Effects of Feeding Frequency on Growth, Feed Efficiency, Body Composition, and Biochemical Responses in Common Carp Fingerlings (*Cyprinus carpio*)

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Abstract

This research aimed to examine the impact of various feeding frequencies on growth performance, feeding utilization, body composition and serum biochemical parameters in fingerling common carp (*Cyprinus carpio*) over seven week period. Fish were offered a commercial diet at four feeding intervals; once (F1), twice (F2), three times (F3) and four times daily (F4). Key performance metrics such as final weight, weight gain, daily weight gain, specific growth rate (SGR), feed intake (FI), protein intake (PI), feed conversion ratio (FCR), feed conversion efficiency (FCE) and protein efficiency ratio (PER) were significantly influenced by feeding frequency ($P<0.05$). Fish in the F3 and F4 groups demonstrated superior growth and feed utilization, with F4 showing the most notable improvement. Whole body proximate composition analysis indicated significant changes in crude protein, lipid and ash content due to feeding frequency. Fish fed at F2 and F4 had the highest crude protein levels, while lipid content increased progressively with more frequent feeding. Serum biochemical indicators such as AST, ALT, amylase, and glucose levels were significantly raised in fish fed more frequently, particularly in the F4 group, though all remained within physiologically acceptable ranges. In contrast, lipase and ALP levels decreased, suggesting enhanced nutrient assimilation. The study exhibited that feeding fingerling *Cyprinus carpio* three to four times daily improves growth performance, feed efficiency, and body composition, without compromising health. These findings emphasize the importance of optimized, species-specific feeding strategies in aquaculture to promote sustainability, improve productivity, and maintain fish welfare. Feeding frequency have to be carefully managed to balance growth benefits with economic and ecological considerations in intensive aquaculture systems.

Key words: feeding frequency, common carp, growth response, body composition, biochemical indicators

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Introduction

The aquaculture industry significantly contributes to meeting the worlds food demand. plays a vital role in global food security, providing nearly half of the world's animal-based protein through fish, which is a cost-effective and protein-rich resource [1]. As modern aquaculture has evolved, efficient feed utilization has become a key factor in optimizing fish growth and nutrient deposition, thereby improving overall production [2]. The common carp (*Cyprinus carpio*) is widely found in nutrient rich (eutrophic) fresh water habitats throughout Europe and Asia. Their popularity in aquaculture stems from several favorable traits, including rapid growth, efficient feed conversion, an enhanced ability to utilize carbohydrates and plant-based proteins, and strong resilience to environmental fluctuations and diseases. These characteristics make them a vital food source for meeting the demands of a growing global population [3].

Feed is the most expensive variable in aquaculture operations, representing 40–60% of operational costs depending on the intensity of culture [4]. Thus, understanding fish nutritional requirements and applying effective feeding strategies are essential to decline waste, promote growth, and ensure economic viability [5]. Appropriate feed management during the grow-out phase significantly influences profitability and competitiveness [6]. Optimizing feeding practices specifically feeding rate and frequency is critical to achieving balance. Overfeeding leads to increased costs, poor water quality, and reduced growth due to excess waste and oxygen depletion. Conversely, underfeeding results in poor growth, higher competition, increased mortality, and lower fish welfare [7]. Therefore, adjusting feeding frequency is essential to ensure efficient nutrient utilization while minimizing feed waste and water quality deterioration.

Feeding strategies essential to consider ration size, feeding frequency, timing, and efficient feed distribution [8]. These factors vary based on species, fish size, and environmental conditions [9]. Feeding frequency, in particular, strongly influences early growth, survival, and physiological development [10, 11]. Internal factors like digestive activity and hormonal regulation, along with external factors such as food type and ecological conditions, also impact feeding efficiency and fish growth [12, 13].

During the fingerling stage, efficient feeding strategies are particularly crucial to support rapid growth and physiological development. Studies have shown that inappropriate feeding frequency can lead to suboptimal growth, poor feed conversion, and stress-induced metabolic disturbances [14,15]. Growth performance and feed utilization parameters such as specific growth rate (SGR), feed conversion ratio (FCR)and weight gain (WG) are commonly employed to assess the impact of feeding regimes. Moreover, feeding frequency can influence body composition, particularly the deposition of muscle protein and lipid content, which are important indicators of fish quality and health [16, 17]. In addition, serum biochemical parameters such as glucose, total protein, cholesterol, and enzyme activity (e.g., AST, ALT) provide an analysis of the physiological responses and general health status of fish subjected to varying feeding frequencies [18, 19].

Given the importance of efficient feeding practices, this trial aims to investigate the impact of varying feeding frequencies on feed utilization efficiency, growth performance, body composition and serum

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biochemical parameters in fingerling *Cyprinus carpio*.

2. Material and methods

2.1. Experimental diet

The commercial pelleted diets (Super fish) were purchased from Barah feed company in Erbil and used as an experimental diet, which were contained (%33 crude protein, %8 lipid and 2957 metabolic energy kcal kg^{-1}). The formulation of dietary experiment and proximate composition of the diets are presented in Table 1.

Table 1: Formulation and proximate composition of the experimental diets (on dry weight bases)

Ingredient	g kg^{-1}
Soybean meal	540
Corn meal	150
Fishmeal	100
Mineral premix	25
Soya oil	50
Wheat flour meal	90
Wheat bran meal	33
Vitamin Premix	11
Enzyme	1
Proximate composition	
Moisture	10.67
Protein %	32.7
Fat %	7.6
Ash %	6.7
Fiber %	4.3
Met. Energy kcal/kg	2957

2.2. Fish and Experimental design

400 fingerlings of common carp (*Cyprinus carpio*) were sourced from a privately operated hatchery situated in Gwer town, within Erbil governorate of the Kurdistan Region of Iraq. Following collection, the fish were transferred to the outdoor aquaculture facility containing rectangular concrete ponds at the Grdarasha research station, joined with the Fish health and production, College of Agricultural Engineering Sciences- Salahaddin university Erbil. A total of two hundred and forty healthy fish were randomly allocated across twelve rectangular concrete pond, each measuring nearly $2m^3$ in volume (2m in length x 1m in width x 1m in depth), with a

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stoking density of twenty fish per pond. The initial mean weight of the fish was 17.967 ±0.037. The fish were provided with commercial diet containing (33% crude lipid, 8% crude lipid, and metabolizable energy content of 2957 K kal kg^{-1}. The fish were distributed into triplicate groups and cultured in separate ponds. Feeding was carried out over seven weeks.

The fish were fed at 3% of their live body weight, with different feeding frequencies as follows:

F1: Once daily at 08:00
F2: Twice daily at 08:00 and 17:00
F3: Three times daily at 08:00, 12:30, and 17:00
F4: Four times daily at 08:00, 11:00, 13:00, and 17:00

Fish biomass was monitored at weekly basis, and feeding rates were adjusted in accordance with observed changes. Continuous aeration was provided using an electric aerator, and approximately two-thirds of the pond water was substituted biweekly to maintain optimal water quality.

2.3. Water quality measurements

Water collection was conducted at each concrete pond at a depth of 15 cm to evaluate both chemical and physical water quality parameters. Daily measurements encompassed pH, total dissolved solid (TDS), electrical conductivity (EC), dissolved Oxygen (DO) and Temperature.

The pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature (TEMP) were measured in site using portable multi parameter instrument (Hanna H198129, EC; manufactured in Mauritius). Dissolved oxygen (DO) concentrations were determined on site utilizing a portable DO meter (AZ 8403) based on electrometric method. In addition, water samples were analyzed weekly for ammonia (NH_3) and nitrate (NO_3) concentrations. All measured water quality parameters were within acceptable limits for fish performance, as outlined by Boyd [20].

During the experiment, the means of dissolved oxygen was 6.98 ± 0.08 mg/L, water temperature 13.06 ± 2.38 °C, pH 7.90 ± 0.03, TDS 328.25 ± 4.90 mg/L, Ec 656.06 ± 4.21 µS/cm, ammonia was 1.33 ± 0.22 mg/L and nitrate 27.23 ± 1.19 mg/L.

2.4. Fish growth performance

After a 49-day feeding trial, the equations were employed to assess growth performance and feed utilization:

- Weight Gain (g/fish) = Final biomass (g) – Initial biomass (g)
- Specific Growth Rate (SGR, %/day) = (LN Final body weight – LN Initial body weight) / Number of feeding days × 100
- Daily Weight Gain (g/day) = Total weight gain (g) / Number of feeding days
- Feed Conversion Ratio (FCR) = Total feed intake (g) / Total weight gain (g)
- Feed Conversion Efficiency (FCE, %) = Liveweight gain(g)/Total feed intake (g)Live weight gain (g) / Feed intake (g) Liveweight gain(g)/Feed intake (g) × 100
- Protein Efficiency Ratio (PER) = Total wet weight gain (g) / Dry weight of protein consumed (g).

2.5. Proximate Analysis

Proximate analysis was performed on both the experimental diets and the fish specimen. At the start of the study, ten fish were collected, dried, and homogenized into a fine powder for baseline analysis.

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Following the seven weeks feeding trial, two specimens were randomly sampled from each pond, resulting in a total of six specimens per treatment group, for subsequent proximate composition assessment, subsequent the standard methods outlined by the AOAC [21]. All analyses were performed in triplicate to ensure accuracy.

The fish samples were dehydrated for 48 hours at 105 °C in fan assisted oven until their weight remained. The fish were dried and then pulverized into a powder for additional examination. Weight loss following drying was used to calculate the moisture content. The Kjeldal method, which involves digestion, distillation, and titration, was used to measure the crude protein concentration. digestion, distillation, and titration. Using a flying droplet siphon, crude fat was removed. The samples were burned for 24 hours 550 °C in a muffle furnace to assess the amount of ash present. Crude fat was extracted using the flying droplet siphon method. Crude fiber analysis was performed through a sequential process: the samples were treated with diluted sulfuric acid and boiled, followed by filtration. Then, sodium hydroxide (NaOH) was added, and the mixture was boiled and filtered again. The final residue was considered the fiber content.

All analyses were performed at the Barash feed company laboratory, located in Erbil, in the Kurdistan Region of Iraq.

2.6. Biochemical analysis of the blood

A needle was inserted into the ventral body wall of the six fish per treatment group for drawing blood from their caudal vein at the end of the trial. The fish were starved for 24 hours prior for sampling collection. Collected blood was immediately transferred to vacuum tubes comprising K3-EDTA as an anticoagulant. The blood samples were carefully transferred into vacuum K3-EDTA tubes. The blood samples were promptly inverted eight to ten times to provide adequate anticoagulation. Following this, the tubes were put on ice and brought to the laboratory for biochemical examination. For serum preparation, additional blood samples were collected into clot activator and sun-val tubes. These samples were kept on ice and immediately centrifuged at 3500 rpm for 15 minutes to facilitate clot separation. The resulting supernatant (serum) was carefully aspirated and transferred into pre labeled Eppendorf tubes. Serum sample were then stored at 80 °C until subsequent biochemical analyses were performed.

Serum biochemical assessments were measured including aspartate aminotransferase (AST), alanine transaminase (ALT), alkaline phosphate (ALP) amylase and lipase enzymes, total protein (TP), albumin (ALB), Globulin, and glucose level. The tests were performed at Alpha Medical laboratory for Disease Diagnosis in Erbil city using Cobas c111.

2.7. Statistical analysis

All data are expressed as mean ± standard error (SE). prior to conducting statistical analysis, the assumption of normality and homogeneity of variance were assessed. To evaluate the impact of feeding frequency on growth performance, body composition, feed efficiency and serum biochemical parameters, a one-way analysis of variance (ANOVA) was conducted using SPSS software (version 26). When significant differences were detected, Duncan's multiple range test was employed for post

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hoc comparisons. Statistical significance was conventional as threshold of $P < 0.05$.

3. Results

The growth performance and feed utilization of fingerling common carp were evaluated over a 49-day period under different feeding frequencies (Table 2). No mortality rates were observed during the entire study. Fish fed F4, F3 and F2 demonstrated statistically significant increase (P<0.05) in FW, DWG, WG and SGR compared to fish fed F1. The fish fed F4 exhibited significantly higher growth parameters (P<0.05) followed by those fish fed F2 and then fish fed F3. The results clearly showed that two, three and four feeding frequency positively affected growth performance. A significant increase (P<0.05) in feed intake (FI) and protein intake (PI) was detected with increasing feeding frequency. Fish fed F2, F3 and F4 significantly exhibited better FCR compared to those fish fed F1. The best FCR observed in fish fed F4. The fish fed F4 revealed significantly higher FCE and PER (P<0.05) compared to those fed F2 and F3. In contrast fish fed F1domonstrated significantly lower FCE and PER.

Table (2): Effects of different feeding frequencies on growth performance and feed conversion in common carp fingerlings.

Parameters	F1	F2	F3	F4
IW	17.85±0.08	17.97±0.07	17.98±0.04	18.07±0.07
FW	23.62±0.25 ^{c}	26.15±0.35 ^{b}	26.10±0.65 ^{b}	28.13±0.51 ^{a}
DWG	2.75±0.13 ^{c}	3.90±0.14 ^{b}	3.87±0.32 ^{b}	4.79±0.21 ^{a}
WG	5.77±0.27 ^{c}	8.18±0.29 ^{b}	8.11±0.66 ^{b}	10.1±0.44 ^{a}
SGR	0.67±0.03 ^{c}	0.893±0.02 ^{b}	0.885±0.06 ^{b}	1.05±0.03 ^{a}
FI	26.2±0.24 ^{c}	27.9±0.28 ^{b}	28.0±0.37 ^{b}	29.5±0.14 ^{a}
FCR	4.56±0.17 ^{a}	3.42±0.93 ^{b}	3.49±0.25 ^{b}	2.94±0.11 ^{b}
FCE	21.98±0.86 ^{c}	29.30±0.78 ^{b}	28.90±2.03 ^{b}	34.11±1.33 ^{a}
PER	0.69±0.03 ^{c}	0.92±0.02 ^{b}	0.91±0.06 ^{b}	1.07±0.04 ^{a}
PI	166.71±1.50 ^{c}	177.50±1.76 ^{b}	178.27±2.37 ^{b}	187.55±0.87 ^{a}

Values in the same row with different subscripts are significantly different (P<0.05).
Data is presented as (Mean ± SE).

Nutritional composition of whole-body fingerling common carp at the end of the experimental period given in Table 3. The moisture content of whole-body fish was not significantly affected by feeding frequency (P>0.05). The crude protein content in fish fed F4 and F2 was significantly elevated (P<0.05) relative to those fed F1. Conversely fish fed F3 exhibited a significantly reduced crude protein content. Crude lipid content improved in response to higher feeding frequency; though, a statistically significant difference (P<0.05) was observed only in fish subjected to feeding frequency F3 and F4. The crude ash content in fish fed F1, F2 and F3 showed a slight increase, however the differences were not statistically significant. In contrast fish fed F4 observed a significantly lower crude ash content.

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Table (3): Effect of feeding frequency on body chemical composition of whole-body fingerling common carp.

Parameters	F1	F2	F3	F4
Moisture	73.50±1.82	73.59±2.01	75.54±0.97	78.32±0.95
Crude protein*	53.71±0.46 [b]	55.96±0.42 [a]	51.00±0.89 [c]	56.52±0.37 [a]
Crude lipid*	23.99±0.46 [b]	25.61±2.07 [ab]	28.71±0.20 [a]	27.96±0.47 [a]
Crude ash*	7.72±0.76 [ab]	8.33±0.68 [ab]	9.04±0.20 [a]	7.02±0.22 [b]

Values in the same row with different subscripts are significantly different (P<0.05).
Data is presented as (Mean ± SE).
*Dry matter basis.

Serum biochemical parameters of fingerling common carp are presented in Table 4. The AST activity in fish fed diets F1, F2 and F3 exhibited fluctuations but remained significantly lower (P<0.05) than that obtained in fish fed diet F4. The lowest ALT activity was obtained at fish fed F2 and F1, while fish fed F4 and F3 recorded significantly higher (P<0.05) ALT activity. The ALP significantly decreased (P<0.05) with increasing feeding frequency, the height ALP activity was obtained in fish fed F1, while the and the lowest ALP activity was obtained in fish fed F4. Amylase levels varied between fish fed different feeding frequencies and the high significant (P<0.05) levels was found in fish fed F4. Fish fed with diets F2 and F1 showed significantly higher lipase levels (P<0.05) compared to those fed with F4 and F3, respectively. Globulin levels were significantly higher (P<0.05) in fish receiving the F4 diet, while fish fed with F2 exhibited significantly lower globulin levels. Additionally, glucose levels were significantly elevated (P<0.05) in fish fed diets F3 and F4 compared to those fed diet F1. There were no significant differences (P<0.05) There were no significant differences in the cholesterol (CH), triglycerides (TG), total protein and albumin levels among the fish fed at different feeding frequencies.

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Table (4): Effect of feeding frequency on the biochemical parameters of common carp fingerling.

Parameters	F1	F2	F3	F4
AST	314.3±6.64 ^{b}	286.7±5.21 ^{b}	362.0±5.51 ^{b}	573±58.4 ^{a}
ALT	46.4±11.6 ^{b}	40.8±5.99 ^{b}	148.0±16.7 ^{a}	158.0±19.9 ^{a}
ALP	53.0±3.21 ^{a}	37.3±1.45 ^{b}	20.0±3.46 ^{c}	13.0±2.89 ^{c}
Amylase	116.0±4.93 ^{b}	108.0±5.20 ^{b}	110.0±4.93 ^{b}	133.3±1.76 ^{a}
Lipase	25.7±1.45 ^{a}	26.3±0.67 ^{a}	17.3±0.88 ^{b}	19.3±1.76 ^{b}
CH	210.3±14.9	211.7±10.2	214.3±4.37	188.3±16.7
TG	775.0±47.4	673.0±75.2	661.0±29.0	626.3±94.3
Total Protein	4.13±0.03	5.60±1.80	5.07±0.30	4.30±0.36
Albumin	1.10±0.06	2.77±1.77	1.97±0.19	1.37±0.22
Globulin	3.13±0.09 ^{ab}	2.90±0.12 ^{b}	3.47±0.22 ^{ab}	3.60±0.21 ^{a}
Glucose	51.1±5.40 ^{b}	91.9±18.6 ^{ab}	127.5±5.63 ^{a}	122.1±16.3 ^{a}

Values in the same row with different subscripts are significantly different (P<0.05).
Data is presented as (Mean ± SE).

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4. Discussion

Feeding frequency significantly influenced the growth performance and feed utilization of common carp (*Cyprinus carpio*) fingerling. Growth performance increased significantly with the rise in feeding frequency from one (F1) to four (F4) times per day. In this study, feeding frequency had significant effect on final weight (FW), weight gain (WG), specific growth rate (SGR), and daily weight gain (DWG) of common carp fingerling. These findings correlate with study of da Sliva *et al.*, [22] indicated that Lebranche mullet juveniles had observed significant WG, SGR and FW in fish fed diet three, five and seven times a day than fish fed diet one time per day reread in recirculation systems. Also, Wang *et al.*, [23] found that feeding *Schizothorax wangchiachii* two, three and four times per day resulted in significantly higher FW and SGR compared to feeding daily. Very recently, Huang *et al.*, [24] reported that increased feeding frequency from one to four times per day significantly enhanced FW, WG and SGR in hybrid grouper (*Epinephelus fuscoguttatus* × *Epinephelus lanceolatus*). This outcome may be attributed to the number of daily meals, as more diurnal feeding has been shown to enhance nutrient utilization compare to a single daily feeding [25]. In contrast with our research, Nasrin *et al.*, [26] determined that Nile tilapia GIFT (*Oreochromis niloticus*) reared in hapa system, feeding twice a day exhibits better FW, WG and SGR than three and four times a day but no significant differences were reported between the treatments. Furthermore. Wang *et al.*, [13] demonstrated that largemouth bass (*Micropterus salmoides*) cultured in in-pond raceway closed culture system for 120 days observed significantly lower FW, WG and SGR when fed twice daily, compared to those fed three or four times per day.

Feed intake (FI), feed conversion efficiency (FCE), protein efficiency ratio (PER) and protein intake (PI) in common carp fingerlings elevated significantly with increasing feeding frequency. Similar to our study, Wu *et al.*, [27] found that hybrid beam juveniles tend to significantly increase with increasing feeding frequency from 0.5, one, two, three, and four times a day. Recently, da Silva *et al.*, [22] indicated that the TFI increased significantly with increasing feeding regimes at one, three, five and seven times a day. While, Feed intake significantly decreased when Bagird catfish juveniles fed at three and four times daily [28], and no significant differences were found in FI, FEC and PER among rabbitfish (*Siganus rivulatus*) fry fed two, three and four times per day [29].

Protein intake (PI) increased significantly with increasing feeding frequency. In Japanese flounder (*Paralichthys olivaceus*) reported by Uyan *et al.*, [30]. PER and FCE improved significantly with feeding frequency *S. rivulatus* fed at three levels (two, three and four) in a day [29]. In contrary with our results, the results of Oh *et al.*, [31] recorded that there were no significant differences in PER that there were no significant differences in PER when dark- banded rockfish fed at different meals for 70 days. Moreover, Wang *et al.*, [23] found that there was no significant effect on FCE when *S. wangchiachii* fed at different frequencies for eight weeks.

The feed conversion ratio (FCR) is a critical parameter used to determine the efficiency which with fish convert a unit of feed into corresponding gain in the body weight. In contract with our findings, Daudpota *et al.*, [32]; Abdel-Aziz *et al.*, [29] and Wu *et al.*, [27] indicated that FCR improved significantly with increasing at different feeding frequencies fed to Nile tilapia, rabbitfish and hybrid bream, respectively. In addition, Rahman *et al.*, [33] showed that *O. niloticus* fry fed four and three meals per day had significantly better FCR than fish fed two times per day. In contrast to the finding of the present study, Busti *et al.*, [18] reported that gilthead sea bream (*Sparus aurata*) fed at

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varied frequencies had no significant effect on FCR. Also, Nasrin *et al.,* [26] found that FCR tend to be worse with increasing feeding frequency fed to GIFT *O. niloticus*. Furthermore, Huang *et al.,* [24] indicated that hybrid grouper fed from one to four times a day had slightly decreased without any significant differences between treatments. One of the major reasons of the improvements of growth and feed indices in this study is with different feeding frequency may have better intestinal digestion, which would promote growth and feed utilization Tian *et al.,* [7].

As a standard, the nutritional quality of the fish is usually assessed by whole body chemical composition [34], and whole-body chemical composition affected by several factors including feeding frequency [35]. The finding of this study showed that feeding frequency significantly affects the crude protein, crude lipid and crude ash. Increased feeding frequency, improved crude protein in fish fed F2 and F4, then fish fed F3 decreased compare to F1 fed fish. Crude lipid tends to increase with increasing feeding frequency. These findings are similar to those found in other study on Japanese flounders [30], hybrid grouper [24], fed at different feeding frequencies. The possible reason for that is fish fed at adequate food amount through increase feeding frequency decreases competition for food and cannibalism, which subsequently lowers energy supplies and therefore enables greater accumulation of protein and lipid in the body of the fish [36]. The Ash increase with increasing feeding frequency up to F3, then significantly decreased compare to fish fed F1. Similar results indicated by Güroy *et al.,* [37] who found that crude ash in the body of (*Argyrosomus regius*) increased gradually with increasing feeding frequencies but the significant differences recorded at fish fed at four times daily. Moisture content in the fish increased with higher feeding regimes, however, no significant trends were reported among the treatment groups. The findings of this study agree with the studies done by Cadorin *et al.,* [38] on farmed Nile tilapia and Güroy *et al.,* [37] on juvenile meagre fed at different feeding frequencies.

In the present study, serum ALT and AST levels were affected by feeding frequency, significant changes appeared in the fish fed at F3 and F4. Our results are in agreements with the findings of Guo *et al.,* [39] indicated that juvenile dolly varden char *Salvelinus malma* fed at three, four, five and six times daily increased significantly than fish fed one or two times daily. This increase could be an indicates that the un adequate feeding frequency might cause hepatic damage. ALP level was not affected by feeding frequency. Similar to our study Guo *et al.,* [39] and Wang *et al.,* [23] documented that increasing frequency had no significant influence on ALP level.

The most important digestive enzyme are amylase and lipase which involved in the digestion of carbohydrate and lipid [40]. Amylase activity level exhibited a stable trend from F1, F2 or F3 a day followed by significant increase when fish fed F4. In disagreement with the present result, the juvenile *Megalobrama amblycephala* (blunt snout bream) indicated that higher level in amylase activity due to a further increase in feeding frequency from one to three times, led to a reduction in amylase activity [7]. The juveniles gilthead sea bream (Sparus aurata) reported that improvement in amylase level as feeding frequency increased from one to two meals daily, but three meals daily led to reduce in amylase activity [18]. Furthermore, da Sliva *et al.,* [22] indicated that in juveniles Lebranche mullet amylase activity level had significantly higher in fish fed at three times daily than other fish fed one and seven times daily. Lipase activity level significantly reduced in fish fed F3 or F4 than fish fed F1 or F2. In contrast to our findings Pedrosa *et al.,* [41] Juveniles arapaima (*Arapaima gigas*) exhibited that there was no significant in lipase activity among various feeding strategy,

including self feeding system, feeding to apparent satiation two or three times per day, and feeding at a fixed ration. In juveniles white mullet Lebranche (*Mugil liza*), lipase activity was escalation in fish fed three times daily compared to those fed once, five or seven times per day [22]. A reasonable description for this effect is that, although maintaining a full complement of gastrointestinal enzyme activity requires additional energy outflow, it represents an adaptive strategy that enables the species to competently utilize all available food resources in the environment [41].

In the current study, CHO, TG, TP, ALB and GLO contents were not significantly affected by increasing feeding frequency. Similar findings were reported in the study conducted by Guo *et al.,* [39] showed that *Salvelinus malma* fed at six different frequencies were no influenced significantly in TP, ALB, GLO, CHO and TG among the groups [39]. In *Sparus aurata* fed at different feeding frequency observed no significant effect in CHO, TG, TP and ALB contents [18]. Serum glucose levels were significantly enhanced in fish fed diet F3 and F4 compared to those fed diets F1 and F2. Similar to our study, mullet juveniles fed five and seven times daily had higher glucose due to overloaded dietary carbohydrate, glucose increase [42, 43, 44].

5. Conclusion

In conclusion, this study clearly reveals that feeding frequency significantly affects growth performance, feed utilization, and physiological responses of common carp fingerling. Fish fed more frequently up to four times per day exhibited improved growth performance, as evidenced by increased final weight, weight gain, specific growth rate, and daily weight gain. Improved protein efficiency ratio, feed conversion efficiency and feed intake, further suggest more effective nutrient assimilation at higher feeding frequencies. These findings align with previous studies on various fish species, reinforcing the positive relationship between feeding frequency and performance.

Whole-body composition also improved, with increased levels of crude protein, lipid, and ash content, indicating enhanced nutritional quality. While physiological parameters such as serum ALT, AST, and glucose levels rose with feeding frequency, they remained within normal physiological limits, suggesting adaptive metabolic responses rather than health impairments. Digestive enzyme activity showed variable trends, likely reflecting species-specific physiological mechanisms.

Overall, feeding fingerling common carp three to four times daily appears optimal for promoting growth, feed efficiency, and favorable body composition, while maintaining fish health. These results emphasize the importance of species-specific feeding strategies in aquaculture management.

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