Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 30(3): 3815 – 3828 (2026)
www.ejabf.journals.ekb.eg

Effects of Water Exchange Frequency on Growth Performance, Survival, and Feed Utilization of Common Carp (*Cyprinus carpio* L.) Fingerlings

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ARTICLE INFO

Article History:
Received: March 10, 2026
Accepted: May 29, 2026
Online: June 28, 2026

Keywords:
Sustainable aquaculture,
Water exchange management,
Static culture system

Abstract

This study evaluates the effects of different water exchange frequencies on water quality, growth performance, survival, and feed utilization of common carp fingerlings (*Cyprinus carpio* L.) reared under static culture conditions. A total of 150 fingerlings (initial weight: 14.56 ± 1.44 g) were randomly distributed into 15 plastic tanks (54 L each) at a stocking density of 10 fish per tank (approximately 2.7 kg m^{-3}). The experiment was conducted for 56 days using five water exchange treatments with three replicate tanks per treatment: T1 (daily exchange), T2 (every 2 days), T3 (every 3 days), T4 (every 4 days), and T5 (every 5 days). Approximately 50–60% of tank water was renewed during each change. Water quality parameters, including temperature, dissolved oxygen, pH, and salinity, were monitored throughout the experiment. Growth performance and nutrient-utilization indices were significantly affected by water exchange frequency ($p < 0.05$). Fish reared under T2 and T3 showed the highest final weights (28.33 ± 1.21 and 28.60 ± 1.19 g, respectively) and weight gains (13.94 ± 0.97 and 14.02 ± 1.06 g, respectively), compared with T5, which recorded the lowest weight gain (5.87 ± 1.91 g). Weight gain in T2 and T3 increased by approximately 36–37% compared with the daily exchange treatment (T1) and by more than 130% compared with T5. Feed conversion ratio was also improved in T2 (2.901 ± 0.162) and T3 (2.921 ± 0.195) relative to T5 (7.568 ± 2.522). Survival rates were significantly higher in T1, T2, and T3 (86.66–93.33%) than in T5 (70%). These findings indicate that moderate water-change intervals (every 2–3 days) improve growth performance, feed utilization, and survival of common carp fingerlings under static culture conditions while reducing unnecessary water use.

INTRODUCTION

Cyprinus carpio, commonly known as the common carp, is extensively cultivated and ranks among the most abundant freshwater fish species worldwide **(Rahman, 2015)**. Despite advances in aquaculture practices and improved biological understanding, carp pond production systems remain largely comparable to traditional production models **(Araujo *et al.*, 2022; Hossain *et al.*, 2023; Manan *et al.*, 2023)**. The water exchange process is a critical management factor that strongly influences water quality and,

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consequently, fish growth and production efficiency **(Hopkins *et al.*, 1993; Sidoruk & Cymes, 2018; Aldoghachi, 2022)**. Common carp culture remains one of the major freshwater aquaculture activities in Iraq and neighboring countries. Recent studies on common carp larvae demonstrated that environmental management and natural food availability strongly influence survival and growth performance in pond systems **(Hammadi *et al.*, 2024)**.

The common carp is among the most widely farmed species in Iraqi pond systems **(Al-Hamed, 1967; Salman, 2011; Abbas *et al.*, 2016; Taher & Al-Dubakel, 2020; Fahad & Shuhaib, 2021; Al-Dubakel *et al.*, 2022)**. It is well adapted to local environmental conditions, easy to manage, and capable of utilizing naturally available food resources, which makes it highly productive in polyculture and monoculture systems **(Salman, 2011; Ahmed *et al.*, 2020; Salman *et al.*, 2022)**. Owing to these characteristics, carp farming plays a major role in global and regional aquaculture production **(Woynarovich *et al.*, 2011; Dey *et al.*, 2013)**.

Fish growth and productivity in pond systems are influenced by multiple interacting factors, including water temperature, dissolved oxygen, salinity, pH, light intensity, stocking density, feed availability, and overall water quality **(Huang *et al.*, 2023)**. Water parameters such as temperature, pH, transparency, and oxygen concentration are particularly important, as they can be actively managed to promote healthy fish growth **(Ssekyanzi *et al.*, 2022; Aldoghachi *et al.*, 2025)**. However, maintaining optimal water quality remains a major challenge, especially in intensive and semi-intensive pond systems **(Araujo *et al.*, 2022)**.

Because fish complete all physiological and metabolic processes within the aquatic environment, the physical and chemical properties of culture water are fundamental determinants of aquaculture success **(Verma *et al.*, 2022)**. **Ajana *et al.* (2006)** emphasized that water quality is a decisive factor affecting the outcome of aquaculture activities. In high-density systems with supplemental feeding, water quality deterioration commonly occurs due to organic loading, oxygen depletion, elevated carbon dioxide levels, and the accumulation of toxic nitrogenous compounds **(Lindholm-Lehto, 2023)**. Poor water quality management increases the susceptibility of fish to diseases, parasites, and physiological stress **(Diana *et al.*, 2017)**.

Although natural self-purification processes can partially stabilize pond water quality, continuous management interventions are required to maintain conditions suitable for optimal fish growth and health **(Pratiwi *et al.*, 2023)**. Aeration and water exchange are widely applied techniques to control oxygen levels and reduce the accumulation of harmful metabolites, including ammonia and nitrite **(Okomoda *et al.*, 2016; Dauda *et al.*, 2023)**. Recent advances in aquaculture technology, such as recirculating aquaculture systems (RAS), biofloc systems, and flow-through raceway systems, have been developed to enhance water quality control **(Fermon, 2011; Zhang *et al.*, 2011; Soderberg, 2017; Jatobá *et al.*, 2019; Ahmed & Turchini, 2021)**. However, the application of these systems is often constrained by high operational costs, energy requirements, water availability, and technical expertise, particularly in developing regions **(Henriksson *et al.*, 2021)**.

Consequently, many aquaculture farms continue to rely on traditional pond systems with periodic water exchange to maintain acceptable water quality. Farmers commonly replace 50–75% of pond water weekly, while others apply lower change rates, often without clear scientific guidance on optimal change frequency **(Okomoda *et al.*, 2016; Dauda *et al.*, 2023)**. Similar findings regarding the importance of water-change management and stocking density in improving fish growth and feed utilization have been reported in the rabbitfish and Nile tilapia culture systems **(Abdel-Aziz *et al.*, 2016; Azab *et al.*, 2018)**. In addition, recent aquaculture studies highlighted the role of advanced systems such as biofloc and recirculating aquaculture systems in maintaining water quality and improving fish performance **(AbouelFadl *et al.*, 2023; Ragaa *et al.*, 2024)**. Despite numerous studies examining the effects of water exchange on water chemistry and fish growth **(Petit, 1986; Buentello *et al.*, 2000; Boyd, 2001)**, information remains limited regarding the optimal frequency of water exchange in static pond systems, particularly for common carp culture in Iraq. Therefore, the present study aims to evaluate the effects of different water exchange frequencies on water quality, growth performance, survival, and feed utilization of common carp fingerlings cultured under static conditions, providing experimental evidence to support improved water-management strategies for carp aquaculture.

MATERIALS AND METHODS

The study was conducted at the fish farming station of the Department of Marine Vertebrates, Marine Science Centre, University of Basrah, Basrah Province, Iraq. A total of 150 common carp (*Cyprinus carpio*) fingerlings, with an initial mean weight of 14.56 ± 1.44 g, were obtained from the Marine Science Centre Hatchery. The fish were acclimated for two weeks under laboratory conditions before the experiment.

Following acclimation, the fingerlings were randomly distributed into 15 plastic tanks (60 × 30 × 30 cm), each containing 54 L of freshwater and continuous aeration. Ten fish were stocked per tank, and the experiment consisted of five water change treatments with three replicate tanks per treatment (n = 3 tanks per treatment). The experimental design was arranged as a completely randomized design (CRD). In all statistical analyses, the tank was considered the experimental unit. Fish were fed a commercially pelleted diet twice daily at 5% of body weight, and the feeding ration was adjusted biweekly according to tank biomass.

The feed contained 38% crude protein, 5% lipid, 7.5% moisture, and 8.6% ash. Five water exchange treatments were applied: T1 (daily exchange), T2 (every 2 days), T3 (every 3 days), T4 (every 4 days), and T5 (every 5 days). During each change, 50–60% of the tank water was removed by siphoning to eliminate accumulated wastes and uneaten feed from the tank bottom. Replacement freshwater was previously aerated and stored for 24 h before use to allow stabilization of water quality. Water temperature and pH of the replacement water were adjusted to match those of the experimental tanks before each exchange to minimize environmental shock. Water exchange was conducted carefully to reduce fish disturbance and handling stress, and fish were not removed from the tanks during the procedure.

Fish were fed a commercially pelleted diet twice daily (09:00 and 16:00 h) at a feeding rate equivalent to 5% of the total tank biomass. The daily ration was calculated separately for each tank based on the total biomass of fish within that tank and was adjusted biweekly after fish weighing. Feed was supplied gradually to minimize feed loss, and uneaten feed and fecal residues were removed during siphoning before water exchange. Feed intake values were calculated on the basis of the amount of feed offered per tank during the experimental period, assuming negligible feed wastage due to the observed rapid feed consumption by fish. Therefore, the tank biomass was used as the basis for feed allocation and feed-intake calculations throughout the experiment.

The experimental period lasted eight weeks. Water quality parameters, including temperature, pH, salinity, and dissolved oxygen (DO), were measured twice weekly using a digital multi-parameter meter.

At the end of the eight-week feeding trial, growth performance and nutrient utilization indices were calculated according to the following formulas:

Weight gain (g) = Final weight (g) – initial weight (g)

- Daily Weight Gain (g/day) = Weight gain/ days of experiment
- Relative growth rate (%) = Weight gain (g) / Initial weight (g) × 100
- SGR (% day^{-1}) = 100 × [ln(final weight) − ln(initial weight)] / days
- Feed intake = amount of feed consumed divided by the number of culture days
- Feed conversion ratio = Feed intake (g) / wet weight gain (g)
- Survival rate (%) = number of fish survived / number of fish stocked × 100
- Protein efficiency ratio = Weight gain/protein intake
- Lipid efficiency ratio = Weight gain/lipid intake

The yield parameter was recalculated and expressed as fish biomass produced relative to the total water volume used during the experimental period, including both the initial tank volume and cumulative changed water. Therefore, yield was expressed as g per total water volume used (g $water^{-1}$ used). The calculation was performed according to the following equation:

Yield (g per water volume used) = Total final fish biomass (g)/ Total water volume used throughout the experiment (L).

Statistical Analysis

Data were expressed as tank means ± standard error (SE), where each treatment consisted of three replicate tanks (n = 3). The tank was considered the experimental unit for all statistical analyses. Prior to analysis, data were checked for normality and homogeneity of variance using the Shapiro–Wilk and Levene’s tests, respectively.

Growth performance, water quality, and nutrient-utilization data were analyzed using one-way analysis of variance (ANOVA). When significant differences among treatments were detected, Duncan's multiple range test was applied for post-hoc comparisons. F-values, degrees of freedom, and exact *p*-values were calculated and considered statistically significant at $p < 0.05$. Survival-rate data, expressed as percentages, were arcsine square-root transformed before analysis to satisfy ANOVA assumptions. All statistical analyses were performed using SPSS software (IBM SPSS Statistics, version 26).

RESULTS

Water Quality Parameters

Table (1) presents the water quality parameters of fish-rearing tanks subjected to different water-exchange frequencies, including temperature (°C), dissolved oxygen (mg/L), pH, and salinity (g/L). Water temperature and salinity did not differ significantly among treatments, remaining at approximately 27 °C and 1.31–1.43 g/L, respectively. In contrast, dissolved oxygen concentrations ranged from 4.7 to 6.6 mg/L, with the lowest value recorded in T5, while pH values ranged from 6.8 in T5 to 7.5 in T1, showing significant variation among treatments ($p < 0.05$).

Table 1. Water quality parameters (Mean ± SE) under different water change frequencies.

Water parameter	Treatments				
	T1	**T2**	**T3**	**T4**	**T5**
Temperature(C°)	27±0.03a	27±0.03a	27±0.02a	27±0.01a	27±0.02a
Dissolved Oxygen (mg/L)	6.6±0.3a	6.5±0.4a	6.2±0.3a	5.8±0.3a	4.7±1.05b
pH	7.5±0.002 a	7.4±0.001 b	7.4±0.001 b	7.2±0.003 c	6.8±0.004 d
Salinity(g/L)	1.31±0.10 a	1.33±0.09 a	1.35±0.06 a	1.41±0.08 a	1.43±0.06 a

*Values with different superscripts along the same row are significantly different ($p < 0.05$).

Growth Performance and Nutrient Utilization

Growth-performance indices varied significantly among the different water exchange treatments (Table 2). Overall, improved growth performance was associated with moderate water-exchange frequencies. Final weight, weight gain, daily weight gain, relative growth rate, and specific growth rate were significantly higher ($p < 0.05$) in treatments T2 (water exchange every 2 days) and T3 (every 3 days) compared with the remaining treatments.

The feed-conversion ratio (FCR) was the lowest under T2 and T3, with values of 2.901 ± 0.162 and 2.921 ± 0.195, respectively. These values were not significantly different ($p > 0.05$) from those observed in T1 and T4 but were markedly higher in T5. Feed intake tended to be higher in T2 and T3 compared with other treatments; however, no significant differences were detected ($p > 0.05$).

Protein-efficiency ratio (PER) and lipid-efficiency ratio (LER) were significantly influenced by water exchange frequency. The highest PER values (0.908 ± 0.051 and 0.902 ± 0.061) and LER values (6.906 ± 0.384 and 6.865 ± 0.458) were recorded in T2 and T3, respectively, and were significantly higher ($p < 0.05$) than those of the other treatments.

Yield per unit volume of water used increased with moderate water exchange intervals, with the highest yields (257.716 ± 18.711 g L^{-1} and 259.629 ± 19.629 g L^{-1}) obtained in T2 and T3, respectively. These yields were significantly greater ($p < 0.05$) than those observed in the remaining treatments. Survival rate was also significantly higher ($p < 0.05$) in T1, T2, and T3 compared to T4 and T5.

Table 2. Growth performance, feed utilization, and survival indices (mean ± SE) of *Cyprinus carpio* fingerlings under different water exchange frequencies.

Growth performance	**Treatments**				
	T1	**T2**	**T3**	**T4**	**T5**
Initial Weight(g)	14.42±0.25a	14.38±0.24a	14.58±0.13a	14.47±0.18a	14.74±0.15a
Final Weight(g)	24.70±1.04b	28.33±1.21a	28.60±1.19a	25.82±1.09b	20.61±2.06c
Weight Gain(g)	10.24±0.79b	13.94±0.97a	14.02±1.06a	11.35±0.91b	5.87±1.91c
Daily Weight Gain (g/day)	0.18±0.014a	0.25±0.018a	0.25±0.018a	0.20±0.016b	0.11±0.034c
Relative Growth (%)	71.016±4.25b	96.69±5.38a	96.12±6.41a	78.39±5.31b	39.73±12.55c
SGR (% day^{-1})	0.957±0.O44a	1.209±0.045a	1.201±0.058a	1.033±0.053a	0.592±0.161b
Feed Conversion Ratio	3.023±0.235a	2.901±0.162a	2.921±0.195a	3.582±0.243a	7.568±2.522b
Feed intake (g)	40.37±0.36a	41.27±0.42a	40.82±0.71a	40.51±0.51a	40.26±0.66a
Protein efficiency ratio	0.667±0.401b	0.908±0.051a	0.902±0.061a	0.736±0.500b	0.373±0.118c
Lipid efficiency ratio	5.072±0.304b	6.906±0.384a	6.865±0.458a	5.599±0.379b	2.838±0.896c
Yield (g per water	189.753±14.	257.716±18	259.629±19	210.185±16	108.703±35

volume used)	668b	.711a	.629a	.851b	.370c
Survival Rate (%)	86.66±5.77a	93.33±5.77 a	93.33±5.77 a	80±10ab	70±10b

*Values with different superscripts along the same row are significantly different (p <0.05).

DISCUSSION

Fish farming is considered an important agricultural activity that contributes to global food security and poverty reduction **(Kaleem & Sabi, 2021)**. Efficient fish production depends on three essential factors: high-quality seed, nutritionally balanced feed, and adequate water supply in both quality and quantity **(Dauda *et al.*, 2023)**. Freshwater is a finite and increasingly limited resource in aquaculture **(Widanarni *et al.*, 2012)**; therefore, effective water-management strategies are critical for sustainable production. Among the available management approaches, water exchange remains one of the most commonly applied methods for maintaining acceptable water quality in pond systems **(Okomoda *et al.*, 2016; Dauda *et al.*, 2017)**. The frequency of water exchange plays a crucial role in balancing water quality and quantity to achieve optimal fish-culture performance **(Bhatnagar & Devi, 2013)**. Recent studies have shown that improved water quality management through recirculating aquaculture systems and biofloc technology can significantly enhance fish growth and reduce environmental stress **(AbouelFadl *et al.*, 2023; Ragaa *et al.*, 2024, Yaseen *et al.*, 2026)**. Although the present study was conducted under static culture conditions, the results similarly indicate that optimizing water exchange intervals can improve growth performance while reducing excessive water use.

The growth of aquatic organisms is strongly influenced by the quality of their surrounding water environment. As a sensitive species, common carp growth is particularly affected by dissolved oxygen availability and temperature fluctuations **(Goolish & Adelman, 1984; Rahman, 2015)**. Accordingly, water quality parameters are widely used as indicators of the health and productivity of aquaculture systems. The present study demonstrated that water exchange frequency significantly affected water quality and growth performance of common carp fingerlings. While temperature and salinity remained relatively stable among treatments, dissolved oxygen levels declined markedly in the treatment with the longest exchange interval (T5), likely due to the accumulation of metabolic wastes and organic matter **(Boyd, 2001)**.

Dissolved oxygen dynamics in aquaculture systems are influenced by aeration, diffusion, photosynthesis, respiration, and decomposition processes **(Chin, 2012)**. Although the minimum dissolved oxygen concentration recorded in this study (4.7 ± 1.05 mg/L) remained within the tolerance range for common carp fingerlings **(Homoki *et al.*, 2021)**, suboptimal oxygen availability can still negatively affect feeding activity and growth efficiency. **Bergheim *et al.* (2005)** reported that reduced oxygen availability limits fish activity and feed utilization, while **Nordgarden *et al.* (2003)** showed that fish exposed to hypoxic conditions exhibit reduced appetite. This mechanism likely explains the elevated feed conversion ratio observed in T5, where oxygen levels were the lowest.

The pH values recorded across all treatments remained within the acceptable range for common carp culture **(Heydarnejad, 2012; Nasir *et al.*, 2019; Resen *et al.*, 2023)**, indicating that pH was not a limiting factor in the present study. Interestingly, although daily water exchange (T1) resulted in superior water quality parameters, this did not translate into improved growth performance. This outcome suggests that frequent water exchange may induce handling-related or environmental stress, which can negatively affect growth. In contrast, in advanced systems such as recirculating aquaculture systems (RAS), continuous water treatment and minimal disturbance allow fish to adapt more effectively, resulting in lower stress levels **(Nasir *et al.*, 2022; Yaseen *et al.*, 2024)**.

Stress is a critical factor influencing fish physiology and growth performance **(Tom, 1998; Moyle & Cech, 2000; Poon *et al.*, 2002)**. The reduced growth observed under daily water exchange in this study supports the hypothesis that excessive disturbance may outweigh the benefits of improved water quality. Conversely, extending the water exchange interval to five days resulted in a decline in growth performance (WG = 5.87 ± 1.91 g), primarily due to progressive deterioration of water quality beyond optimal thresholds. Previous studies have shown that dissolved oxygen levels below 4 mg/L and extreme pH conditions induce physiological stress and impair growth in tropical fish species **(Boyd, 2001; Marium *et al.*, 2023)**.

Growth performance indices, including weight gain, daily weight gain, relative growth rate, and specific growth rate, were significantly enhanced under moderate water exchange frequencies (T2 and T3). The superior growth performance observed under moderate water-exchange frequencies in the present study agrees with **Abdel-Aziz *et al.* (2016)**, who reported improved growth and feed utilization under optimized water exchange conditions in rabbitfish culture. Similarly, **Azab *et al.* (2018)** demonstrated that water quality and fish productivity are strongly influenced by management practices, including stocking density and feeding strategy.

This improvement may be attributed to greater environmental stability and reduced disturbance, which enhance feed intake and nutrient utilization. Similar trends were reported by **Okomoda *et al.* (2016)**, who observed superior growth performance in African catfish reared under less frequent water exchange regimes.

Nutrient utilization indices further supported these findings, as feed conversion ratio, protein efficiency ratio, and lipid efficiency ratio were optimized under T2 and T3 treatments. Reduced mortality rates and stable water quality conditions under these treatments further indicate that moderate water exchange intervals provide a balance between water quality maintenance and stress minimization **(Akinwole *et al.*, 2014; Alshkarchy *et al.*, 2021)**. Moreover, the increased yield per unit volume of water observed in T2 and T3 suggests that these exchange frequencies can support stocking densities of up to 2.5 kg m^{-3} in static pond systems, provided that water exchange does not exceed three-day intervals. These findings support the concept that moderate water exchange strategies may improve water-use efficiency without compromising fish performance, which is consistent with previous aquaculture studies focusing on sustainable water management practices **(Abdel-Aziz *et al.*, 2016; Ragaa *et al.*, 2024)**.

CONCLUSION

The findings of this study demonstrate that water exchange frequency significantly influences water quality, growth performance, feed utilization, and survival of common carp (*Cyprinus carpio*) fingerlings reared under static culture conditions. Moderate water exchange intervals (every 2–3 days) provided the most favorable balance between water quality maintenance and fish performance, while also improving water-use efficiency. Under the conditions of the present study, common carp fingerlings were successfully reared at stocking densities of up to approximately 2.5 kg m^{-3} when water exchange did not exceed three-day intervals. These results provide useful information for improving water-management practices in common carp culture systems; however, further studies involving different freshwater fish species and culture conditions are required before broader generalizations can be made.

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