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Effect of Feed Deprivation and Refeeding Cycles on Growth Performance and Feed Utilization in the Common Carp (*Cyprinus carpio* L.)

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ABSTRACT

This study was carried out to investigate the effects of compensatory growth (starvation and refeeding) and its subsequent influences on weight gain (WG), daily growth rate (DGR), relative growth rate (RGR), specific growth rate (SGR), feed conversion ratio (FCR), and efficiency of feed conversion (ECR) in the common carp (*Cyprinus carpio* L.). Fish initial weight was 22.29 ±3.40g, while total length was 6.47±1.31cm. The experiment included six treatments, each with three replicates: T1 (continuous feeding), T2 (one day fasting and two days feeding), T3 (two days fasting and four days feeding), T4 (three days fasting and six days feeding), T5 (four days fasting and eight days feeding), and T6 (five days fasting and ten days feeding). The trial lasted for 70 days (February 6 to April 15, 2024), excluding a 14-day acclimatization period. In statistical analysis, there was significant improvement ($P \leq 0.05$) in weight gain in continuous feeding treatment (control, T1) compared to other treatments, with a mean value of 50.07g. Similarly, specific growth rate, relative growth rate, and daily growth rate were significantly higher ($P \leq 0.05$) in the control treatment, recording 1.69%/day and 227.8%, respectively, compared to other treatments. No significant differences ($P > 0.05$) were observed in survival rate among all treatments. Regarding feed conversion ratio (FCR) and efficiency of feed conversion (ECR%) of experimental fish during the 70-day trial, significant improvement ($P \leq 0.05$) was indicated in FCR in treatments T5 and T2 compared to the others, with values of 1.27 and 1.50, respectively. At the same time, starvation for four days followed by eight days of refeeding (T5) recorded the best feed conversion efficiency at 77.81%. In conclusion, the four-day starvation and eight-day refeeding cycle improved feed efficiency, suggesting potential feed cost reduction without affecting the survival of cultured fish.

INTRODUCTION

Experts in aquaculture are now focusing on optimizing fish and aquatic organism rearing because of global population growth, which is expected to reach 9.7 billion by 2050. This will necessitate the provision of sufficient food resources to meet the growing demand **(Paul *et al*., 2022)**.

Feed costs represents the highest expenditure in aquaculture, typically accounting for 60–70% of the total production costs **(Singh *et al*., 2006)**. Therefore, any reduction in feed costs—whether through improved rearing practices, dietary modifications, or other direct and indirect strategies—is of crucial importance for the sustainability and profitability of aquaculture industry.

Fish show a higher capacity to tolerate prolonged periods of feed restriction, particularly when compared to mammals **(Miriam *et al*., 2011)**. During starvation, fish undergo distinct metabolic phases; Starting with a short transient stage, followed by a prolonged steady state during which lipid oxidation serves as the primary energy source in order to preserve protein, and the final phase involves a shift toward protein catabolism as the main energy source **(Bar, 2014)**. In aquaculture, one practical strategy to reduce feed cost is the provision of suitable feeding management practices, such as cycles of feed restriction (starvation) followed by refeeding **(Azodi *et al*., 2013)**.

Starvation followed by refeeding may improve growth performance in certain species, a process known as compensatory growth. This phenomenon describes a period of accelerated growth occurring after the resumption of feeding, following feed deprivation or exposure to unfavorable conditions such as low temperature, hypoxia, or reproductive stress **(Ali *et al*., 2003)**. Compensatory growth is a physiological response in animals characterized by an increased growth rate, allowing the organism to compensate lost growth opportunities and potentially attain a size comparable to non-deprived individuals. Fish, in particular, exhibit strong compensatory growth responses, typically associated with elevated feed intake, enhanced mitogenic activity (chemical stimulation of mitosis), and improved feed conversion efficiency **(Won & Borski, 2013)**.

In order to successfully induce compensatory growth, endogenous energy reserves must be moderately depleted. This could trigger endocrine alterations that stimulate appetite and growth potential. Achieving compensatory growth in fish has numerous potential advantages in aquaculture, including reduced feed and labor costs, decreased water pollution during fasting periods, improved feeding activity upon refeeding, and increased fish production efficiency **(Cho *et al*., 2006)**.

The common carp (*Cyprinus carpio* L.) is one of the most significant members of the family Cyprinidae, which is the largest family of freshwater fish. This species inhabits rivers, ponds, and lakes **(Bauer & Schlott, 2004)**. Globally, the common carp ranks as the fourth commonly cultured fish species and is highly valued for its ability to withstand diverse environmental conditions **(FAO, 2022)**.

MATERIALS AND METHODS

Experimental diet

A commercial Iranian diet was used. The diet contained fish meal, soybean meal, wheat flour, barley, corn, wheat gluten, wheat bran, fish oil, vegetable oils, vitamin premix, mineral premix, yeast, antioxidants, choline, methionine, and lysine.

Table 1. Chemical analysis of the experimental diet used in the study

No.	Component	Percentage (mean ± SE)
1	Moisture	3.17 ± 0.71
2	Fat	5.58 ± 0.037
3	Protein	23.40 ± 0.632
4	Carbohydrates	63.97 ± 0.603
5	Fiber	3.92 ± 0.176
6	Ash	3.70 ± 0.008

Culture system

A total of 250 common carp (*Cyprinus carpio*) fingerlings were collected from aquaculture unit ponds in Al-Hartha District belonging to the College of Agriculture, University of Basrah. Of these, 108 fish were used in the experiment. Initial weights ranged from 21.5 to 23.61g and initial lengths fluctuated from 5.27 to 7.45cm. Fish were transported in 25-L nylon bags half-filled with source pond water, 30 fish per bag. Oxygen was supplied via an air pump and bags were tightly sealed with canvas cords. Transport occurred in the morning in line with preparations to stop feeding the day before. Upon arrival at the Aquaculture Laboratory, fish were disinfected using 3% sodium chloride for 10 seconds to remove external bacteria and parasites, if present **(Muheisen, 1983)**.

Feeding and growth experiments were carried out using a recirculating aquaculture system (RAS). This system comprised eighteen tanks distributed among three identical units. Each unit was arranged in four rows; rows 1–3 each contained two 30-L tanks connected by 0.5-inch PVC pipes for water transfer, equipped with air pumps for oxygenation and perforated lids to prevent fish escape jumping. Row 4 was the filtration unit, comprising a glass tank divided into three compartments. The first compartment contained sponge and fabric filter to withhold waste and uneaten feed and was cleaned daily. The second was filled with limestone to stabilize pH and activated carbon for biological treatment. A backup power inverter (6 A) with a 200-Ah battery was installed, along with heaters maintaining stable water temperature. After treatment in first and second compartments, the water proceeded to the third compartment and was pumped back to the experimental tanks via 0.5-inch PVC pipes. Plastic tanks were cleaned and refilled bi-weekly. This closed RAS can be applied for intensive fish culture with lower water requirements, promoting aquaculture in water-scarce regions **(Badiola *et al*., 2018)**. Fish are highly sensitive to environmental changes because of their constant contact with water; successful and sustainable aquaculture relies on controlling environmental factors to maintain conditions suitable for growth and survival **(Cabillon & Lazado, 2019)**.

The experiment involved six treatments with three replicates each (18 tanks). The first treatment was T1 (control treatment, continuous feeding); the second treatment was T2 (starvation for one day and feeding for two days); the third treatment was T3 (starvation for two days and feeding for four days); the fourth treatment was T4 (starvation for three days and feeding for six days); the fifth treatment was T5 (starvation for four days and feeding for eight days); and the sixth treatment was T6 (starvation for five days and feeding for ten days).

At the start, fish averaged 22.29 ± 0.78g, stored with six fish per tank. They were acclimated for 14 days and fed a 2-mm imported commercial diet. Feeding was gradually increased to 3% of body weight, offered twice daily (09:00 and 16:00). Trial lasted 70 days excluding the 14-day acclimation, conducted from 6 February to 15 April 2024. Fish were weighed every 14 days and feed amounts were adjusted accordingly. Trial 2 used 108 fingerlings (initial weight 53.70 ± 2.75 g) in 18 plastic tanks and the same diet at 3% body weight, fed twice daily. The experiment lasted for 70 days (from February 6 to April 15, 2024), excluding a 14-day acclimatization period.

Feeding level (Satiation)

During the trial, fish were fed a known ration equal to 3% of body weight per day, split into two meals (morning and evening). One hour after feeding, uneaten feed was siphoned, filtered, air-dried in the laboratory for 24h, and weighed to calculate feed intake. The satiation level (%) over the two-week trial was calculated as: Satiation (%) = [Feed intake (dry weight) / Body weight] × 100.

Physico-chemical parameters

Water temperature, dissolved oxygen, ammonia, pH, and salinity were measured weekly throughout the experiment using various measuring items:

1) Temperature: Measured with a digital thermometer.

2) Dissolved oxygen: Measured with a portable digital DO meter.

3) Ammonia (NH_3): Measured using Salifert colorimetric test strips (Netherlands).

4) pH: Measured using an ADWE pH meter.

5) Salinity: Measured using an ADWE salinity meter.

Table 2. Selected water quality parameters during the growth trial of common carp fingerlings

Parameter	Value (Mean ± SE)
Temperature (°C)	25.33 ± 0.32
pH	6.81 ± 0.03
Total dissolved solids (mg/L)	65.75 ± 3.45
Dissolved oxygen (mg/L)	7.26 ± 0.03
Ammonia (mg/L)	< 0.1

Growth performance indices

Growth parameters were calculated following **Jobling and Koskela (1996)** equations:

1) Weight gain (WG, g) = Final weight − Initial weight

2) Specific growth rate (SGR, %/day) = [(ln Final weight − ln Initial weight) ÷ days] × 100

3) Relative growth rate (RGR, %) = [(Final weight − Initial weight) ÷ Initial weight] × 100

4) Daily growth rate (DGR, g/day) = Weight gain ÷ Experimental period

5) Feed conversion ratio (FCR) = Feed given ÷ Weight gain

6) Feed conversion efficiency (FCE, %) = (Weight gain ÷ Feed given) × 100

Statistical analysis

Data were analyzed using SPSS (Version 20). Differences among means were tested using Duncan's multiple range test **(Duncan, 1955)**, at a significance level of $P \leq 0.05$.

RESULTS

1. Growth trial

Table (3) and Figs. (1–4) present initial and final weights, weight gain (g), specific growth rate (%/day), relative growth rate (%), and daily growth rate (g/day) for the common carp fingerlings over the 70-day trial. Statistical analysis indicated a significant improvement ($P \leq 0.05$) in weight gain in the continuous feeding treatment (T1) compared with other treatments, with a value of 50.07g. Likewise, SGR, RGR, and DGR improved significantly ($P \leq 0.05$) in T1 compared with other treatments, reaching 1.69%/day, 227.8%, and 0.72g/ day, respectively. No significant differences ($P > 0.05$) were recorded in survival rate among treatments.

Table 3. Growth metrics of common carp fingerlings after 70 days (mean ± SD)

T.	Initial weight (g)	Final weight (g)	Weight gain (g)	SGR (%/day)	RGR (%)	DGR (g/day)	Survival (%)
T1	22.18 ± 3.27 (a)	72.25 ± 6.25 (a)	50.07 ± 3.03 (a)	1.69 ± 0.09 (a)	227.8 ± 22.4 (a)	0.72 ± 0.04 (a)	100.0 ± 0.0 (a)
T2	21.50 ± 3.67 (a)	49.05 ± 6.21 (b)	27.55 ± 2.58 (b)	1.18 ± 0.07 (b)	129.3 ± 10.9 (b)	0.39 ± 0.04 (b)	100.0 ± 0.0 (a)
T3	22.48 ± 4.55 (a)	50.08 ± 6.34 (bc)	27.60 ± 1.79 (b)	1.16 ± 0.11 (bc)	124.9 ± 16.8 (b)	0.39 ± 0.03 (b)	100.0 ± 0.0 (a)
T4	21.65 ± 4.69 (a)	42.87 ± 4.81 (bc)	21.22 ± 0.91 (c)	0.99 ± 0.14 (c)	100.8 ± 19.7 (b)	0.30 ± 0.01 (c)	100.0 ± 0.0 (a)
T5	23.62 ± 4.84 (a)	61.08 ± 10.60(ca)	37.47 ± 5.85 (d)	1.36 ± 0.07 (d)	160.0 ± 12.4 (c)	0.54 ± 0.08 (d)	100.0 ± 0.0 (a)
T6	22.32 ± 1.91 (a)	46.90 ± 3.09 (b)	24.58 ± 1.18 (bc)	0.30 ± 0.21 (bc)	110.4 ± 4.1 (b)	0.40 ± 0.10 (bc)	100.0 ± 0.0 (a)

Different superscript letters within a column indicate significant differences ($P \leq 0.05$).

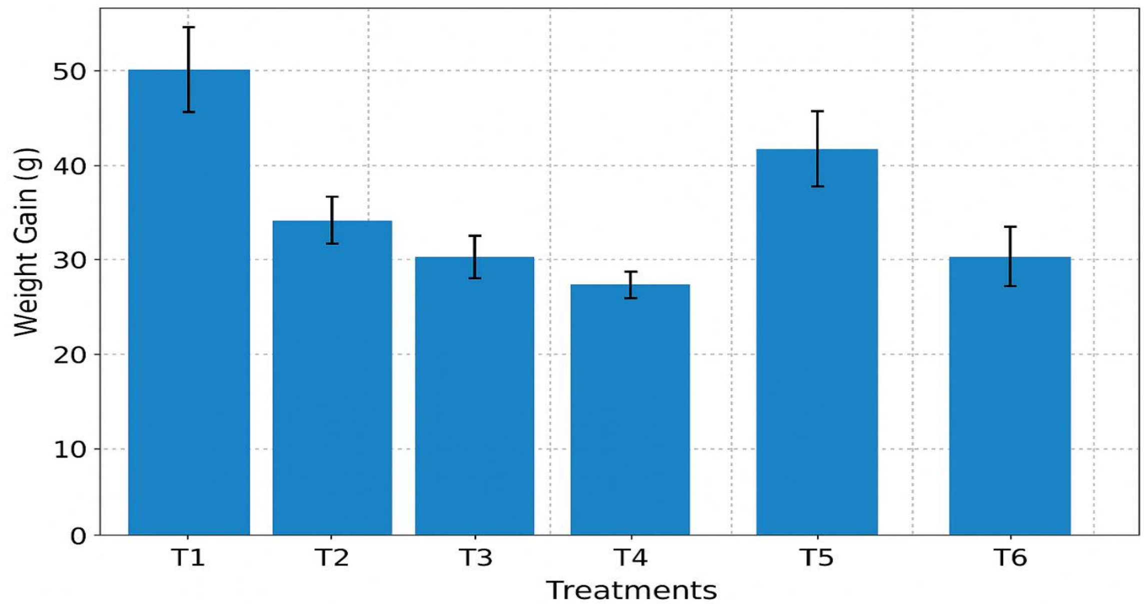

Fig. 1. Total weight gain of common carp fingerlings after 70 days

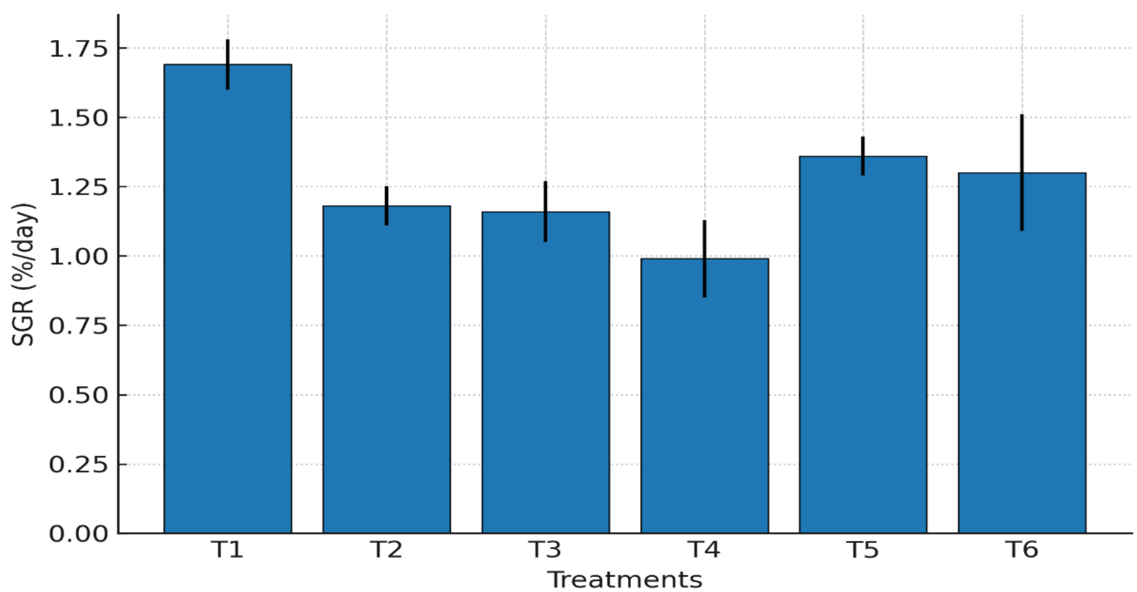

Fig. 2. Specific growth rate (SGR) after 70 days

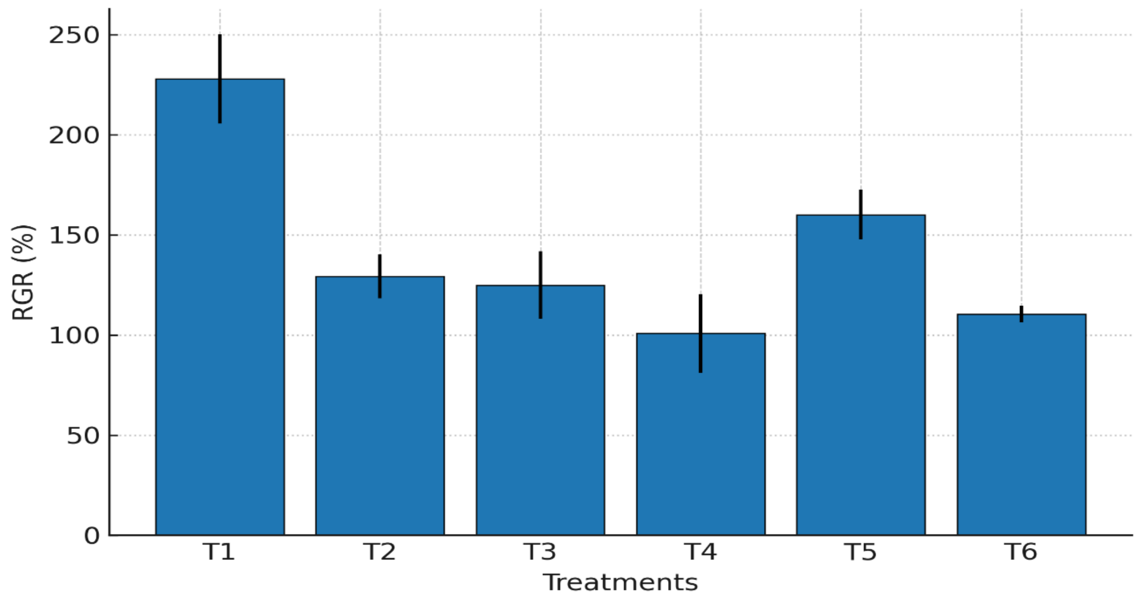

Fig. 3. Relative growth rate (RGR) after 70 days

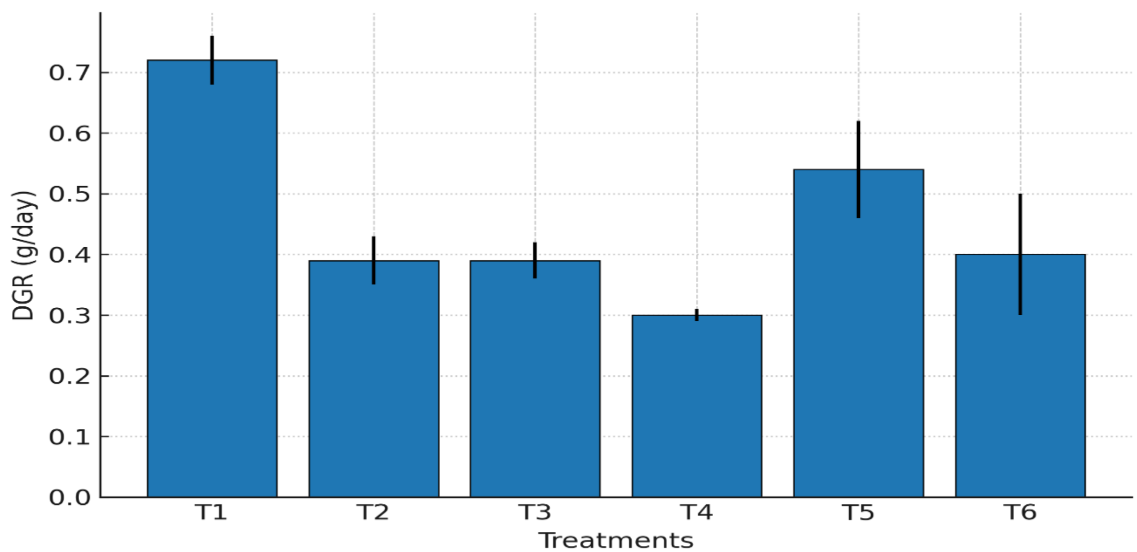

Fig. 4. Daily growth rate (DGR) after 70 days

2. Feeding efficiency

Table (4) and Figs. (5, 6) show feed conversion ratio and feed conversion efficiency (%) for the common carp fingerlings during the 70-day trial. FCR improved significantly ($P \leq 0.05$) in treatment T5 compared with the other treatments (1.27). Similarly, ECR (%) improved significantly ($P \leq 0.05$) in T5, which recorded 77.81%.

Table 4. Feeding efficiency of common carp during the trial (mean ± SD)

Treatment	FCR (mean ± SD)	ECR (%) (mean ± SD)
T1	1.65 ± 0.07 (a)	60.47 ± 2.71 (a)
T2	1.50 ± 0.08 (ac)	66.57 ± 3.92 (a)
T3	1.59 ± 0.12 (a)	62.95 ± 5.14 (a)
T4	1.99 ± 0.32 (b)	51.08 ± 7.72 (b)
T5	1.28 ± 0.05 (c)	77.81 ± 3.45 (c)
T6	1.66 ± 0.03 (a)	60.02 ± 1.19 (a)

Different superscript letters within a column indicate significant differences ($P \leq 0.05$).

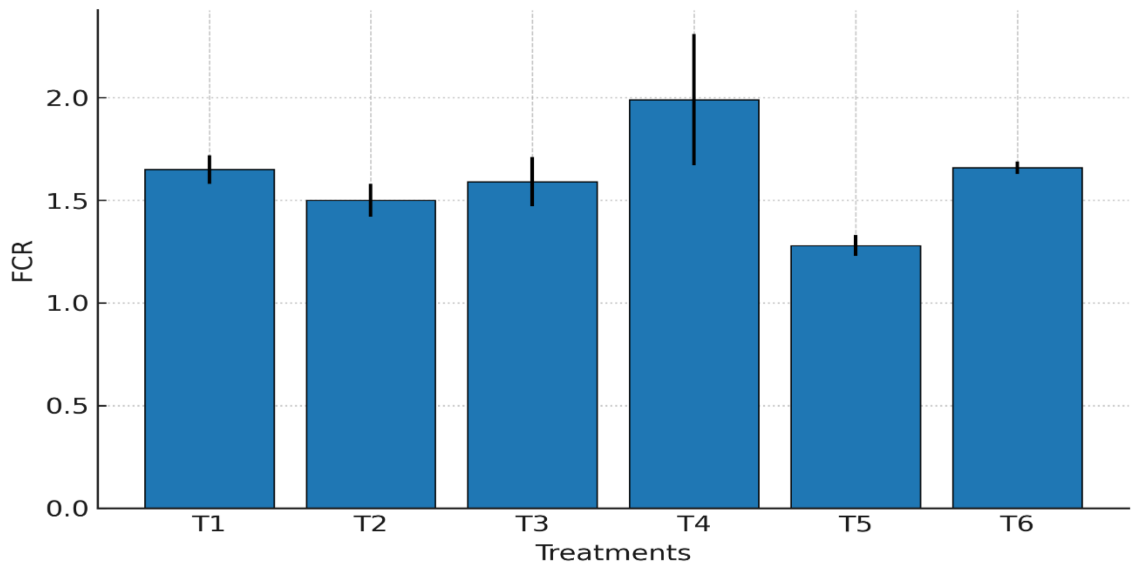

Fig. 5. Food conversion ratio (FCR) after 70 days

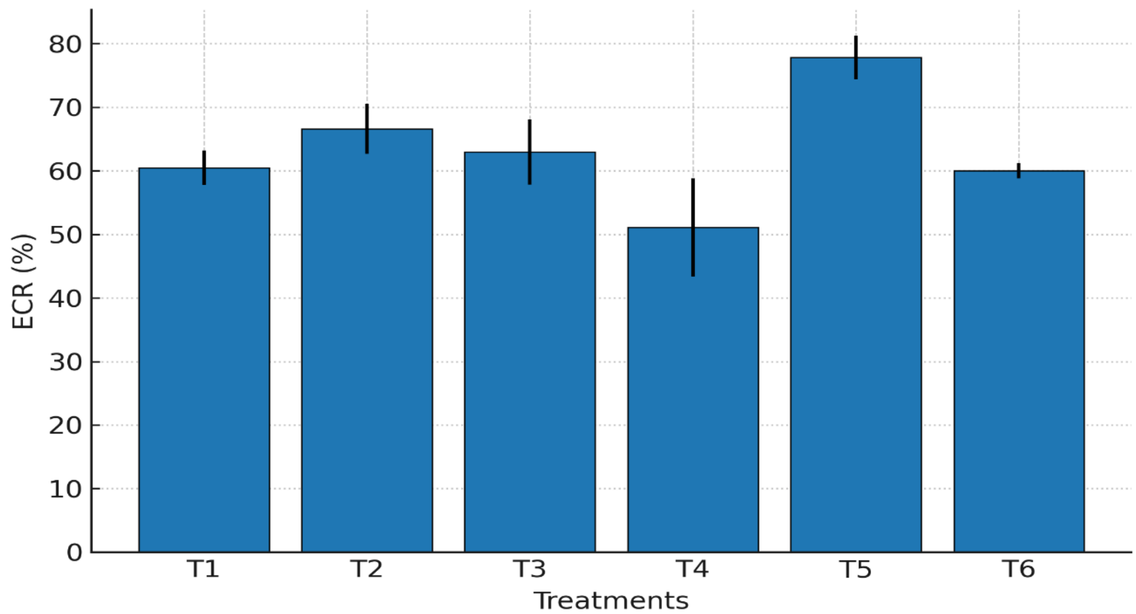

Fig. 6. Food conversion efficiency (FCE) after 70 days

DISCUSSION

Growth parameters

Compensatory growth (CG) is a key physiological mechanism in aquaculture aimed at improving production efficiency and reducing feeding costs. This phenomenon occurs when fish undergo a period of feed restriction or fasting, followed by refeeding, during which they may show rapid growth to compensate for the loss in body weight and length. This response enables them to catch up with fish that have been continuously fed. Applying this strategy is characterized by its ability to lower feed costs through controlled cycles of feeding and fasting, improving feed conversion efficiency by directing available energy toward growth rather than fat storage, and reducing pond pollution by minimizing uneaten feed residues. In addition, it enhances production rates within a shorter period due to the accelerated growth that occurs after refeeding **(Won & Borski, 2013)**.

Compensatory growth is commonly used to study its effect on fish performance when refeeding follows periods of starvation of varying durations, whether short or long, within different cycles **(Mattila *et al*., 2009)**. The occurrence of compensatory growth in fish is closely associated with water temperature, fish length and weight, feeding method, and feeding protocols **(Adaklı, 2012)**.

In this study, the highest weight gain, relative growth rate (RGR), and specific growth rate (SGR) were recorded in the control group compared with other treatments after applying compensatory growth to common carp fingerlings. This finding is consistent with the empirical observations reported by **Sultan (2013)**, who demonstrated that prolonged feed deprivation induces a progressive reduction in body weight and suppresses growth performance in common carp (*Cyprinus carpio* L.), whereas subsequent refeeding triggers a gradual restoration of body mass and enhancement of growth-related physiological indices. **Al-Tameemi *et al*. (2011)** reported that prolonged starvation in the common carp (*Cyprinus carpio* L.) reduces growth and delays recovery after refeeding. In contrast, the study by **Al-Shawi and Younis (2014)** found that short-term starvation in *Cyprinus carpio* induced compensatory growth and improved feed efficiency, along with reduced glucose and total protein levels during fasting. Our results also agree with the findings of **Chowdhury *et al*. (2025)**, who reported that continuous feeding improved the growth of common carp fingerlings compared with starvation. They attributed this improvement primarily to the continuous availability of nutrients, which supports the optimal physiological and metabolic functions necessary for growth. Regular feeding could also ensure a constant energy supply, which enhances weight gain in comparison with intermittent starvation regimes.

Juvenile snook were reported to compensate only partially for lost growth, resulting in adverse impacts on growth processes. **Yengkokpam *et al*. (2013)** observed that fasting rohu (*Labeo rohita*) fingerlings for two to three days weekly could cause stress. Feed deprivation may also deplete antioxidant reserves in organs and increase reactive oxygen species. Our results are consistent with those of **Zheng *et al*. (2016)**, who demonstrated that feed deprivation depletes endogenous energy reserves necessary for maintaining physiological balance, leading to weight loss. Accordingly, compensatory growth responses vary depending on fish species, age, rearing conditions, and the duration of feed restriction.

Feeding efficiency

Feed management plays a crucial role in aquaculture systems, as both the quantity and frequency of feeding directly affects fish growth and feed utilization. According to **Blanquet and Oliva-Teles (2010)**, in a study conducted on turbot (*Scophthalmus maximus*) under commercial rearing conditions, they demonstrated that periods of feed restriction followed by refeeding resulted in compensatory growth, where fish subjected to restricted feeding were able to catch up in weight with continuously feeding fish. This feeding strategy significantly increased feed conversion efficiency (FCE) without adversely impacting fish survival rates or overall health. These findings indicate that controlled feed restriction, when properly managed, can serve as an effective approach to optimize feed utilization and enhance growth recovery in turbot production systems.

Efficient feed management is crucial from an economic point of view, as both the feed conversion ratio (FCR) and feed conversion efficiency (FCE) are basic indicators of technical and financial performance in the aquaculture sector **(FAO, 2020)**. Previous studies have indicated that feed costs typically account for the majority of operational costs in aquaculture projects, highlighting the need to improve feed utilization to enhance profitability and ensure the long-term sustainability of aquaculture industry **(Tacon & Metian, 2015)**.

Klahan *et al*. (2023) reported that compensatory growth in the red tilapia was frequently accompanied by hyperphagia, or increased appetite, which improves feed efficiency. In the present study, statistical analysis indicated significant improvement ($P \leq 0.05$) in FCR in treatment T5, which was not significantly different from T2, with values of 1.27 and 1.50, respectively. Similarly, FCE improved significantly ($P \leq 0.05$) in the treatment involving four days of starvation followed by eight days of refeeding (T5), recording 77.81%.

These findings corroborate those of **Bolivar *et al*. (2006)**, who reported that the daily fed Nile tilapia exhibited higher growth but did not significantly differ from fish subjected to alternate-day feeding. Moreover, better FCR values were observed in fish subjected to alternate-day feeding compared with those fed daily. **Bjørnevik *et al*. (2021)** found that Atlantic cod (*Gadus morhua*) subjected to alternate-day feeding consumed 27% less feed than those fed daily. Similarly, **Solberg *et al*. (2006)** noted that Atlantic cod fed on alternating days experienced only half the feeding days compared with continuously fed groups, yet achieved superior feed conversion ratios.

This improvement may be attributed to naturally enhanced digestive capacity during short-term starvation, resulting in more effective nutrient absorption upon refeeding **(Bolasina *et al*., 2006)**. Improvements in digestive enzyme activity have also been previously reported in Atlantic salmon **(Krogdahl & Bakke-Mckellep, 2005)** and rohu **(Yengkokpam *et al*., 2013)** subjected to cycles of starvation and refeeding.

CONCLUSION

In conclusion, the present study indicate that short periods of feed deprivation followed by refeeding can be effectively utilized to improve feed efficiency in common carp (*Cyprinus carpio*), without affecting survival rates. Although continuous feeding resulted in the highest growth performance indices (WG, SGR, and RGR), the treatment involving four days of starvation followed by eight days of refeeding (T5) achieved the best feed conversion performance (FCR and FCE).

Finally, the current findings suggest that short-term cyclic fasting could stimulate physiological and digestive processes that improve nutrient absorption and energy utilization, thereby reducing feed consumption and production costs while maintaining satisfactory growth. Moreover, this strategy contributes to minimizing feed waste and water pollution, making it a sustainable and economically viable approach for intensive common carp aquaculture systems.

REFERENCES

Adaklı, A. (2012). Effects of different feeding and fasting cycles on growth performance and body chemical composition of European seabass (*Dicentrarchus labrax*) [Master's thesis, Çukurova University]. Institute of Science.

Ali, M.; Nicieza, A. G. and Wootton, R. J. (2003). Compensatory growth in fishes: A response to growth depression. Fish and Fisheries, 4(3): 147–190. https://doi.org/10.1046/j.1467-2979.2003.00109.x

Al-Shawi, A. A., and Younis, K. H. (2014). Effect of feed deprivation and refeeding on growth performance and some blood parameters of common carp (*Cyprinus carpio* L.). Basrah Journal of Agricultural Sciences, *27*(1): 38–50.

Al-Tameemi, R. A.; Al-Niaeem, K. S. and Al-Hamadany, Q. H. (2011). Effect of starvation on some enzymes in common carp (*Cyprinus carpio* L.). Journal of King Abdulaziz University: Marine Sciences, 22(1): 113–153. https://doi.org/10.4197/mar.22-1.10

Azodi, M.; Ebrahimi, E.; Farhadian, O. and Mahboobi-Soofiani, N. (2013). Response of rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) to short-term starvation periods and refeeding. World Journal of Fish and Marine Sciences, 5(5): 474–480.

Badiola, M.; Basurko, O. C.; Piedrahita, R.; Hundley, P. and Mendiola, D. (2018). Energy use in recirculating aquaculture systems (RAS): A Review. Aquacultural Engineering, 81: 57–70. https://doi.org/10.1016/j.aquaeng.2018.03.003

Bar, N. (2014). Physiological and hormonal changes during prolonged starvation in fish. Canadian Journal of Fisheries and Aquatic Sciences, 71(10): 1447–1458. https://doi.org/10.1139/cjfas-2013-0574

Bauer, C. and Schlott, G. (2004). Overwintering of farmed common carp (*Cyprinus carpio* L.) in the ponds of a central European aquaculture facility—Measurement of activity by radio telemetry. Aquaculture, 241(1–4): 301–317. https://doi.org/10.1016/j.aquaculture.2004.08.031

Bjørnevik, M.; Imsland, A. K.; Hanssen, H.; Roth, B.; Vikingstad, E. and Foss, A. (2021). The effect of alternate-day feeding on growth and feed conversion in

Atlantic cod (*Gadus morhua*). Aquaculture Nutrition, 27(4): 1206–1211. https://doi.org/10.1111/anu.13264

Blanquet, I. and Oliva-Teles, A. (2010). Effect of feed restriction on the growth performance of turbot (*Scophthalmus maximus* L.) juveniles under commercial rearing conditions. Aquaculture Research, 41(8): 1255–1260. https://doi.org/10.1111/j.1365-2109.2009.02418.x

Bolivar, R. B.; Jimenez, E. B. T. and Brown, C. L. (2006). Alternate-day feeding strategy for Nile tilapia grow out in the Philippines: Marginal cost-revenue analyses. North American Journal of Aquaculture, 68(2): 192–197. https://doi.org/10.1577/A05-017.1

Cabillon, N. A. and Lazado, C. C. (2019). Mucosal barrier functions of fish under changing environmental conditions. Fishes, 4(1): 2. https://doi.org/10.3390/fishes4010002

Cho, S. H.; Lee, S. M.; Park, B. H.; Ji, S. C.; Lee, J.; Bae, J. and Oh, S. Y. (2006). Compensatory growth of juvenile olive flounder (*Paralichthys olivaceus* L.), and changes in proximate composition and body condition indexes during fasting and after refeeding in summer season. *Journal of the World Aquaculture Society*, 37(2): 168–174. https://doi.org/10.1111/j.1749-7345.2006.00021.x

Chowdhury, A.; Ghosh, T. K.; Khatua, S.; Hore, S.; Kumari, P.; Kajal, K. and Jana, P. (2025). Effect of different feeding regimes in amur common carp fingerlings: Compensatory growth, physio-metabolic responses, and expression of IGF-1 gene. Aquatic Living Resources, 38, 4. https://doi.org/10.1051/alr/2025003

Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics, 11(1): 1–42. https://doi.org/10.2307/3001478

FAO. (2020). The state of world fisheries and aquaculture 2020. Sustainability in action. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/ca9229en

Sultan. F. A. M. (2013*).* Effect of starvation on oxygen consumption and some blood parameters of the common carp *(Cyprinus carpio* L.). Basrah Journal of Agricultural Sciences, 26(2): 20–36. College of Agriculture, University of Basrah.

Jobling, M. and Koskela, J. (1996). Interindividual variations in feeding and growth in rainbow trout during restricted feeding and in a subsequent period of compensatory growth. Journal of Fish Biology, 49(4): 658–667. https://doi.org/10.1111/j.1095-8649.1996.tb00066.x

Klahan, R.; Yuangsoi, B.; Whangchai, N.; Ramaraj, R.; Unpaprom, Y.; Khoo, K. S. and Pimpimol, T. (2023). Biorefining and biotechnology prospects of low-cost fish feed on Red tilapia production with different feeding regime. *Chemosphere*, *311*, 137098. https://doi.org/10.1016/j.chemosphere.2022.137098

Krogdahl, Å. and Bakke-Mckellep, A. M. (2005). Fasting and refeeding cause rapid changes in intestinal tissue mass and digestive enzyme capacities of Atlantic salmon (*Salmo salar* L.). Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 141(4): 450–460. https://doi.org/10.1016/j.cbpb.2005.07.002

Mattila, J., Koskela, J. and Pirhonen, J. (2009). The effect of the length of repeated feed deprivation between single meals on compensatory growth of pikeperch *Sander lucioperca*. Aquaculture, 296(1–2): 65–70. https://doi.org/10.1016/j.aquaculture.2009.07.017

Miriam, F. and Ana, S. (2011). Physiological changes during starvation in fish. In Biology of starvation in humans and other organisms (pp. 347–356). Nova Science Pub Inc.

Muheisen, F. D. (1983). Fish diseases and parasites. 1st ed. Basrah University Press.

Paul, A.; Baral, B.; Parida, S.; Naveen, N. D. and Sahoo, P. K. (2022). Mixed infections in tropical freshwater fish culture systems: A potential emerging threat for successful aquaculture. Aquaculture Asia, *26*: 20–24.

Singh, P. K.; Gaur, S. R. and Chari, M. S. (2006). Growth performance of *Labeo rohita* fed on diet containing different levels of slaughterhouse waste. Journal of Fisheries and Aquatic Science, 1(1): 10–16.

Solberg, C.; Willumsen, L.; Amble, S.; Johanessen, T. and Sveier, H. (2006). The effects of feeding frequencies on seasonal changes in growth rate and chemical composition of farmed cod (*Gadus morhua*). Aquaculture Nutrition, *12*(2): 157–163. https://doi.org/10.1111/j.1365-2095.2006.00401.x

Tacon, A. G. J. and Metian, M. (2015). Feed matters: Satisfying the feed demand of aquaculture. Reviews in Fisheries Science & Aquaculture, 23*(1), 1–10. https://doi.org/10.1080/23308249.2014.987209*

Won, E. T. and Borski, R. J. (2013). Endocrine regulation of compensatory growth in fish. Frontiers in Endocrinology, 4, *74.* https://doi.org/10.3389/fendo.2013.00074

Yengkokpam, S.; Debnath, D.; Pal, A. K.; Sahu, N. P.; Jain, K. K.; Norouzitallab, P. and Baruah, K. (2013). Short-term periodic feed deprivation in *Labeo rohita* fingerlings: Effect on the activities of digestive, metabolic and anti-oxidative enzymes. Aquaculture, 412–413, 186–192. https://doi.org/10.1016/j.aquaculture.2013.07.001

Zheng, J. L.; Zhu, Q. L.; Shen, B.; Zeng, L.; Zhu, A. Y. and Wu, C. W. (2016). Effects of starvation on lipid accumulation and antioxidant response in the right and left lobes of liver in large yellow croaker (*Pseudosciaena crocea*). Ecological Indicators, 66: 269–274. https://doi.org/10.1016/j.ecolind.2016.01.046