, thereby supporting growth and reducing the risk of hypoxic conditions.

The pH levels ranged between 7.36 and 7.45 and were within the ideal 6.7 to 9.5 recommended for tilapia growth, facilitating optimal enzymatic activity and metabolic processes [20]. Water pH is a critical parameter as it influences various biochemical processes in fish including enzyme activity and ion regulation. The consistency in pH across treatments indicates a stable aquatic environment conducive to fish health. Maintaining a stable pH is essential in aquaculture. This initiative prevents stress and physiological disruptions. Extreme pH levels can cause gill damage and affect the fish's ability to regulate body functions.

The ammonia levels remained low due to the daily siphoning of the tanks, preventing the accumulation of waste and leftover feed. Ammonia levels ranged from 0.2 to 2 mg/L and were within the recommendable thresholds for supporting aquatic life [20]. The values were comparable to those observed by [20] in *C. rendalli* fed with maize bran and Amaranthus hybridus leaves, demonstrating the effectiveness of daily tank maintenance in controlling ammonia levels [20]. Reports have also shown that low ammonia levels are beneficial as they are quickly utilized by phytoplankton and aquatic macrophytes, minimizing the risk of ammonia toxicity.

4.2. Growth Performance of C. rendalli

The study revealed significant differences ($p < 0.05$) in the growth rates of *C. rendalli* fed with three different supplementary diets. Experimental fish fed with the commercial pellet and chicken egg yolk diet exhibited the highest growth rates of *C. rendalli* compared to the Artemia-fed group. These variations may be attributed to feed quality, as reported by [20]. The superior nutrient composition of a commercial diet, with a high % protein content of 48%, and the rich nutrient profile of chicken egg yolk may be responsible for the enhanced growth rates of *C. rendalli* in this study. The balanced nutrient profile of a commercial feed diet ensures that the fish receives an adequate supply of vitamins and minerals, promoting optimal health and efficient nutrient absorption. For instance, [20] emphasized the role of balanced diets in enhancing growth performance, while [20] highlighted the potential of alternative protein sources like insect meal in supporting healthy fish development. Protein is a fundamental component of fish diets, providing the essential amino acids necessary for muscle development and overall fish growth. Higher protein diets result in the better growth performance in tilapia as they promote faster growth rates and better feed conversion. Thus, it can be deduced that the high nutrient density and better digestibility of the commercial pellets and egg yolk diet facilitated more efficient nutrient uptake and conversion into biomass, leading to higher weight gains and final total weights. In addition, the higher digestibility and nutrient density of the commercial diet feed likely contributed to the observed enhanced growth rates, as the fish could more effectively convert the feed into body mass.

4.3. Feed Conversion Ratios (FCRs)

The results presented in Table 4 demonstrate the influence of different types of feed on the growth efficiency and survival of *C. rendalli*. The use of commercial pellets resulted in a lower feed conversion ratio (FCR) and higher survival rate, which can be attributed to the well-balanced nutritional composition of this feed. However, the high costs associated with commercial pellets necessitate the exploration of alternative options. Although less conventional, egg yolk showed promising results with a competitive FCR and relatively high survival rate. This suggests that it has the potential to be a cost-effective alternative feed, especially during the early stages of fish development. On the other hand, the Artemia diet, commonly used in larval stages, exhibited a higher FCR and significantly lower survival rates. This indicates that it may not be suitable as the sole feed source beyond the larval stage. The superior FCR observed for the egg yolk can be attributed to its moderate protein content and balanced nutrient profile, which optimizes nutrient utilization and minimizes waste. For instance, refs. [1,6] underscored the importance of high-quality feeds in achieving optimal FCR, highlighting the direct relationship between feed composition and feed. Efficient FCR is crucial for aquaculture's economic viability as it reduces the feed costs and improves profitability.

4.4. Survival Rates

Survival rate is a critical metric in aquaculture, reflecting the overall health and viability of the fish population under different feeding regimes. The highest survival rates were observed in fish fed with a commercial diet and chicken egg yolk, which were higher than those fed with Artemia. The high survival rates associated with experimental fish fed with a commercial diet and egg yolk can be attributed to the excellent acceptability and high nutritional value of these feeds, which supported better overall health and reduced mortality. The observed survival rates in this study were higher than those reported by [22], further emphasizing the importance of feed quality and acceptability in the survival of *C. rendalli*. This finding aligns with the study conducted by [22], who reported that high-quality, well-accepted feeds resulted in better survival rates in juvenile fish. It is more likely that good water quality is crucial for reducing stress and preventing diseases, thus supporting higher survival rates. High survival rates are essential for the economic sustainability of aquaculture operations. Reduced mortality means that more fish reach market size, improving the overall yield and profitability of the farm. Thus, proper nutrition plays a crucial role in maintaining fish health and reducing the incidence of diseases and mortality. Conversely, the lower survival rate in fish fed with the Artemia diet may be attributed to poor feed acceptability and increased cannibalism. The rapid decrease in fish population fed with Artemia suggests that this feed is not well-accepted by juvenile *C. rendalli*, leading to high mortalities.

4.5. Implications for Aquaculture

The general outcomes of this study revealed that a commercial diet with 48% crude protein promoted the best growth performance in *C. rendalli*. This feed consistently outperformed chicken egg yolk and Artemia regarding the specific growth rate (SGR) and weight gain. The supremacy of this commercial diet was attributed to its high protein content, which is crucial for the growth and development of the fish. Thus, the findings of this study have significant implications for aquaculture practices, mainly in the context of feed selection and cost management. Regarding feed selection, while the commercial diet offers the best growth performance and feed efficiency, its high cost may be prohibitive for small-scale farmers. On the other hand, chicken egg yolk provides a cost-effective and readily available alternative that still supports good growth because of its high FCR and high survival rates. This feed demonstrated considerable efficacy in promoting healthy fish growth and maintaining high survival rates, making it a viable alternative for farmers who need to minimize production costs. Egg yolk can significantly reduce the reliance on expensive commercial feeds, allowing small-scale farmers to sustain their operations more economically. Using chicken egg yolk as a feed in integrated aquaculture systems presents a sustainable and economical approach to fish farming. Integrated aquaculture involves combining fish farming with other agricultural practices, such as poultry farming, to create a system where the by-products of one enterprise serve as inputs for another. In this scenario, farmers can raise fish and poultry on the same farm, using the egg yolks from the chicken eggs to feed the fish. This integration reduces the feed costs and enhances resource efficiency and sustainability. Integrated aquaculture systems can provide multiple benefits. First, they ensure a continuous supply of fresh egg yolk throughout the year, offering a steady and reliable source of nutrition for the fish. This consistency is crucial for maintaining stable growth rates and high survival rates in the fish population. Second, by utilizing egg yolks that might otherwise be discarded, integrated systems minimize waste and promote environmental sustainability. Integrated aquaculture systems can improve farm productivity and profitability. Farmers can generate multiple income streams by diversifying their production, reducing financial risk and increasing economic resilience. This approach also reduces the dependence on external feed suppliers; it can also integrate aquaculture to create a balanced and efficient farming system that promotes the strengths of both poultry and fish farming.

5. Conclusions

This study emphasizes the crucial significance of water quality and feed composition in aquaculture, specifically for the growth and well-being of *C. rendalli*. By maintaining consistent water parameters in all treatments, we could firmly ascribe the observed differences in growth to the nutritional content of the diets. Fish that were provided with a commercial diet displayed the highest growth rates. Egg yolk had the most efficient feed conversion ratios (FCRs), emphasizing the advantages of a well-balanced nutrient profile with a high protein content. The fish fed with chicken egg yolk also demonstrated substantial growth and excellent survival rates, providing a cost-efficient substitute for commercially available diets. These discoveries have significant consequences for aquaculture practices. Although commercial diets offer optimal growth performance, their exorbitant price can be a barrier for small-scale producers. Using chicken egg yolk as a cost-effective and easily obtainable substitute promotes favorable development and increased survival rates, hence offering a feasible solution to minimize production expenses. By incorporating chicken egg yolk into aquaculture systems, fish farming can become more sustainable and cost-effective. This can be achieved by reducing the need for costly commercial feeds and improving the resource utilization efficiency. Therefore, it is crucial to prioritize the optimization of feed selection and the maintenance of steady water quality to ensure the successful growth and health of *C. rendalli* in aquaculture.

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