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Implication of Thermal-Unit Growth Coefficient of the Common Carp (*Cyprinus carpio* L.) in Different Water Temperatures

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ABSTRACT
The present study was conducted in the Fish Feeding laboratory at the College of Agriculture, University of Basra, to estimate the thermal unit growth coefficient of common carp (*Cyprinus carpio*) at different temperatures. The experiment extended from December 16 till the 1st of June 2022. Three temperatures of 20, 25 and 30°C were determined, and the average values of initial fish weight were assessed with 18.49 ± 2.50, 24.13 ± 3.38, and 19.02 ± 4.72g, respectively. The experiment included three different temperatures, and each treatment was repeated in three replicates. Fish samples were fed on a commercially manufactured diet, with a feed rate of 3% of body weight. The initial weight, final weight, weight gain, relative growth rate, specific growth rate, thermal unit growth coefficient and feed conversion rate were calculated. For the specific growth rate, the thermal unit growth coefficient and the feed conversion ratio, the highest values were obtained at a low temperature of 20°C; the values of these parameters were 0.73%/ day, 0.37 and 3.94, respectively. It was concluded that in temperatures between 20 and 30°C, no effect was detected on the growth of common carp. This temperature range was considered optimal for growth, achieving good growth rates for common carp fish.

INTRODUCTION

Carp accounts for 25.2 % of the world aquaculture production **(Miao & Wang, 2020)**. The common carp, *Cyprinus carpio* L., is one of the most important fish of the Cyprinidae family; in general, it represents the largest family of freshwater fish. These fish live in freshwater lakes, rivers and ponds **(Barust *et al*. 2001)**.

The common carp is the fourth species that is highly harvested in the world due to its ability to withstand different environmental conditions **(FAO, 2022)**. Common carp fish are distinguished by their resistance to different temperatures, but the rise and fall of temperatures beyond the appropriate limits may affect the process of eating food normally. Fish stop feeding at 4°C while showing the best growth at temperatures ranging between 20 and 28°C; they survive in low values of dissolved oxygen between 0.3 & 0.5mg/ liter as well as attaining the best saturation **(Horva´th *et al*., 1992; Billard, 1995)**.

Growth is one of the most important factors in fish farming, which is the change in size (weight/length), tissue and chemical composition. Fish are considered a poikilothermic animal; thus, the temperature of the environment in which they live is considered an important factor and has an impact on the metabolism, growth and physiological functions of fish **(Pang *et al*., 2016; Bureau *et al*., 2000)**. Moreover, temperature impacts fish management and productivity in fish farms due to the effect of high temperatures on oxygen levels, which means that the warmer water contains the least amount of dissolved oxygen. This indicates that, temperature is an important factor for maintaining a continuous fish growth; whereas, the decrease in the amount of oxygen may lead to the death of fish **(Pichavant *et al*., 2001; Thetmeyer *et al*., 1999).**

Numerous mathematical models have proven their indispensability in the field of nutrition to estimate growth and food requirements, which are among the most important requirements in the field of production **(Dumas *et al*., 2010)**. One of these models is "thermal-unit growth coefficient (TGC)", which is a modern and effective way to evaluate the hypothetical results of fish growth at different ages (for any age group) at different temperatures. This model was proposed in 1981 **(Iwama & Tautz, 1981)** and later modified by **Cho (1990)**. This model works on the basis of collecting a certain set of data for growth at a certain temperature, and it can also be used to predict the growth of different sizes at different temperatures **(Jobling, 2003)**.

TGC gives the best prediction of growth over time and that it is often affected by temperature, compared to the specific growth coefficient (SGR) and the daily growth coefficient (DGR). Therefore, it was used as an alternative to these measures, and by improving the TGC values, the time required to reach the size of marketing will be reduced by increasing food intake **(Besson *et al*., 2017)**.

The current study aimed to estimate the thermal-unit growth coefficient upon feeding common carp fish at different temperatures and compare it to other growth measures. Thus, this work would determine the appropriate conditions, improve growth and increase feed conversion rates by raising the feeding efficiency and vitality of the fish, which results in an increase in financial and economic yield in addition to the possibility of reducing farming costs and achieving the optimal utilization of food.

MATERIALS AND METHODS

Aquaculture system

The open culture system was designed in the fish nutrition laboratory at the Department of Fisheries and Marine Resources, using 18 aquaria with dimensions of 60 x 40 x 30cm; the capacity of each was 50 liters. The aquariums were arranged parallel and in one row and were sterilized before filling them with water mixed with sodium hypochlorite solution at a concentration of 200 ppm for one hour **(Herwing *et al*., 1979)**. Aquariums were filled with liquefied water stored in a special tank inside the laboratory.. Aquariums were equipped with electric aeration pumps to raise the level of dissolved oxygen in water, and some of them were also supplied with electrical heating devices (electric heater) to raise water temperature. Plastic screens were placed on all tanks to prevent the fish from jumping out of the tanks.

Experimental fish

Common carp fish were brought from the Aquaculture Unit of the Agricultural Research Station in Al-Hartha district. The fish were caught using the draft net, and when the net was extracted from the water, the fish of the required sizes were isolated and placed in a cork container containing ice and water from the fish collection site, after which the fish were transferred to the laboratory. The fish were distributed in aquariums, with 8 fish per tank at a rate of three replications for each treatment (20, 25 and 30°C). After that, the fish were left to acclimatize for a full week. Experiments were conducted from December 16, 2021 to Feb. 16, 2022 for treatments of 20 and 25°C and from April 1 to June 1, 2022 for treatment of 30 °C.

Growth indicators

Weight gain (WG) (g) = W2 (g) – W1 (g)

Relative growth rate (RGR) (%) = [WG (g) / W1 (g) [× 100

Specific growth rate (SGR) (% / day) = (ln W2 – ln W1)/(D) x 100

Thermal-unit growth coefficient (TGC) = $(BW2^{1/3} – BW1^{1/3}) / \sum (t.(C°) * D)$

Where

W1: Initial weight; W2: Finial weight; B: Body; D: Period; t: Temperature

Feed efficiency

The experiment continued for 63 days for each treatment, fishes were fed six days a week using 3% of body weight as feeding ratio (Table1). Fishes were weighed every two weeks in each replicate to change the feeding quantity to the new body weight. For the purpose of evaluating the feeding efficiency, the feed conversion ratio, the protein efficiency ratio and the value of the productive protein value were calculated based on the study of **Hepher (1988)** with the following formulas:

Feed conversion ratio (FCR) = Food intake/ WG

Protein efficiency ratio (PER) = WG/ Protein intake

Protein productive value (PPV) (%) = Final body protein- Initial body protein/ Protein intake x 100

Statistical analysis

The complete randomized design (CRD) was used in the design of the experiment with three treatments and three replicates for each treatment, and the least significance differences (LSD) test was used. All statistical tests were conducted using SPSS version 26.

Table 1. Proximate analysis of the experimental diet

Proximate composition (%)	
Moisture	5.215 ±0.106
Crude protein	34.195 ±0.007
Crude lipid	6.575 ±0.021
Ash	8.085 ±0.148
Fiber	4.195 ±0.021
NFE	41.735 ±0.035
Gross energy (Kcal.kg-1)	4383.425 ±0.035

RESULTS

Water quality parameters

Table (2) shows the environmental factors measured for the water of the experimental aquariums, including the average water temperature, oxygen, pH, and salinity. The average temperature ranged between 20.10 & 29.12°C, and the oxygen ranged between 6.16 & 10.13mg/ l; for the pH value, it ranged between 7.2 & 7.8, and the salinity ranged between 2.51 & 2.62 ppt; these factors were among the levels required for fish farming in the rearing system.

Table 2. Water quality parameters during the experimental period

Treatment	water temperature (°C)	Oxygen (mg/l)	pH	Salinity (PSU)
20	٢٠.٠١	١٠.١٣	٧.٨	٢.٦٢
25	٢٥.00	٨.٦٣	٧.٥	٢.٥١
30	٢٩.١٢	٦.١٦	٧.٢	٢.٥٦

Table (3) illustrates the rates of initial and final weight, weight gain, specific growth rate, relative growth rate and thermal-unit growth coefficient for common carp for all treatments. The highest value of the final weight in the treatment was 30°C (33.12g), and the lowest value in the treatment was 25 °C (23.26g). On the other hand, for weight gain, the highest value in the treatment was 30°C (12.04g), and the lowest value in the treatment was 25°C (4.76g). The relative growth rate excelled in the parameter 30°C (55.74%). For the specific growth rate, the highest value was recorded in the treatment of 20°C (0.73%/day) and the lowest value in the treatment of 25°C (0.39 %/day). The best values of TGC were represented in the treatment of 20 °C, with a value of 0.37. The results of the statistical analysis showed significant differences ($P \leq 0.05$) between the 25°C treatment and the 20°C treatment for the specific growth rate, relative growth rate and TGC, while significant ($P \leq 0.05$) differences were detected with 30°C treatment in weight gain. Whereas, no significant differences ($P>0.05$) were recorded consideing each of the initial and final weights.

Table 3. Growth parameters for common carp fish during the experimental period

Treatment	Initial weight (g)	Final weight (g)	WG (g)	SGR (%/day	RGR (%)	TGC
20	18.49±2.50a	29.49±6.19s	10.49±2.61ab	0.73±0.10a	55.66±9.44a	**0.37±0.05a**
25	24.13±3.38s	23.26±0.92a	4.76±2.61b	0.39±0.22b	27.16±16.40b	**0.15±0.09b**
30	19.02±4.72a	33.12±7.97a	12.04±5.03a	0.73±0.16a	55.74±15.16a	**0.27±0.08ab**

Data in each column with different letters are significantly different ($P\leq0.05$).

Table (4) shows the feed conversion ratio (FCR), protein efficiency ratio (PER) and productive protein value (PPV). The results showed that the best feed conversion ratio was in the 20°C treatment (3.94), which displayed a significant difference ($P\leq0.05$) with the 25°C treatment, while the protein efficiency ratio and the productive protein value were the highest values in the 30°C treatment (0.75 and 10.88, respectively). For the results of the statistical analysis, significant differences ($P\leq0.05$) were recorded between the treatments 25°C and 30°C, with regard to the productive protein value; while for the protein efficiency ratio, it was found that there were no significant differences ($P>0.05$) between all treatments.

Table 4. Feed conversion ratio, protein efficiency ratio and productive protein value

Treatment	FCR	PER	PPV %
20	3.94±0.28b	0.74±0.51a	6.89±0.87ab
25	5.31±0.33a	0.55±0.34a	4.92±3.00b
30	4.00±0.94b	0.75±0.18a	10.88±2.61a

Data in each column with different letters are significantly different ($P\leq0.05$).

DISCUSSION

The results showed that the environmental factors that were measured during the experimental period were within the appropriate range for the growth of common carp, as temperatures between 20 & 30°C were considered good for fish in general **(Assiah *et al.*, 2004)**. The **National Standard Agency (1999)** stated that, the pH level that ranges between 6.5 & 9 was suitable for common carp culture, and for the appropriate concentration of dissolved oxygen in the water, values should not be less than 5mg/ l to obtain the best growth **(Bhatnagar & Devi, 2013)**. Dissolved oxygen concentration did not reach less than 5 mg/l during the experimental period. The results of the current study showed that the salinity was within the limits that can be tolerated by common carp. In this respect, **Hepher (1988)** demonstrated that the common carp can tolerate 11ppt.

Results indicate that the increase in temperature has a clear effect on the growth parameters since the treatment represented by a temperature of 30°C affected the final weight, weight gain and the relative growth rate. The increase in growth of common carp at high temperatures can be due to the increase in the fish's metabolism, which in turn improves the digestion of nutrients, ending in a superior growth. This finding agrees with that of **Björnsson (2001)** who explained that, upon increasing temperature, food intake increases, causing an increase in the growth of common carp at a temperature of 28°C. In addition, the current result is similar to that of **El-Gamal (2009)** who noted that, the best common carp weight gain for growth occurred at a temperature of 30°C. Additionally, the present result coincides with that of **Jauncey (1982)** who defined the optimum temperature for growth at 28°C at the feeding level of 3, 6 and 9% of body weight. On the other hand, the current findings are close to those of **Veluchamy and Dhanushsri (2022)** who specified that, the optimal temperatures for the growth of common carp ranged between 28 & 34 °C. While, the results of the present study differed with the results of the study of **Sapkal *et al*. (2011)** who determined that, the maximum growth rate of common carp occurs at a temperature of 26°C, and contradict with the results of **Oyugi *et al*. (2012)** who assessed that, the best growth rate and feeding rate are achieved at temperature of 20 and 24°C, respectively. Remarkably, the current results disagree with those of **Korwin-Kossawsh (2008)**, who elucidated that, the best temperature for the growth of the common carp ranges between 20 & 24°C. Furthermore, our finding differed from that of **Pang *et al*. (2016)** who mentioned that, the temperature of 25°C is the optimal temperature for the growth of common carp juveniles. Furthermore, the study of **Zeng *et al*. (2017)** is not comparable to the results of the present study since the former showed that the optimum temperature for the growth of juvenile common carp was 25°C.

For the specific growth rate and TGC, the best values appeared in the treatment represented by a temperature of 20°C, compared to the other treatments. The results of this study agree with those of **Jafaryan *et al*. (2011)** who stated that, TGC values of common carp larvae at 24- 26^{0} C were 0.319- 0.472. In this context, **Sahandi *et al*. (2012)** reported the same values of TGC with temperature of 30^{0} C. While, **Roy *et al*. (2019)** found that water temperature affects the nutrient digestibility in common carp, and it seems that ingredient specific and TGC ranged between 0.58 & 1.13 for different common carp size. This result contradicts with that of **Al-Noor *et al*. (2014)** who obtained higher values of TGC (0.509 - 0.474) for common carp fry, but without mentioning water temperature. **Chatterjee *et al*. (2004)** concluded that, water temperature affects health of fish by increasing metabolic rates and oxygen demand if it was beyond the optimum limits; however, common carp can tolerate temperature fluctuation.

The present outcome is consistent with the results of **Ronyai and Csngeri (2008)** who denoted that, the best TGC and specific growth rate of salmon were obtained at low temperatures. At the same time, it agrees with the result of **AL-Dubakel *et al*. (2011)**, obtaining the lowest values for the TGC at a temperature of 26°C, compared to a temperature of 23°C for silver carp in the previous study. The current finding did not agree with results of **Velazquz *et al*. (2006)**, who obtained a better specific growth rate and TGC at a temperature of 26°C for sea bream, and these results were not similar to the results of **Savic *et al*. (2013)**, as he noticed during his study a decrease in the values of each of the TGC and specific growth rate at low temperatures. The present study did not show convergence with the study of **Novriadi *et al*. (2017)** who mentioned that, there is a difference in growth parameters, including TsGC in Florida pompano (*Trachinotus carolinus*) fingerlings at a temperature of 28°C.

The results of the experiment showed that the common carp that were fed at a low temperature of 20°C recorded the best feed conversion ratio. This result matches with that of **Afzal *et al*. (2008)** who observed the lowest feed conversion rates for the bighead carp at temperatures of 26- 30°C. While, in the study of **Van Ham *et al*. (2003)**, these rates were attained at 16°C, compared to 22°C for *Scophthalums mayimus*. In addition, the present result is similar to that of **Al-Faiz (2005)** who determined the best food conversion at a temperature of 22°C, compared to a temperature of 28°C for molly fish. However, the results of current study did not agree with those of **Kausar and Salim (2006)**, as they obtained the best feed conversion ratio at a water temperature of 24- 26°C for the Indian carp. An inconsistency of the current results was detected with the findings of **Costa *et al*. (2014)** who obtained the highest rate of feed conversion and consumption of diet at temperatures of 26.2- 28.8°C. Furthermore, the current outcome disagrees with that of **Hwang and Lin (2002)** who achieved the best feed conversion ratio at 35°C, compared to 25°C for common carp. The reason for improving the feed conversion rate of common carp at low temperatures may be the ability of the fish to absorb the feed materials, and thus a better feed conversion rate was obtained, as the increase in temperature may accelerate the movement of food inside the intestine, which reduces the absorption of feed materials and not being used for growth.

Based on the results, it was shown that, both the protein efficiency ratio and the productive protein value improved with increasing temperatures. These results agree with those of **Desai and Sing (2009)** as they achieved a protein efficiency ratio at 32°C for common carp. Besides, these results are close to those of **Xiao- Jun Ruyung (1992)** who obtained high feeding efficiency with rising temperatures; these results did not agree with those of **Pandit and Makamura (2010)** who noted a low feeding efficiency at temperatures of 35- 37°C for the Nile tilapia. While, some studies showed a decrease in the efficiency of feed conversion with lower temperatures **(De-vlaming, 1971; Goolish & Adelman, 1984)**.

CONCLUSION

Temperatures between 20 & 30°C did not affect the growth of common carp and are considered the optimal range for growth as they played a role in obtaining good growth rates for common carp fish. One of the most important growth criteria that achieved good growth is the thermal unit growth coefficient (TGC).

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