Biological and Applied Environmental Research

Vol. 6(2): 204-217, 2022

https://doi.org/10.51304/baer.2022.6.2.204

ISSN: 2002-6153
Biol. Appl. Environ. Res.
www.baerj.com
editor@baerj.com

Comparison of Growth of Common Carp, *Cyprinus carpio* Cultivated in and outside Cages in Earthen Ponds in Basrah, Iraq

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Abstract: The current experiment was conducted in one earthen pond (2500 m^2) at Agricultural Research Station of the Aquaculture Unit, College of Agriculture at the University of Basrah, Al-Hartha District from 17 February to 10 June 2021. This experiment aims to investigate growth differences between common carp cultivated in small cages (2 x 3 x 2 meter) located inside earthen pond and those were released in the same pond. Effects of fish stocking density inside small cages were also investigated. Four stocking densities were used [100 fishes in cages 1 and 2 (T1); 150 fishes in cages 3 and 4 (T2); 200 fishes in cages 5 and 6 (T3); 250 fishes in cages 7 and 8 (T4); while 1600 fishes were stocked in the earthen pond (T5)]. Fishes were fed daily 3% of fish weight on commercial sinking pellets manufactured by Agricultural Consultant Office of the College of Agriculture. Total length and weight of fishes were measured at the beginning and at the end of the experiment, while subsamples of fishes were weighed periodically and daily feed changed after each weighing. Daily feed was divided into three meals, the first one was given early at the morning, the second one at mid-day and the third one at afternoon. Results of current experiment revealed best growth criteria in T1 where average final weight was 750.5 g, average weight increment was 454.6 g, average daily growth rate was 4.33 g/day and average feed conversion rate was 2.77. Some of these criteria showed significant differences ($P \leq 0.05$) between T1 and other treatments, while feeding conversion rate (3.33) was achieved by fishes reared outside cages in the pond. As a conclusion, it can be pointed out that growth criteria of fishes reared inside cages were better than fishes reared outside cages and fish stocking densities were not affecting growth criteria of fishes reared inside cages.

Keywords: Cages, Condition factor, Length-weight relationship, Growth.

Introduction

Fishes are considered as one of an important highly value protein resources around the world that comprise 20% of total consumed protein (FAO, 2016). Fish production of aquaculture in 2018 comprised around 46% of total world fish

Received May 12, 2022, accepted June 14, 2022

production, and it must be increased at least five times to face the increasing demand of fishes during the next two decades (FAO, 2020). Expansion of traditional fish culture projects leads to negative environmental effects because of pollution that leads to reduce the capacity of these fish culture projects (Martins et al., 2010). For this reason, new production systems must be improved to be depend on little amount of water to reduce environmental effects, such as recirculating aquaculture systems, RAS (Zachritz et al., 2008; Martins et al., 2010). It is well known that the RAS projects need more treasury funds than traditional projects (Schneider et al., 2006), so fish density must be too high in these projects to increase fish production in small area and achieve benefits quickly (Martins et al., 2005).

Recent country reviews of FAO support that the characteristics of fish ponds make it very suitable to produce cultivated fishes in an inexpensive integrated way (Hasan et al., 2007). Common carp, *Cyprinus carpio* is considered as one of the most common species that generates a significant part of fish production in inland freshwater environments. It was introduced to inland waters of different regions around the world (Vilizzi et al., 2015). Khan et al. (2016) stated that the common carp was introduced into many countries around the world, in addition to Asia, Europe, Australia and North America. It was revealed that common carp farming had a key role in the Blue Revolution at a global level (Gyalog et al., 2017). Common carp in 2018 occupied the fourth place of the total world production which consisted 7.7%, after grass carp *Ctenopharyngodon idella* that consisted 10.5% of world production, silver carp *Hypophthalmichthys molitrix* (8.8%) and Nile tilapia *Oreochromis niloticus* which consisted 8.3% (FAO, 2020).

Badilles et al. (1996) pointed out that cultivated fish growth depends on many factors, stocking rate and available natural food, were the most important. Fish density is the important or key factor in determining the management of fish pond including fish production (Hassan & Mahmoud, 2011). It is well known that the competition for food increases with increasing stocking density. It is hardly to consider optimum stocking densities for different species and for the same species in different rearing systems, but also it is important to determine these densities in order to improve fish performance and economic profitability of any aquaculture system. Musa et al. (2010) stated that the data of optimum stocking density of common carp are highly variable. Al-Daham et al. (1991) found that 0.17 fish/m^2 stocking density of common carp provided superior results in respect to growth and food conversion. Mehta et al. (2016) pointed out that fish production level of existing practice of fish culturists may be enhanced up to 1.5 times with proper stocking density.

Pond and cage fish culture is the main aquaculture systems in Iraq, but the absence of correct understanding about the scientific fish culture and management practices in Iraq, the common carp production per hectare is much lower than in other countries around the world. The present study aims to evaluate the growth of the common carp in different stocking densities, inside cages located in earthen pond and also comparing it with the growth of common carp outside cages in earthen pond.

Materials and Methods

The current experiment was conducted in one earthen pond (2500 m^3) at Agricultural Research Station of the Aquaculture Unit, College of Agriculture of the University of Basrah at Al-Hartha District, about 16 km northern-east of Basrah Province (30°65\`64.6"N, 47° 74\`79.5"E) from 17 February to 10 June 2021. Feeding experiment begin after eight days of fish acclimation. The current experiment was conducted to investigate growth differences between common carp cultivated in small cages (2 x 3 x 2 meter) located inside earthen pond and those fishes which were released in the same pond. Effects of fish stocking density inside small cages was also investigated. Four stocking densities were used [100 fishes in cages 1 and 2 (T1); 150 fishes in cages 3 and 4 (T2); 200 fishes in cages 5 and 6 (T3); 250 fishes in cages 7 and 8 (T4); while 1600 fishes were stocked in the earthen pond (T5)]. Initial average fish weigh was 295.9 g for T1, 234.2 g for T2, 257.5 g for T3, 209.6 g for T4 and 258.1 g for T5.

Fishes were fed daily 3% of fish weight on commercial sinking pellets manufactured by Agricultural Consultant Office of the College of Agriculture by using different ingredients (Fishmeal 25%, wheat flour 28%, wheat bran 25%, barley 15%, soya meal 5% and vitamins-minerals premix 2%). Total length and weight of fishes were measured at the beginning and at the end of the experiment, while subsamples of fishes were weighed periodically and daily feed was changed after each weighing. Daily feed was divided into three meals, the first one was given early at the morning, the second one at mid-day and the third one at afternoon.

Temperature, pH and salinity of the water of pond were measured at each sampling period. Throughout this period, six sampling data were collected to calculate the following equations:

Weight increments (WI, g) = FW – IW

Daily growth rate (DGR, g/day) = (FW – IW)/ days

Specific growth rate (SGR, %/day) = 100 ∗ [(ln FW) - (ln IW)]/ days

Where: FW = Final fish weight (g); IW = Initial fish weight (g)

Length-weight relationship and condition factor were calculated for fishes at the beginning and the end of the experiment for each treatment. The following equation was used to calculate the length-weight relationship:

$W= aL^b$ (Pauly, 1983).

Where W= weight of fish in g, L= Length of fish in cm, a = the rate of change in weight with length (intercept), and b = weight at unit length (slope).

The condition factors (K) were estimated by using the following equations:

1- Fulton’s condition factor, the value of K was calculated according to Froese (2006) as $K3 = 100\ w/L^3$

2- Modified condition factor (Ricker, 1975) was estimated following Gomiero & Braga (2005) as $Kb = 100\ w/L^b$

3- Relative condition factor ‘Kn’ (Le Cren, 1951) was estimated following Sheikh et al. (2017) as Kn = W/ ^W

Where W= the actual total weight of the fish in g, ^W= the expected weight from length-weight relationship formula.

Statistical Analysis

The results of current experiment was conducted with a completely randomized design, and the differences between the means were tested by analysis of variance (ANOVA). The significant differences were tested by LSD test at 0.5% probability level by SPSS program Ver. 26.

Results

Table 1 shows the measurement of water temperature which ranged from 17 ^{0}C during Feb. to 27 ^{0}C during May and June, pH ranged between 7.8-8.0 and the salinity between 3.14-4.01 psu.

Table 1: Environmental parameters during the experimental period.

Date	Water temperature (°C)	pH	Salinity (psu)
24 February 2021	17	8.0	3.19
18 March	21	7.8	3.22
8 April	25	7.9	3.14
29 April	26	7.9	3.34
20 May	27	7.9	3.88
10 June	27	8.0	4.01

Table 2 illustrates the average fish weight with standard deviation during the experiment. Average initial weight ranged from 193.8 g in cage 7 to 352.7 g in cage 2, while it was 258.1 g in the pond.

Table 3 illustrates the growth criteria of the five treatments in the experiment. The highest average final weight (750.5 g) was achieved by T1, while the lowest (592 g) was achieved by T2. Statistical analysis for FW showed significant differences ($P \leq 0.05$) between T1 and other treatments, while there were no significant differences ($P > 0.05$) between the other treatments. The highest average weight increment (454.6 g) was achieved by T1, followed with 395.4 g achieved by T3 and the lowest average weight increment (347.9 g) was achieved by T5. Statistical analysis for WI showed significant differences ($P \leq 0.05$) between T1 and other treatments, while there were no significant differences ($P > 0.05$) between the other treatments. Fishes in T1 recorded the highest average daily growth rate (4.33 g/day) followed by T3 (3.77 g/day), while the lowest (3.33 g/day) was recorded by T5. Statistical analysis for DGR showed significant differences ($P \leq 0.05$) between T1 and other treatments, while there were no significant differences ($P > 0.05$) between the other treatments. The average specific growth rates recorded were 0.89, 0.88, 0.89, 1.00 and 0.81 %/day for T1, T2, T3, T4 and T5, respectively.

Statistical analysis for SGR showed no significant differences (P>0.05) between all treatments. Average feed conversion rates recorded were 2.77, 2.72, 2.50, 2.77 and 3.33 for T1, T2, T3, T4 and T5, respectively. Statistical analysis for FCR showed significant differences (P≤0.05) between T5 and other treatments, while there were no significant differences (P>0.05) between other treatments.

Table 2: Measurements of average fish weight during the experiment period.

Treatment	Date					
	24 February 2021	18 March	8 April	29 April	20 May	10 June
T1C1	239.2±103.2	309.5±180.9	404.5±220.4	467.6±260.8	551.2±290.4	680.3±315.0
T1C2	352.7±101.1	489.5±170.9	594.5±210.8	670.5±290.8	743.2±320.9	820.8±377.0
T2C3	229.1±118.5	263.6±150.9	333.3±170.6	400.3±190.8	492.6±220.8	598.6±239.1
T2C4	239.3±85.6	247.3±110.9	313.6±170.6	376.4±195.8	454.2±210.6	585.5±256.2
T3C5	280.1±175.6	296.3±120.9	367.6±170.6	421.4±195.2	517.2±200.8	650.9±223.5
T3C6	235.0±183.5	296.3±130.9	367.6±180.5	421.4±220.6	517.2±240.8	655.0±270.9
T4C7	193.8±99.8	285.7±131.9	329.9±170.5	468.9±210.7	519.2±244.6	576.0±314.7
T4C8	225.5±100.1	244.1±111.7	327.3±171.5	397.3±201.7	510.4±214.2	616.6±247.0
T5	258.1±140.5	329.0±148.7	373.9±212.8	420.1±268.9	500.0±300.0	606.0±354.8

Table 3: Growth criteria of different treatments in the experiment.

Growth Criteria	Treatments								
	T1		T2		T3		T4		T5
	C1	C2	C3	C4	C5	C6	C7	C8	
FW	680.3	820.8	598.6	585.5	650.9	655.0	576.0	616.6	606.0^{b}
Average	750.5^{a}		592.0^{b}		652.9^{ab}		596.3^{b}		
WI (g)	441.1	468.1	369.5	346.2	370.8	420.0	382.2	391.1	347.9^{b}
Average	454.6^{a}		357.8^{b}		395.4^{b}		386.6^{b}		
DGR (g/day)	4.20	4.46	3.52	3.30	3.53	4.00	3.64	3.72	3.31^{b}
Average	4.33^{a}		3.41^{b}		3.77^{b}		3.68^{b}		
SGR (%/day)	0.99	0.80	0.91	0.85	0.80	0.98	1.04	0.96	0.81^{a}
Average	0.89^{a}		0.88^{a}		0.89^{a}		1.00^{a}		
FCR	2.67	2.88	2.72	2.73	2.62	2.37	2.92	2.62	3.33^{b}
Average	2.77^{a}		2.72^{a}		2.50^{a}		2.77^{a}		

Different letters in each row indicate significant differences (P≤0.05).

Table 4 shows data on length and weight of common carp before and after the experiment. In all treatments there was an increase in total length and weight. The highest increase (9.3 cm) in total length was achieved by T4, followed by T1, T2 and T3 with an increase of 9.2 cm, while lowest increase was 8.4 cm by T5. Figure 1 pointed out the length-weight relationship for fishes before the experiment. There was a negative allometric pattern of growth (b less than 3) in the five treatments as b values were 2.8788, 2.7455, 2.8999, 2.9485 and 2.7959 for T1, T2, T3, T4 and T5, respectively. Figure 2 points out the length-weight relationship for five treatments after the end of experiment with positive allometric pattern of growth (b more than 3) in the treatments, where b values were 3.5704, 3.4817, 3.1702, 3.3724 and 3.3502 for T1, T2, T3, T4 and T5, respectively. Table 5 points out the parameters of the length weight-relationship for common carp before and after the experiment. Statistical analysis showed that there were no significant differences (P>0.05) between values of b with value 3 (Isometric pattern of growth) of common carp before and after the experiment for the five treatments.

Table 4: Data of length and weight of common carp before and after the experiment.

Treatments	Length range (cm)	Weight range (g)	Mean length (cm)	Mean weight (g)
Before experiment				
T1	20.6-34.5	144-742	26.2	304.4
T2	17.9-35.0	104-682	23.7	234
T3	16.7-38.1	91-943	23.8	258.8
T4	18.1-32.8	75-541	23.0	208.2
T5	16.2-34.2	87-781	24.2	254.9
After experiment				
T1	23.0-51.0	185-2890	35.4	750.5
T2	28.2-43.8	275-1325	32.9	592.0
T3	23-42.2	185-1250	33.0	652.9
T4	29.2-48.0	334-1840	32.3	596.3
T5	25.2-47.4	205-1720	32.6	606.0

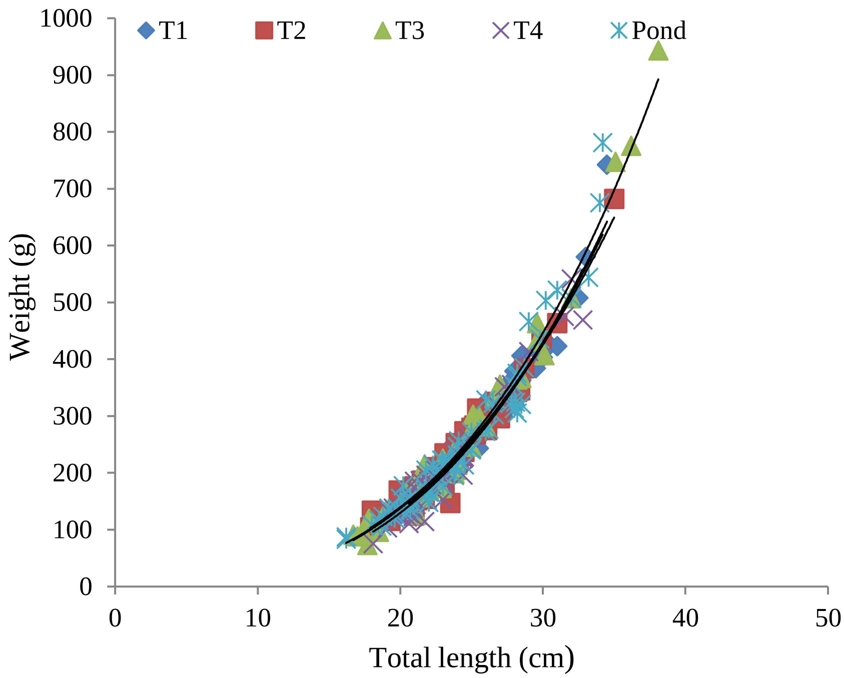

Figure 1: Length-weight relationship for treatments of common carp before the experiment.

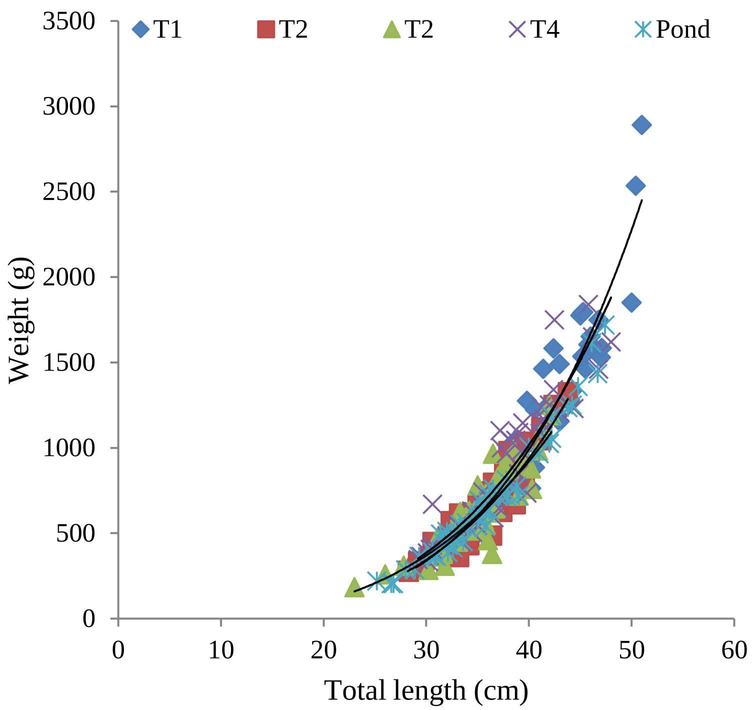

Figure 2: Length-weight relationship for treatments of common carp after the experiment.

Table 5: Equation parameters of length-weight relationship for common carp before and after the experiment.

Treatments	a	b	R^2	t value (calculated)	Significance of t
Before experiment					
T1	0.0240	2.8788	0.9700	0.940	0.258
T2	0.0374	2.7455	0.9355	1.210	0.219
T3	0.0232	2.8999	0.9665	1.347	0.203
T4	0.0189	2.9485	0.9137	1.271	0.212
T5	0.0318	2.7959	0.9601	1.613	0.176
After experiment					
T1	0.0018	3.5704	0.9362	0.727	0.299
T2	0.0025	3.4817	0.8848	1.074	0.238
T3	0.0077	3.1702	0.8256	0.797	0.285
T4	0.0040	3.3724	0.8969	0.698	0.306
T5	0.0040	3.3502	0.9713	2.270	0.132

Table 6 shows three models of condition factors for common carp at the beginning and the end of the experiment. The results show little differences in the value of K3 and Kn before and after the experiment, while there were notable differences in the values of Kb (range differs from 1.90-3.76 before the experiment to 0.19-0.79 after the experiment) related to differences in the value of b. Statistical analysis proved that there were significant differences ($P \leq 0.05$) in modified condition factor (Kb) between some of the five treatments at the end of the experiment, while there were no significant differences (P>0.05) in relative condition factor (Kn) and Fulton's condition factor (K) in all the treatments.

Table 6: Condition factors of common carp before and after the experiment.

Treatments	Condition factors		
	Modified condition factor Kb= 100 W/ L^b	Relative condition factor Kn= W/ W^	Fulton's condition factor K3= 100 W/ L^3
Before experiment			
T1	$2.41^c \pm 0.15$	$1.00^a \pm 0.06$	$1.62^a \pm 0.10$
T2	$3.76^a \pm 0.36$	$1.00^a \pm 0.10$	$1.69^a \pm 0.18$
T3	$2.33^{cd} \pm 0.24$	$1.01^a \pm 0.10$	$1.70^a \pm 0.18$
T4	$1.90^d \pm 0.22$	$1.01^a \pm 0.11$	$1.62^a \pm 0.18$
T5	$3.20^b \pm 0.31$	$1.01^a \pm 0.10$	$1.68^a \pm 0.17$
After experiment			
T1	$0.19^c \pm 0.03$	$1.05^a \pm 0.16$	$1.46^a \pm 0.26$
T2	$0.25^c \pm 0.03$	$1.00^a \pm 0.13$	$1.39^a \pm 0.19$
T3	$0.78^a \pm 0.12$	$1.01^a \pm 0.16$	$1.43^a \pm 0.22$
T4	$0.41^b \pm 0.07$	$1.02^a \pm 0.17$	$1.56^a \pm 0.27$
T5	$0.79^a \pm 0.07$	$0.99^a \pm 0.08$	$1.38^a \pm 0.3$

Different letters in each row indicate significant differences (P≤0.05).

Discussion

Stickney (2000) stated that cultivated fishes are affected by many environmental factors, such as water temperature, dissolved O_2, salinity, pH and ammonia concentration, whether in an open environment or in RAS systems. The feeding requirements of cultivated fishes differ greatly according to many factors such as species, fish size and other environmental parameters such as water temperature, physiological situation, stress and balance feed (Piska & Naik, 2013). Many researchers around the world stated that optimum water temperature for cultivation of common carp ranged between 25 and 28 °C (Korwin-Kossakowski, 2008). It was suggested that the desirable range of water temperature for common carp culture in ponds was from 20 to 30 °C (Bhatnagar & Devi, 2013; Mocanu et al., 2015; Oprea et al., 2015). In the current experiment, most environmental factors were as optimum factors for growth.

Results of the current experiment revealed many facts for cultivation of common carp in high densities to achieve good economic income. It has illustrates that increasing fish stocking density in small cages don't affected growth criteria and also feed conversion. Taher & Al-Dubakel (2020) stated that growth criteria of common carp cultivated in earthen ponds were decreased significantly (P≤0.05) with increasing fish stocking densities. For early stages of common carp, there were mostly negative relationship between fish stocking densities and growth criteria (Irwin et al., 1999; Usandi et al., 2019). Many studies found that low fish density of common carp exhibited high weight gain (Musa et al., 2010; Hossain et al., 2014; Rumpa et al., 2016). The results of these studies may be attributed to the availability of natural food that decreased with increasing stoking density. Anadu & Nwokoye (1993) stated that common carp stocked at 9 fish/ m^2 and above might likely resulted in poor growth because of poor feed conversion. Ble et al. (2011) stated that the growth and final average weight were much affected by high density treatment than the yield in situation of low availability of food resources. Shafiullah et al. (2019) reported significantly higher ($P<0.05$) production in high density.

Growth criteria are not affected by stocking density in the current experiment, may be due to that natural food doesn't play any important role inside cages. Another fact noticed in the current experiment was the low growth of fishes reared in pond outside cages compared with fishes reared inside cages, in spite of natural food that found in pond. This result may be attributed to less movement energy lost by fishes reared inside cages comparing with fishes reared outside cages. It was found that fast and strong continues water currents affect growth performance and inhibit digestion (Farrell et al., 2001; Hvas et al., 2021).

Growth criteria in the current experiment differ from criteria of other experiments. Weight increment ranged between 347.9 and 454.6, DGR between 3.31-4.33 g/day, SGR between 0.81 and 1.00 %/day and FCR between 2.67 and 3.33. Common carp showed SGR of 0.71, 0.87 and 0.76 %/day when fed on three diets of different protein ratios 25, 30 and 35%, respectively (Al-Jader & Al-Sulevany, 2012). Taher et al. (2014) recorded WI of 186.8 g, DGR of 3.16, SGR of 1.85 %/day and FCR of 2.63 for common carp cultivated in floating cages on 5% feeding ratio. Mirror carp (*C. carpio*) recorded SGR of 4.95 and 4.80 %day-1 in two densities during 90 days (Hossain et al., 2014). Taher et al. (2018) revealed SGR of 2.44 %/day and FCR of 2.12 for common carp reared in semi-closed system for 52 days. Taher (2020) recorded WI of 484.5-411.4, DGR of 4.07-8.21 g/day and FCR of 2.56-7.07 when investigated four imported floating pellets. Albahadly et al. (2021) recorded WI of 178.4 g, DGR of 2.35 g/day and SGR of 0.23%/day for ungraded common carp cultivated in floating cages. The differences between results of the current study with other studies may be attributed to differences in initial weights and period of cultivation.

The length-weight relationship is an important tool for fishery management, and it may differ for the same species in the population due to many factors such as feeding and reproduction activities. Results of the current experiment revealed that the growth pattern of carp was negative allometric before experiment for all treatments, while it was positive allometric after experiment. The modified condition factor (kb) was also different, while other two condition factors did not differ between before and after the experiment. Kadhar et al. (2014) recorded negative allometric growth for common carp cultivated in different ponds at Bhavanisagar, Tamil Nadu, India, while Singh et al. (2015) recorded positive allometric growth ($b=3.097$) for common carp reared in Bengal with relative condition factor (Kn) varied from 0.93 to 1.10 in males and 0.95 to 1.19 in females.

Rashid et al. (2018) recorded negative allometric growth ($b = 2.574$) for common carp stocks from Taqtaq Region of Little Zab River, Northern Iraq. Similar results have been found for the common carp population of Lake İznik (b=2.830) by Tarkan et al. (2006) and Gölhisar Lake (b=2.874) by Alp & Balık (2000). Positive allometric growth (b>3) was observed for some populations of common carp in Almus Dam Lake (b=3.319) and Ömerli Reservoir (b=3.140) by Karataş et al. (2007) and Vilizzi et al. (2013), respectively. Das et al. (2019) studied the length weight relationship of common carp in the river Ganga, Allahabad, India and found b = 2.7805 with relative condition factor of more than 1 in both sexes. These variations in b value may be attributed to differences in age, maturity and sex. Bagenal & Tesh (1978) pointed out that geographic location, environmental conditions, seasonality, stomach fullness, disease and parasite loads can affect the value of b.

Conclusions

From results of the current experiment, it can be concluded that growth criteria and feed conversion ratio of the common carp reared inside the cages was better than fishes outside cages, and fish stocking densities inside the cages did not affected growth criteria and feed conversion rate of reared fishes.

Acknowledgements

The authors appreciated the efforts of the Aquaculture Unit staff, College of Agriculture and the staffs of the Agricultural Researches and Experiment Station for all supports and assistance to complete this research work and their help throughout the cultivation and to undertake the field sampling as well as for providing equipment to accomplish this experiment.

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