Turk. J. Vet. Anim. Sci.
2012; 36(3): 245-249
© TÜBİTAK
doi:10.3906/vet-1008-430

Research Article

Survival and growth of common carp (*Cyprinus carpio* L.) exposed to different water pH levels

M. Saeed HEYDARNEJAD*

Fish and Fisheries Laboratory, Zoology Department, Faculty of Science, Shahrekord University, Shahrekord - IRAN

Received: 23.08.2010

Abstract: The aim of the present study was to examine the survival and growth performance of common carp (*Cyprinus carpio* L.) in water with different pH values. Carp (17.8 ± 1.21 cm; 52.14 ± 7.13 g) were transferred to 21 tanks previously adjusted with 7 different pH values: 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, and 9.0. Each value had 3 replicates, and all experiments lasted for 21 days. The survival and growth of carp were assessed at days 7, 14, and 21. At the end of the 21 days, greater weight, length, survival, and biomass were found for pH values of 7.5 and 8.0. The coefficient variations of weight were significantly different among the treatments. The results suggest that the best range for the survival and growth of carp is pH 7.5-8.0.

Key words: Survival, growth, pH, common carp, *Cyprinus carpio*

Introduction

An important factor to ensure good fish production is water pH (1). The optimum pH range differs among species; however, the pH 6.5-9.0 range is generally accepted for fish culture (2). Reports on several teleost species indicate that a 9.0-11.0 pH range decreases growth (2,3), and in this range, many fish species die within a few days. Survival in acidic waters is related to the ability of fish to maintain ion balance (4). In contrast, survival in alkaline waters is due to the adjustments to ion loss (5), nitrogen waste metabolism, and excretion (6,7).

Aquaculture is a rapidly growing industry worldwide. In the future, fish supplies from traditional fisheries are unlikely to increase substantially; therefore, aquaculture production should grow to help satisfy the growing world demand for fishery products (8). One of the most widely cultured species in the world is common carp. It has been suggested that pH variations are important for fish for the modulation of enzyme activity under physiological and pathological conditions (9). For instance, pH level has a major regulating effect on carp brains (10). While there are some pH studies on different aspects of common carp physiology, few studies have been carried out to determine the best pH value for survival and growth in this species. The aim of this study was to examine survival and growth of common carp exposed to different water pH levels.

Materials and methods

Common carp were purchased from a local fish farm and then transferred to the laboratory. They were kept in a single group (water temperature of 20 ± 1

* E-mail: msh@utas.edu.au

°C; pH 7.0) and maintained at 12:12 LD (lights on at 0800 hours and lights off at 2000 hours) with a light intensity of 4.2 μmol s^{-1} m^{-2} at the water surface during the photophase. The photoperiod was provided by fluorescent tubes (Thorn, 36 W, white light), and all lighting was excluded during the scotophase. A timer was used to turn the lights on and off. During a 2-week acclimation period, the fish were fed by hand at random times, with food distributed over the surface of the water twice daily. During this time, the fish were kept in freshwater tanks with a hardness level of 28.9 mg L^{-1} CaCO3 and pH 7.0.

The experiment started (day 0) when groups of 20 fish matched for size (17.8 ± 1.21 cm; 52.14 ± 7.13 g) were transferred to 21 tanks previously adjusted with 7 different pH values: 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, and 9.0 (3 replicates of each). The tanks were kept in continuous aeration. Food was provided in a daily ration of 1.8% body weight (BW) by hand over the aquaria. The feed (commercial diet with 45% protein and 10% lipid) was distributed between 0800 and 0900 hours and between 1600 and 1700 hours. Uneaten feed was collected 30 min after each feeding session in order to measure feed intake. Feces were removed daily by siphoning. To reduce water turbidity and toxicity, 40%-50% of the water in the aquaria was replaced daily with freshwater previously adjusted to the desired pH. With the aid of an in-room air conditioner, water temperature was maintained at 20 ± 1 °C. The experimental water pH was adjusted by adding sulfuric acid or sodium hydroxide (1). Water pH was measured with a pH meter (Oakton pH 510 Benchtop Meter, Oakton Instruments, Vernon Hills, IL, USA) with a sensitivity of 0.01 and 2-point calibration. Using colorimetric methods, as described by Zaniboni-Filho et al. (11), physicochemical parameters of the water including hardness, alkalinity, total ammonia, and nitrite concentrations were analyzed every second day. Dissolved oxygen (DO) was measured with an oxygen meter (YSI-5512, Radford Brothers, Palm City, FL, USA).

The experiments lasted for 21 days. The survival and growth of the carp were assessed at days 7, 14, and 21. A total of 140 fish, 20 from each replicate, were collected. Length and individual mean weight were measured. Before measurement, the fish were anesthetized with clove oil (25 mg L^{-1}). Growth performance was calculated as follows:

Feed intake = amounts of feed supplied – uneaten feed.

Body weight gain (BWG) = (final body weight – initial body weight) / initial body weight × 100.

Feed conversion ratio (FCR) = feed intake / weight gain.

Specific growth rate (SGR) (% day^{-1}) = 100 [ln (W_f) – ln (W_i)] / t (the period of the experiment), where W_f and W_i are final and initial weights, respectively.

Coefficient of variation of weight [CVw (%)] = 100 × (standard deviation / mean weight).

All data were expressed as mean ± SEM. Analysis of variance (ANOVA) and the post hoc Duncan's multiple range test were used among treatment means with SPSS 14.

Survival (%) was determined as follows: (number of fish in each group remaining on day 21 / initial number of fish) × 100. Survival was then analyzed by the chi-square test. The significance level was $P < 0.05$.

Results

Water pH levels showed minor alterations in all treatments and ranged around the predetermined values. All physiochemical parameters of the water were maintained within the expected range throughout the experiment and did not differ significantly among treatments. Ranges were as follows: hardness of 28.9 ± 1.2 mg L^{-1}, alkalinity of 7.8 ± 0.9 mg L^{-1}, total ammonia of 0.24 ± 0.06 mg L^{-1}, nitrite concentrations of 0.18 ± 0.02 mg L^{-1}, and DO of 7.8 ± 0.4.

Figure 1 shows fish survival during the experiment. Carp exposed to pH 9.0 did not survive and died at day 14 of the experiment. However, survival at the end of day 21 was significantly higher at pH levels of 7.5 and 8.0. Figures 2 and 3 depict the mean weight and length of the fish. The increase in weight and length were significantly greater at pH 7.5 and 8.0 ($P < 0.05$), and the maximum fish weight and length were found in this range. In fact, from day 7 onwards, fish weight and length were inversely proportional to a pH

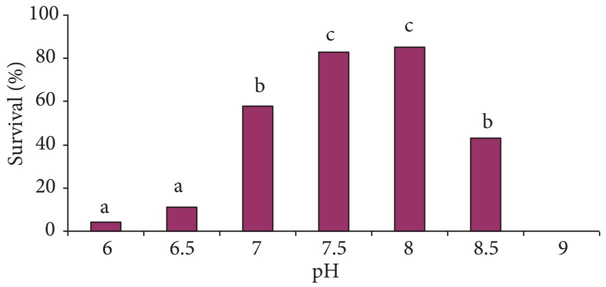

Figure 1. Mean body weight (g) of common carp (*Cyprinus carpio*) at different water pH levels, at the start of the experiment and after 21 days of rearing.

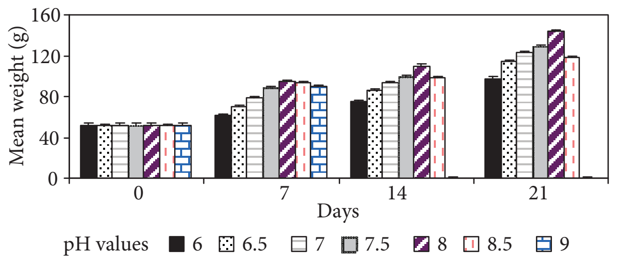

Figure 2. Mean length (cm) of common carp (*Cyprinus carpio*) at different water pH levels, at the start of the experiment and after 21 days of rearing.

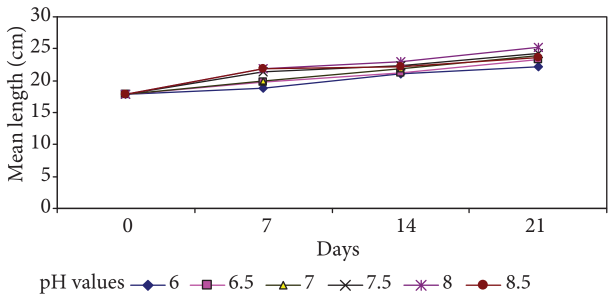

Figure 3. Survival of common carp (*Cyprinus carpio*) as a function of water pH after 21 days. Significant differences between treatments are indicated with letters ($P < 0.05$) as determined by chi-square test comparison of mean values. Treatments sharing the same letters are not significantly different (ANOVA and Duncan's test).

increase from 6.0 up to 8.0. Likewise, fish exposed to a 7.5-8.0 pH range displayed significant increase in BWG and FCR at the end of the experiment (Table). In accordance with the mean weight increase, the SGR decreased significantly among the treatments. At the end of the experiment (day 21), the minimum and maximum values of SGR varied between 0.9 ± 0.1% and 2.3 ± 0.2% BW day^{-1} for pH 6.0 and pH 8.0, respectively. This suggests that fish presented growth potential when reared in more alkaline water. The CVw varied significantly among the treatments. These results suggest that the best range for survival and growth of carp is pH 7.5-8.0.

Discussion

For aquatic animals including fish, pH level plays an important role (12). An increase or decrease in pH disturbs the acid-base balance, ion regulation, and ammonia excretion (13). The results of the current study demonstrate that common carp grow and survive best when exposed to a water pH of 7.5-8.0.

Exposure of carp to lower pH levels (<7.5) or higher pH levels (>8.5) reduced survival compared to pH levels of 7.5-8.0. It has been suggested that the embryonic and larval fish stages are most sensitive to pH changes (14). In this study, while 4%-11% of carp survived exposure to acidic waters (pH 6-6.5), the fish grew better at a higher pH (7.0-8.0). Na^+ release by sodium hydroxide during pH adjustment may explain why pH values ranging from 7.5 to 8.0 produced the highest survival rate (11). Higher water pH had a detrimental effect on survival. The fish died before the second week of the experiment at pH 9.0. In fact, exposure to alkaline waters caused an increase in plasma ammonia, which is toxic to fish (12). Alkaline conditions (pH > 9) can contribute to fish mortality through gill damage, decreased plasma ion concentrations, and decreased NH_3 elimination (15). Thus, the primary cause of observed death at an alkaline pH is the reduction of ammonia excretion and increase in ion loss (16).

This study shows that the growth parameters of carp increase as water pH increases from 6.0 to 8.0, and the best growth performance occurs at water pH 7.5-8.0. Similarly, Wu et al. (17) found that a 7.0-8.0 pH range produced the best functioning of many physiological responses and enzyme activities in the carp. The differences in growth performance among treatments in the current study may be due to food availability and competition for food (18). This is because the food was restricted to 2 daily feedings and was not supplied in excess (1). In addition, as CVw

Table 1. Growth performance of common carp (*Cyprinus carpio*) as a function of water pH.

	pH	CVw (%)	SGR (%, day 1)	FCR	BWG (%)
Day 7	6.0	1.07 ± 0.06^a	2.2 ± 0.1^a	1.6 ± 0.1^a	16.1 ± 2.5^a
	6.5	1.10 ± 0.03^a	2.2 ± 0.3^a	1.5 ± 0.2^a	34 ± 4.8^b
	7.0	1.08 ± 0.09^b	5.7 ± 0.1^b	1.4 ± 0.3^a	49.6 ± 5.2^c
	7.5	1.29 ± 0.03^c	8.2 ± 0.2^c	2.7 ± 0.1^c	68.2 ± 7.9^d
	8.0	1.28 ± 0.05^c	8.4 ± 0.1^c	2.8 ± 0.2^c	80 ± 6.6^d
	8.5	1.09 ± 0.02^a	5.6 ± 0.2^b	2.5 ± 0.2^c	78.5 ± 3.2^d
	9.0	1.11 ± 0.01^a	5.4 ± 0.1^b	1.5 ± 0.3^a	74.2 ± 9.2^d
Day 14	6.0	1.09 ± 0.02^a	1.5 ± 0.1^a	2.2 ± 0.3^a	13.1 ± 6.1^a
	6.5	1.01 ± 0.08^a	1.9 ± 0.2^b	3.4 ± 0.1^b	14.1 ± 8.2^a
	7.0	1.18 ± 0.06^b	1.9 ± 0.2^b	3.3 ± 0.2^b	16.4 ± 3.4^a
	7.5	1.22 ± 0.01^b	2.8 ± 0.1^c	3.5 ± 0.3^c	22.8 ± 3.6^b
	8.0	1.24 ± 0.04^c	2.9 ± 0.1^c	3.6 ± 0.2^c	23.7 ± 4.2^b
	8.5	1.07 ± 0.3^a	1.6 ± 0.3^b	2.4 ± 0.2^c	13.6 ± 7.2^a
Day 21	6.0	1.08 ± 0.02^a	0.9 ± 0.1^a	2.9 ± 0.1^a	17.2 ± 5^a
	6.5	1.07 ± 0.05^a	1.2 ± 0.2^a	3.7 ± 0.3^b	16.8 ± 4.2^a
	7.0	1.09 ± 0.06^b	1.3 ± 0.3^b	3.4 ± 0.5^b	22.4 ± 3.5^b
	7.5	1.19 ± 0.02^c	2.1 ± 0.3^c	4.7 ± 0.1^c	25.9 ± 4.8^c
	8.0	1.20 ± 0.01^c	2.3 ± 0.2^c	4.5 ± 0.2^c	25.6 ± 3.3^c
	8.5	1.09 ± 0.03^a	1.0 ± 0.1^b	3.6 ± 0.4^b	21.1 ± 5.9^b

Significant differences between values in columns are indicated with letters ($P < 0.05$); values in columns with the same letters are not significantly different.

did not remain stable throughout the experiment, an increase in size heterogeneity appeared. The increase in weight and length of carp at higher pH values is in agreement with the findings of Menendez (19), who reported that brook trout (*Salvelinus fontinalis*) grow larger at pH 7.1 than at a lower pH. From an aquacultural point of view, maintaining fish with optimum pH levels and without growth suppression is preferable and will produce a better quality final product. Under favorable pH conditions fish tend to optimize their digestion in order to utilize nutrients in the feed more efficiently, thereby increasing feed conversion (7).

Common carp achieve optimal survival and growth when exposed to water pH values ranging from 7.5 to 8.0. Carp farmers should be made aware of the possible threats of suboptimal water pH and taught how to utilize pH values to increase growth and productivity. Further research should include additional experiments verifying the effects of excess feeding on the survival and growth of carp.

References

1. Lopes, J.M., Silva, L.V.F., Baldisserto, B.: Survival and growth of silver catfish larvae exposed to different water pH. Aqua. Inter., 2001; 9: 73-80.
2. Zweig, R.D., Morton, J.D., Stewart, M.M.: Source Water Quality for Aquaculture. The World Bank, Washington, DC. 1999.
3. Boyd, C.E.: Water Quality for Pond Aquaculture. Research and Development Series 43. International Center for Aquaculture and Aquatic Environments, Auburn, Alabama. 1998.
4. Gonzalez, R.J.: Ion regulation in ion poor waters of low pH. In: Val, A.L., Almeida-Val, V.M.F., Randall, D.J., Eds. Physiology and Biochemistry of the Fishes of the Amazon. IPNA, Manaus, Brazil. 1996; 111-121.
5. Wilkie, M.P., Laurent, P., Wood, C.M.: The physiological basis for altered Na^+ and Cl^- movements across the gills of rainbow trout (*Oncorhynchus mykiss*) in alkaline (pH = 9.5) water. Comp. Biochem. Physiol., 1999; 72: 360-368.
6. Wilkie, M.P., Wood, C.M.: The adaptations of fish to extremely alkaline environments. Comp. Biochem. Physiol., 1996: 113; 665-673.
7. Bolner, K.C.S., Baldisserto, B.: Water pH and urinary excretion in silver catfish *Rhamdia quelen*. J Fish Biol., 2007; 70: 50-64.
8. Food and Agriculture Organisation of the United Nations. Review of the State of World Aquaculture, FAO Fisheries. Circular No. 886 FIRI/C886 (rev. 1). FAO, Rome. 1997.
9. Gorren, A.C., Schrammel, A., Schmidt, K., Mayer, B.: Effects of pH on the structure and function of neuronal nitric oxide synthase. Biochem. J., 1998; 331: 801-807.
10. Conte, A.: Role of pH on the calcium ion dependence of the nitric oxide synthase in the carp brain. Brain Res Bull., 2001; 56: 67-71.
11. Zaniboni-Filho, E., Nuner, A.P.O., Reynalte-Tataje, D.A., Serafini, R.L.: Water pH and *Prochilodus lineatus* larvae survival. Fish Physiol. Biochem., 2008; 35: 151-155.
12. Miron, D.S., Moraes, B., Becker, A.G., Crestani, G.: Ammonia and pH effects on some metabolic parameters and gill histology of silver catfish, *Rhamdia quelen* (Heptapteridae). Aquacul., 2008; 277: 192-196.
13. Wood, C.M.: Toxic responses of the gill. In: Schlenk, D., Benson, W.H., Eds. Target Organ Toxicity in Marine and Freshwater Teleosts. Taylor and Francis, London. 2001; 1-89.
14. Lloyd, R., Jordan, D.H.M.: Some factors affecting the resistance of rainbow trout (*Salmo gairdneri* Richardson) to acid waters. Inter. J. Air Water Poll., 1964; 8: 393-403.
15. Lease, H.M., Hansen, J.A., Bergman, H.L., Meyer, J.S.: Structural changes in gills of Lost River suckers exposed to elevated pH and ammonia concentrations. Comp. Biochem. Physiol., 2003; 134: 491-500.
16. Townsend, C.R., Baldisserto, B.: Survival of silver catfish fingerlings exposed to acute changes of water pH and hardness. Aqua. Inter., 2001; 9: 413-419.
17. Wu, C., Ye, Y., Chen, R., Liu, X.: An artificial multiple triploid carp and its biological characteristics. Aquacul., 1993; 111: 255-262.
18. Albaster, J.S., Lloyd, R.: Water Quality Criteria for Freshwater Fish. Butterworth, London, 1982.
19. Menendez, R.: Chronic effects of reduced pH on brook trout. J. Fish Res. Board Can., 1976; 33: 118-123.