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Winter Dietary Protein Impacts on Growth performance of *Cyprinus carpio*

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ABSTRACT

This study evaluated how feeding the common carp (*Cyprinus carpio*) at multiple protein levels affected their growth and body composition during the winter season. Four experimental diets with varying protein levels were tested, with protein levels of 30% (T1), 28% (T2), 26% (T3), and 35% (T4), respectively. Fish were obtained and kept in a water culture pond with dimensions of 4x4x3 meters. Fish average weight was 148.7± 5.76g, while its length measurements were recorded at 24.33± 2.45cm, fork length at 21.15± 2.34cm, and standard length at 18.96± 1.66cm. The fish were purchased from a hatchery farm in Mosul City, northern Iraq. For 90 days, the fish were fed experimental feed once daily until they reached satiation. Compared to other treatments, fish fed T2 (28% protein) showed higher daily weight gain, total weight gain, weight growth rate, relative growth rate, metabolic growth rate, and specific growth rate. The feed diet T2 had the highest Fulton and modified condition factor, reaching 4.84± 0.14; 2.81± 0.03, whereas the highest condition factor was recorded (3.34± 0.16; 2.1± 0.03) for feed treatment T3. Feeding indicators in the feed treatment T2, such as total feed intake, daily feed consumption, and total protein productivity, were greater. The protein efficiency ratios of the fish groups fed formulations T2, T1, and T3 were recorded at 1.32± 0.004, 1.34b± 0.004, and 1.425c± 0.007%, respectively. In comparison, a significant difference was detected for the fish group consuming feed T4, with a value of 1.058d± 0.009%. For the length-weight relationships, an isometric growth (26, 35%) was recorded for T3, an allometric positive growth for T2, and a negative growth for T1.

INTRODUCTION

In recent years, Iraq's fish breeding sector has undergone an important change, with significant successes in both the quality and quantity of breeding methods. This improvement has been distinguished by a growing interest from investors in the fish breeding industry, resulting in a greater diversity of fish species being raised.

Additionally, this increase in breeding activities has been supported by the adoption of novel approaches, such as the use of nets and foreign-origin breeding apparatus, in the construction of new fish ponds. Furthermore, there has been a huge increase in the number of fish hatcheries in Iraq supplying fish fingerlings **(Al-Mahmood, 2017)**. The common carp (*Cyprinus carpio*), locally known as Samti, has a wide geographical range over Eurasia, encompassing territories from the West of Europe to China, Korea, Japan, South East Asia, and the Middle East **(Chen *et al.*, 2022)**. Some scholars continue to debate the actual origins and natural range of the common carp. This can be related to its extended history of cultivation in Europe and Asia, resulting in numerous translocations across a significant period **(Bernery *et al.*, 2022)**. Cyprinids are regarded as the primary group of teleost fish farmed on a global scale, as indicated by their significant quantity. According to the Food and Agriculture Organization (FAO); in 2022, the total production of the common carp in the aquaculture and fishing sectors reached about 3.3 million tons **(Lichna *et al.*, 2023)**. This fish has become widespread in commerce due to a variety of advantages, including its quick development, ability to adapt to different conditions, ease of management, suitability for dense farming, ability to survive on low protein diets, and the existence of highly productive strains from selective breeding programs **(Chistiakov & Voronova, 2009)**. The growth of population sizes and the rising need for fish meat are driven by fish affordability compared to the meat from domesticated animals like poultry and ruminants, along with the high nutritional value of animal protein abundant in essential amino acids, as well as the presence of essential unsaturated fatty acids, vitamins, and minerals **(Fadhil *et al.*, 2017)**.

Feed is a paramount factor in aquaculture. The expenses associated with feed significantly impact the overall operational costs of commercial fish farming, and these costs can ultimately determine the profitability of aquaculture enterprises **(Taherkhani *et al.*, 2020)**. In aquaculture, the cost of feed accounts for 60% of the total production cost **(Cazenave, 2021)**. Dietary protein constitutes a vital, albeit costly, nutrient in fish diets that exerts a direct influence on fish growth, feed intake, and feed expenses **(Ma *et al.*, 2020; Teles *et al.*, 2020)**. Insufficient levels of this nutrient in diets may give rise to compromised growth and unregulated feed intake, whilst excessive levels can lead to dietary imbalances, escalated feed expenses, nitrogen excretion, and the potential for aquatic pollution **(Mansano *et al.*, 2021)**. Therefore, it is essential to enhance the protein quality of diets to attain well-balanced diets and manage the escalating feed costs and aquatic pollution. The leading aim of this experiment was to determine the optimum protein level needed to maximize the growth of *C. carpio* in the winter season.

MATERIALS AND METHODS

Area of study and fish culture management

The study area for fish culture in fish farming is located in the northwestern part of Mosul Dam in Khanki Township, Duhok Governorate, Iraq. This place was selected based on its well-known reputation as the main hub for circular cage fish farms. It is worth noting that a significant number of fish farms of this nature have been established within this region **(Al Sulivany, 2023)**. A total of 4000 fish, from both sexes, were obtained from a hatchery farm in Nineveh. The fish had an average body weight (BW) of 148.7± 5.76g, and their length parameters included total length (TL) of 24.33± 2.45cm, fork length (FL) of 21.15± 2.34cm, and standard length (SL) of 18.96± 1.66cm. These fish were transported to Khanki township and released into a water culture pond measuring 4×4×3 meters. Subsequently, fish specimens were divided into four groups, each containing 1000 fish. The fish in each group were fed a floating diet with different protein concentrations, as designed according to the following scheme: T1 (30%), T2 (28%), T3 (26%), and T4 (35%). The feed used in this study was obtained from *Kimiyagran-e-taghziyeh* company in Iran. The composition of food includes 40% carbohydrates, 6% fat, 8% fiber, 10% ash, and 10% humidity.

Fish were fed this feed program for ninety days, with every day an eating volume equal to 3% of their expected mass depending on the fish's total biomass **(Ashraf *et al.*, 2023)**. Various instruments and a multimeter were used to evaluate the water parameters in the aquaculture pond aquarium **(Abduljabar *et al.*, 2020)**. These parameters, including temperature (18.7°C), pH (7.7), electrical conductivity (425µS/ cm), total dissolved solids (272ppm), turbidity (2.7), dissolved oxygen (7.5mg/ l), total hardness (275mg/ l), biological oxygen demand over 5 days (3.4mg/ l), total alkalinity (147mg/ l), and salinity (0.26ppt), were assessed. After a feeding period of 90 days, twenty fish were randomly selected from each group for data collection.

Data collection

Measurement of physical parameters

The body weight of fish was determined using a digital balance adventure **(Al Sulivany *et al.*, 2024)**. The length was measured using a slide caliper considering three different dimensions: TL, SL, and, FL **(Ullah *et al.*, 2022)**. The research conducted by **Hassan *et al.* (2021)** evaluated both the daily weight gain (DWG) and total weight gain (TWG). Additionally, other growth rates measures such as weight growth rate (WGR), relative growth rate (RGR), metabolic growth rate (MGR), specific growth rate (SGR), length-weight relationship (LWR), Fulton condition factor (*K*), modified condition factor (*Kb*), and relative condition factor (*Kn*), were assessed in separate studies by **Dietz *et al.* (2019)**, **Guo *et al.* (2021)**, **Lieke *et al.* (2021)**, **Ahmed *et al.* (2022)**, **White *et al.* (2022)**, **Mizory and Altaee (2023)** and **Mrdak *et al.* (2023)**.

DWG (g) = [(FW – IW)/t] × 100.
TWG (g/day) = (FW – IW).
WGR (%) = [(FW-IW) / IW] × 100.
RGR (%) = [(In (FW) – In (IW))/ IW] × 100.
MGR ($gkg^{0.8}$ day^{-1}) =(TWG) / [{$(IW/1000)^{0.8}$ + $(FW/1,000)^{0.8}$}] /2.

SGR (%) = [(ln (FW)-ln (IW))/ t] ×100.
LWR (g/cm) = a × L^b.
K = 100 × W/L^3.
Kb = 100 × W/L^b.
K = W/ ^W.

In the given equation, IW and FW represent the average initial and final weights of the fish; t denotes the duration of the experimental period; L stands for the fish's length in centimeters; 'a' signifies the rate of weight change concerning length (intercept); 'b' denotes the weight at unit length (slope), and ^W indicates the predicted weight.

Measurement of nutritional utilization

All parameters regarding nutrition, including total feed consumed (TFC), total protein consumed (TPC), the feed efficiency ratio (FER), the protein efficiency ratio (PER), protein productive value (PPV), net protein utilization (NPU), and feed conversion ratio (FCR), were examined in separate studies by **Mridula *et al.* (2011)**, **Folorunso *et al.* (2017)**, **El-Dahhar *et al.* (2018)**, **Prakash *et al.* (2020)**, **Ramadhan *et al.* (2021)** and **Colombo *et al.* (2023)**, using the subsequent equation:

TFC (g/day) = Number of fish× Average feed intake per fish × t.
DFC (g/day) = TFC/t.
TPC (g/day) = TFC × Protein content of the diet.
DPC (g/day) = TPC/t.
FER (%) = WG/Dry weight of the diet.
PER (%) = WG/Dry weight of protein.
PPV (%) = (WG/TPC) ×100.
NPU (%) = WG/ Total protein intake.
FCR = Feed consumed/WG.

Statistical analysis

All statistical analyses were performed with the Graph Pad Prism program (Version 8) (Graph Pad Prism Software, Finland). The morphological performances and feed utilization were performed by Kruskal-Wallis-tests (ANOVA). Data were expressed as means ± standard error of the mean (SEM) **(Al Sulivany, 2024)**. To establish the length-weight relationship (LWR) between length and body weight the log-transformed data were correlated with fish standard length and were assessed by linear regression **(Ullah *et al.*, 2022)**.

RESULTS

Growth performance and condition factor

Over a 90-day feeding period during the cold winter in northern Iraq, this study found that feeding the common carp a diet containing 28% protein (T2) significantly improved (P<0.05) growth performance and metabolic rate, including parameters such as DWG, TWG, WGR, RGR, MGR, and SGR. The mean values were 13.64±0.193 g/day, 1231± 18.4g/ day, 826± 14.33%, 44.46± 0.35%, 18.06± 0.11g/ $kg^{0.8}$ day^{-1}, and 3.114± 0.0054%, respectively, compared to fish fed diets with 30% (T1), 26% (T3), and 35% (T4) protein (Table 1 & Fig. 1A- F).

A significant difference in K values (P≤ 0.01) was observed, with fish fed the 28% protein diet (T2) having the highest K value (4.84± 0.14), compared to 3.61±0.15, 3.34± 0.16, and 3.56± 0.15 for T1, T3, and T4, respectively. In contrast, fish fed the 35% protein diet (T4) showed a significant increase in Kb value (P ≤ 0.05) at 2.854± 0.04, while T2 (28% protein) fish had a Kb value of 2.81± 0.03. The group fed a 26% protein diet (T3) showed the lowest Kb value (2.1± 0.03).

Kn values were highest in fish fed the 26 and 28% protein diets (T3: 2.63± 0.009; T2: 1.27± 0.004), while fish fed on the 30 and 35% protein diets showed lower Kn values (T1: 0.98± 0.002; T4: 0.99± 0.002), as shown in Fig. (1G- L)

Table 1. Growth performance and Fulton's condition factors of *C. carpio* over 90 days under the influence of four distinct experimental diets

Parameter	T1 (30%)	T2 (28%)	T3 (26%)	T4 (35)
ITL (cm)	23.95±1.65	24.05±0.243	24.1±1.99	24.33±2.1
FTL (cm)	32.29^{ad}±1.34	30.57^{bc}±1.12	32.57^{da}±1.5	33.24^{dc}±0.99
IFL (cm)	21.95±2.5	22.05±2.12	22.1±1.65	22.33±1.49
FFL (cm)	29.69^{ac}±2.4	28.07^{b}±1.629	30.07^{a}±2.745	30.74^{a}±1.65
ISL (cm)	19.95±0.54	20.05±0.36	20.1±0.78	20.33±1.43
FSL (cm)	24.69^{ab}±0.34	23.07^{b}±0.75	25.07^{a}±0.98	25.74^{a}±0.54
IBW (g)	151.9±5.33	149±7.44	151.9±7.43	151.5±8.22
FBW (g)	1189^{a}±22.5	1376^{b}±36.5	1142^{a}±36.61	1297^{b}±41.55
DWG (g/day)	11.53^{a}±0.224	13.64^{b}±0.193	11^{a}±0.23	12.72^{bc}±0.24
TWG (g/day)	1034^{a}±21.4	1231^{bd}±18.4	984.8^{c}±18.39	1146^{d}±22.69
WGR (%)	685.4^{c}±15.36	826^{bd}±14.33	652.1^{ac}±14.06	757^{dc}±15.91
RGR (%)	40.98^{a}±0.42	44.46^{bd}±0.35	40.11^{ac}±0.46	42.73^{cd}±0.49
MGR (gkg$^{0.8}$ day^{-1})	16.81^{a}±0.14	18.06^{c}±0.105	16.47^{ad}±0.14	17.5^{c}±0.27
SGR (%)	3.05^{c}±0.007	3.114^{a}±0.0054	3.032^{bc}±0.0068	3.087^{a}±0.008

Initial K	1.1±0.022	1.07±0.043	1.09±0.025	1.05±0.45
Final K	3.61[a]±0.15	4.84[b]±0.14	3.34[a]±0.16	3.56[a]±0.15
Initial *Kb*	2.11±0.06	2.11±0.054	2.11±0.06	2.17±0.03
Final *Kb*	2.44[a]±0.012	2.81[b]±0.03	2.1[c]±0.03	2.854[b]±0.04
Initial *Kn*	0.98[a]±0.005	0.98[a]±0.005	1.16[b]±0.008	0.99[a]±0.004
Final *Kn*	0.98[a]±0.002	1.27[b]±0.004	2.63[c]±0.009	0.99[a]±0.002

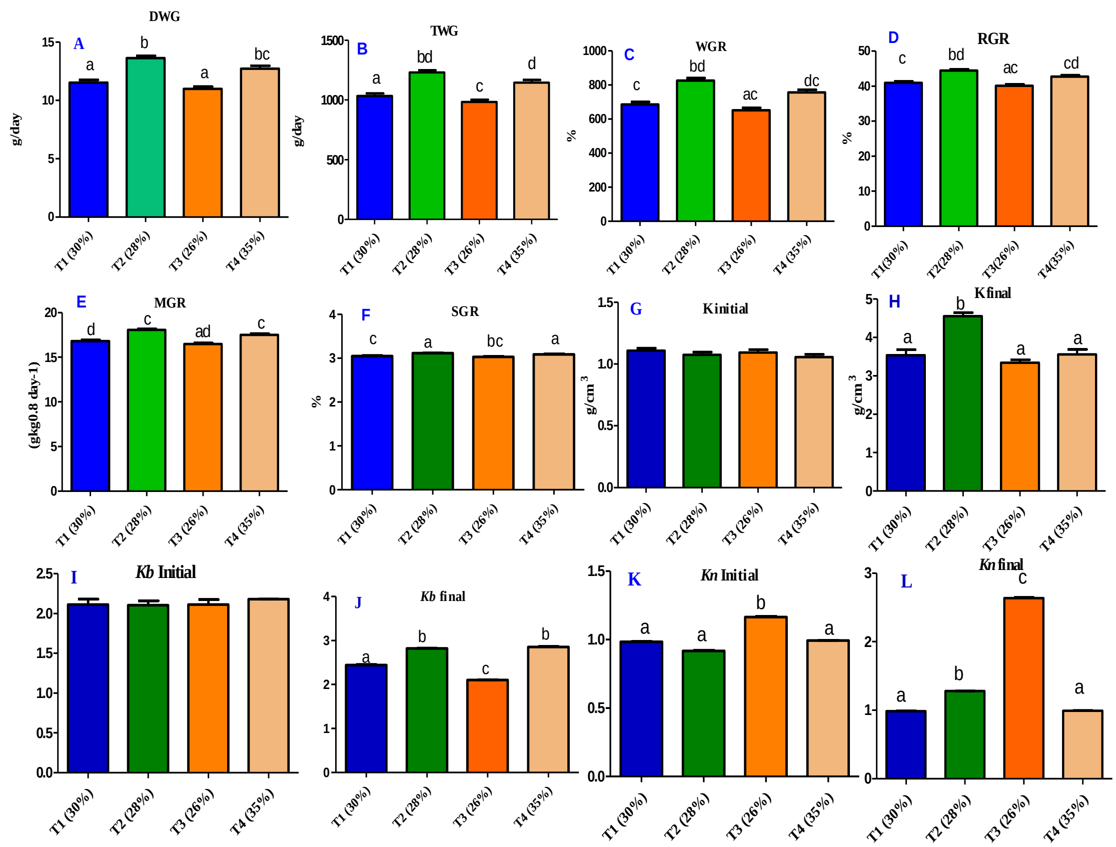

Fig. 1. The effect of varying levels of dietary protein on the growth performance and condition factor of *C. carpio*. Note, data are displayed as means with standard error (SE). Significant differences (*P*< 0.05-0.01) are indicated by distinct superscripts (a, b, and c). The abbreviations used include DWG for daily weight gain, TWG for total weight gain, WGR for weight growth rate, RGR for relative growth rate, MGR for metabolic growth rate, SGR for specific growth rate, *K* for Fulton condition factor, *Kb* for modified condition factor, and *Kn* for relative condition factor

Feed utilization measurement

The results indicate that varying concentrations of protein in fish diets lead to fluctuations in feed and protein utilization data, including daily feed consumption (DFC), total feed consumption (TFC), daily protein consumption (DPC), total protein consumption (TPC), feed efficiency ratio (FFR), protein efficiency ratio (PER), protein productive utilization (PPV), net protein utilization, and feed conversion ratio (FCR) in fish, are revealed in Table (2) and Fig. (2A, B, C, D, E, F, G, H, and I). Remarkably, fish fed a diet containing 28% protein (T2) showed increased levels of DFC and TFC compared to fish in groups T1 (30%), T3 (26%), and T4 (35%) ($P < 0.05$). This difference is supported by mean and standard error (SE) values of 0.45± 0.0057 and 41.28± 2.55, respectively. Conversely, a statistically significant increase ($P < 0.05$) in protein consumption was observed in the diets containing 35% (T4) and 28% (T2) protein compared to groups T1 and T3. The enhancement in feed efficiency was found to be statistically significant ($P < 0.05$) when fish were subjected to diets with a protein content of 28% (T2). However, the protein efficiency ratio (PER) and net protein utilization (NPU) deteriorated as the dietary protein intake increased, particularly evident in fish from groups T4 and T2. However, the PPV rate of fish in the T2 group exceeded that of T1, T3, and T4, attaining statistical significance at a lower level ($P < 0.05$). The T2 group demonstrated the best performance in fish farming, as evidenced by an FCR rate of 3.029± 0.0054, compared to T1 (3.098± 0.0094), T3 (3.12± 0.00915), and T4 (3.06± 0.008).

Table 2. The feeding utilization of *C. carpio* over 90 days under the influence of four distinct experimental diets

Parameter	T1 (30%)	T2 (28%)	T3 (26%)	T4 (35)
DFC (g/day)	0.39^{a}±0.006	0.45^{b}±0.0057	0.38^{a}±0.006	0.43^{bc}±0.007
TFC (g/day)	35.67^{a}±1.65	41.28^{c}±2.55	34.25^{a}±1.77	38.9bc±1.33
DPC (g/day)	0.12^{a}±0.002	0.13^{a}±0.0016	0.098^{b}±0.0014	0.15^{d}±0.003
TPC (g/day)	10.7^{a}±0.44	11.56^{a}±0.34	8.91^{b}±0.88	13.6^{d}±0.45
FER (%)	0.33^{bd}±0.002	0.33^{a}±0.009	0.33^{b}±0.006	0.32^{ad}±0.0012
PER (%)	1.34^{b}±0.004	1.32^{a}±0.004	1.425^{c}±0.007	1.058d±0.009
PPV (%)	0.042^{a}±0.0008	0.044^{a}±0.0005	0.043^{a}±0.0006	0.032^{b}±0.0003
NPU (%)	48.26^{b}±0.0.65	47.75^{a}±0.55	51.43^{c}±0.77	38.2^{d}±1.55
FCR	3.098^{ad}±0.0094	3.029^{bc}±0.0054	3.12^{a}±0.00915	3.06^{dc}±0.008

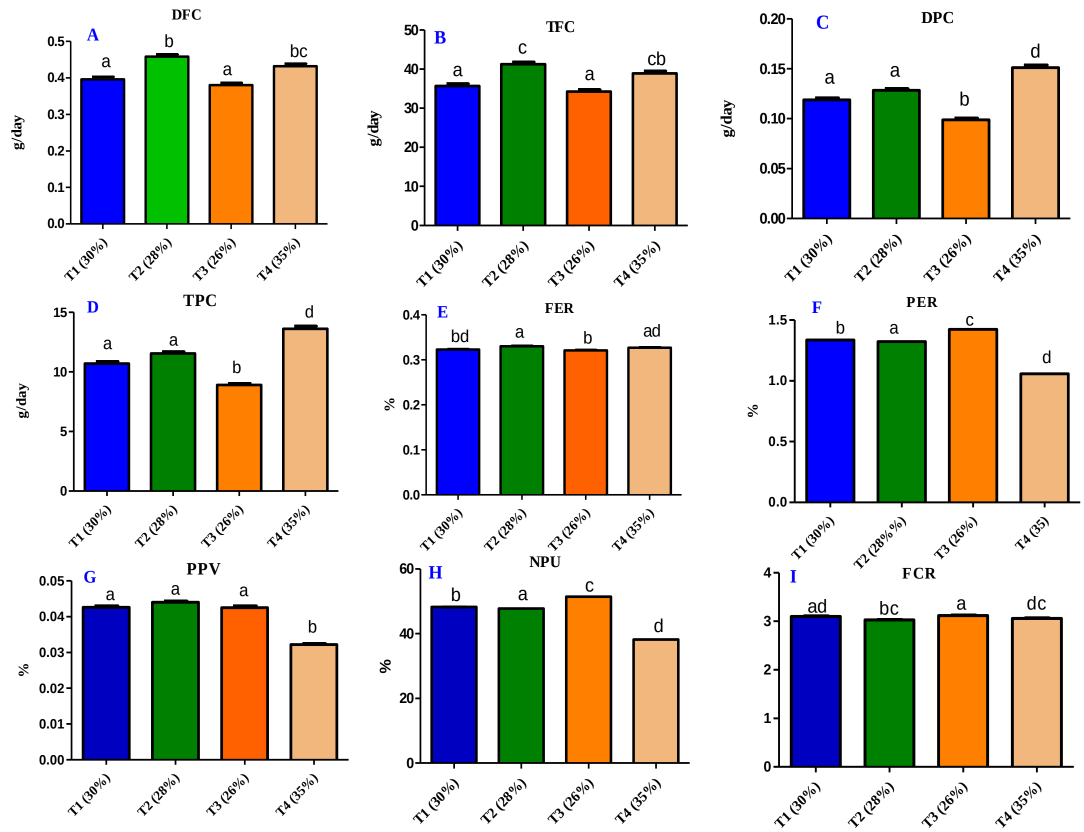

Fig. 2. The effect of varying levels of dietary protein on the feed utilization of *C. carpio*. Note, data are displayed as means with standard error (SE). Significant differences (P< 0.05-0.01) are indicated by distinct superscripts (a, b, and c). The abbreviations used include DFC for daily feed consumed, TFC for total feed consumed, DPC for daily protein consumed, TPC for total protein consumed, FER for feed efficiency ratio, PER for protein efficiency ratio PPV for protein productive value, NPU for net protein utilization, and FCR for feed conversion ratio

Length weight relationships (LWR) measurement

The findings regarding the LWR in fish-fed diets with varying protein concentrations (T1; 30%, T2; 28%, T3; 26%, and T4; 35%) were recorded. Table (3) and Fig. (3A- H) contain crucial details, including regression parameters (a and b) and their 95% confidence intervals, as well as the coefficient of determination (r^2). All relationships exhibited improvement but were statistically non-significant ($P\geq$ 0.05), with r^2 values specific to the species. In the current study, the growth coefficient (a) of the length-weight relationships (LWRs) ranged from 2.61± 0.41 in the 28% protein group (T2) at the start of the experiment to 3.92± 0.49 in the same group at the end of the experiment. The coefficients of determination (r^2) ranged from 0.0018 in fish fed the 30% protein diet (T1) at the start to 0.043 by the end. The LWRs indicated an isometric growth in fish fed diets with 30% (T1) and 35% (T4) protein (3.05± 0.003, 3.7± 0.0034, respectively). While, a negative allometric growth was observed in fish fed the 26% protein diet (T3; 2.45± 0.005), and a positive allometric growth ($P \leq 0.05$) occurred in fish fed the 28% protein diet (T2; 4.93± 0.009), compared to all other groups.

Table 3. Length-weight relationships (LWR) of *C. carpio* over 90 days under the influence of four distinct experimental diets

Treatment	Mean ± SE	a	b	R^2	P value
		Before experiment			
T1	2.29^{a}±0.009	2.25 ± 0.37	-0.05 ± 0.27	0.0018	0.851
T2	2.89^{b}±0.004	2.61 ± 0.41	-0.31 ± 0.29	0.055	0.302
T3	2.12^{c}±0.005	1.95 ± 0.34	0.16 ± 0.24	0.022	0.516
T4	2.23^{d}±0.006	2.21± 0.29	-0.02 ± 0.21	0.005	0.92
		After Experiment			
T1	3.05^{b}±0.003	2.7 ± 0.44	0.27 ± 0.29	0.043	0.374
T2	4.93^{a}±0.009	3.92 ± 0.49	-0.56 ± 0.32	0.1403	0.103
T3	2.45^{c}±0.005	1.68 ± 0.52	0.90 ± 0.34	0.27	0.017
T4	3.7^{c}±0.0034	3.42 ± 0.54	-0.20 ± 0.35	0.018	0.572

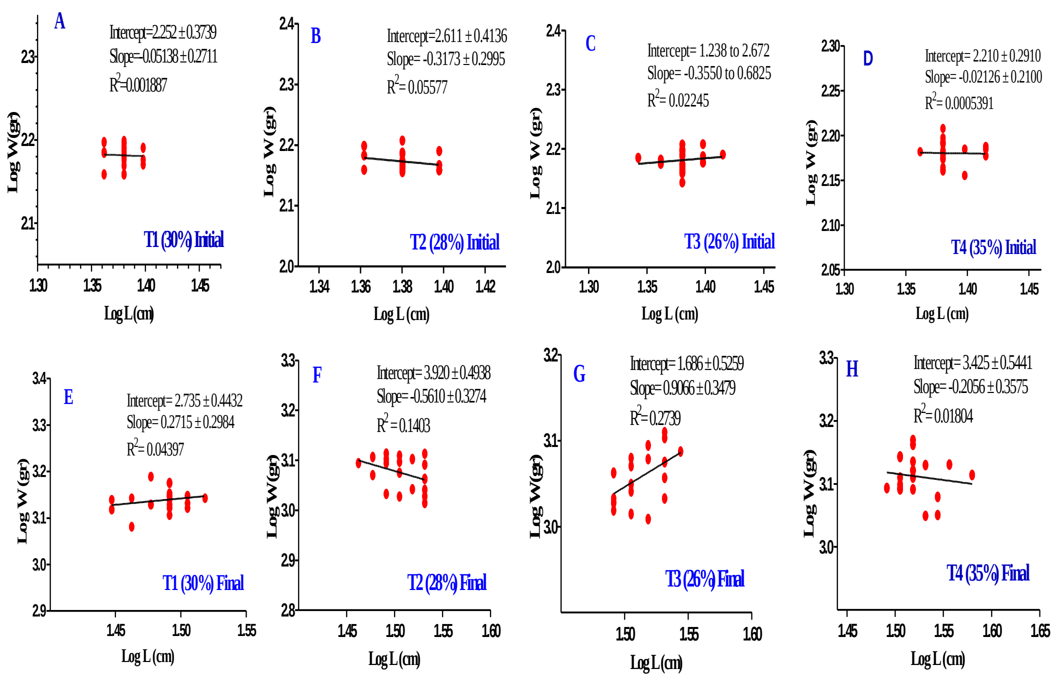

Fig. 3. Influence of using different levels of dietary protein on the length-weight relationship of *C. carpio* during the initial and final steps of the experiment

DISCUSSION

The present study showed significant effects of dietary protein levels on the growth performance (DWG, TWG, WGR, RGR, MGR, and SGR) of carp, and the rates were improved during the winter season after dietary protein levels at a concentration of T2; 28% and decreased with increasing protein levels to 35% (T4). These results align with those reported by **Teles *et al.* (2020)**, who identified the maximum growth in the carp when fed with the optimal level of dietary protein. According to **Cordeli *et al.* (2019)**, dietary protein is considered to be of crucial importance in fish nutrition and feeding. Therefore, a sufficient supply of dietary protein is required for rapid growth. However, **Tejaswini *et al.* (2023)** noted that the temperature of water significantly influences both protein assimilation and growth. **Maji *et al.* (2016)** also observed that the growth of carp is heavily affected by the quality of protein. Protein quality pertains to the nutritional value of proteins, determined by factors such as the amino acid sequence, particularly the content of essential amino acids, and the biological availability of amino acids derived from the protein source.

The elevated protein level of 28% in fish feeds was recorded with a significant impact on the models of condition factors (K, and Kb). The results align with previous studies that have demonstrated the importance of optimal protein levels in fish diets for achieving favorable condition factors **(El-Houseiny *et al.*, 2019; Zhang *et al.*, 2022)**. The winter season, characterized by lower temperatures, can pose challenges to fish metabolism, making the role of protein in energy production and growth even more critical **(Jobling, 1997)**. This shows that the protein consumed is not necessarily used for growth. In general, nutrition must be availablefor metabolism, growth, and reproduction biology **(Tomas *et al.*, 2020)**. This means that, once the nutrients or energy needed for metabolism and growth are met, excess nutrients or energy will be stored.

The elevation in DFC, TFC, FFR, and PPV in fish-obtained diets containing 28% protein (T2) compared to the fish feeds (T1; 30%, T3; 26%, and T4; 35% of protein) can be attributed to several factors supported by the existing research. The observed augmentation in feed efficiency in fish-fed diets with 28% protein is consistent with research on the optimization of protein in supplementary feeds for the pond-raised cyprinids, which showed that net fish yield enhanced as the level of digestible protein in the supplementary diets increased and plateaued at 28% dietary protein level **(Zeb & Javed, 2018)**. Additionally, a study on the catfish (*Silurus lotus*) showed that DFC and DPC were significantly affected by dietary protein levels, with an improvement in the final mean weight associated with increasing the dietary protein levels, indicating a positive correlation between protein levels and feed consumption **(Kim *et al.*, 2012)**. Conversely, these results are in disagreement with other researchers **(Teles *et al.*, 2020)**. It has been identified that the carp exhibits the highest gain at the optimum dietary protein level of 45.56%. Another study by **Khan and Maqbool (2017)** indicated that the most suitable dietary protein level for maximizing growth and ensuring an effective feed utilization in the carp is 41.5%. Additionally, **Aminikhoei *et al.* (2015)** conducted a study on the carp with an average body weight of 1.3± 0.02g to determine the most beneficial dietary protein levels (20%, 30%, 40%, and 50%). The observed decrease in protein efficiency ratio (PER) and net protein utilization (NPU) with increasing dietary protein intake, especially in diets containing 35 and 28% protein, can be attributed to the insufficient availability of non-protein energy. This shortfall prompts the breakdown of dietary protein for energy, subsequentlyreducing the PER and NPU **(Sankian *et al.*, 2017)**. These findings align with those reported in previous studies, which reported a significant decline in the PER as dietary protein levels increased **(Kim *et al.*, 2012)**. Furthermore, the use of high-fat diets in aquaculture, aimed at conserving protein and reducing feed costs, may encourage lipid deposition and compromise flesh quality, further contributing to the decline in the PER **(Welker *et al.*, 2017)**.

Length-weight relationships (LWRs) are crucial for assessing the condition of fish and are widely employed in fish stock assessments and biomass estimation **(Li *et al.*, 2023)**. Understanding the factors that influence these relationships, such as diet composition, is vital for sustainable fishery practices and aquaculture management. The LWRs observed in this study provide valuable insights into the growth patterns of fish in response to varying dietary protein levels. The positive allometric growth seen in fish fed diets with 28% protein (T2) suggests accelerated length growth relative to weight gain, indicating that a 28% protein concentration may promote length development in these fish. Positive allometry has been associated with the enhanced growth performance, and it can reflect favorable nutritional conditions **(Muchlisin *et al.*, 2010; Nazeemashahul, 2020)**. However, protein requirements in fish are influenced by factors such as size, age, culture conditions, and nutrient interactions in experimental diets, including protein and non-protein energy levels. Further studies are needed to determine the optimal dietary protein for each life stage of the carp.

CONCLUSION

Despite the growing value of *C. carpio* as a viable species with great aquaculture potential, no information can be obtained on this freshwater fish species' dietary needs. To the best of our knowledge, this is the first attempt to assess the protein content of this fish in the Kurdistan region of Iraq, revealing that diets for *C. carpio* fish should contain at least 28% protein to maintain high performance. These findings may guide the development of a cost-effective and nourishing feed for *C. carpio* cultures.

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