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Original Research Article

Effect of Water pH on Growth and Survival of *Trichogaster lalius* (Hamilton, 1822) Under Captivity

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Keywords

Dwarf Gourami, *Trichogaster lalius*, *Colisa lalius*, water pH, growth, survival

ABSTRACT

The experiment was carried out to study the effect of water pH on growth and survival of *Trichogaster lalius* (Hamilton, 1822) under captivity during December, 2016 to March, 2017. Juveniles of the fish (average length 4.63±0.23 cm, weight 1.43± 0.03g) were stocked for the experiment of 90 days duration. Five treatments for pH were, pH 7 (control), 5±0.25, 6±0.25, 8±0.25 and 9±0.25 which was maintained with acetic acid and sodium carbonate. During experiment fishes were fed with diet containing 35% crude protein at satiation level. Weight gain (%), SGR%, FCR, FER, PER and survival % was higher in control group, pH 7.0. LC_{50} was 5.71 (5.66 - 5.76) and 1.0%, 50% and 99%, survivals were 7.53, 5.71, 3.89 in acidic range whereas in alkaline range, LC_{50} and 1.0%, 50% and 99%, survivals were found at pH 8.22 (8.17 - 8.27) and 6.47, 8.22 and 9.97 respectively. It is concluded from the present experiment that optimum pH range for captive growth, survival and culture of juvenile *Trichogaster lalius* was found to be 6.5 to 7.5; the pH of water above 8.2 and below 5.71 may cause serious stress to fish in captive condition and mortality may cross 50%.

Introduction

Ornamental fishes are called living jewels due to their lucrative colouration and bizarre appearance (Dey, 1996). Colour of few fish species are not that much beautiful but their unique characters, peculiar morphology and behaviour attract people. Indian native fish have high demand in global market. Ornamental fish keeping culture concept was first started by China, were gold fish was traditionally reared under captivity (Ayyappan, 2011). Generally indigenous fish are both ornamental as well as edible value.

Dwarf gourami also has both value and high market demand in domestic and international market due to their peculiar behaviour and lucrative colour variation. Dwarf gourami coming under Order Perciformes, family Osphronemidae, genus *Trichogaster* and species *lalius* which is found in slow moving water with plentiful vegetation of region Ganga and upper Brmhaputra basin in india and distributed in Singapore, Colombia and United states (Welcomme, 1988; Degani and Schreibman 1993).

Generally fish requires water pH ranges from 6.5 to 8.5, which is considered as optimal ranged for good growth of fish. Growth of most fish species is affected at pH below 6.0 or above 9.0 (Parra and Baldisserotto, 2007). Roberts and Palmeiro (2008) reported suboptimal pH or pH fluctuations can result in lethargy, stress, skin irritation/lesions, behavioural changes (such as attempting to jump out aquarium, flashing), corneal edema, skin colour change, gill irritation, increased mucus production, respiratory sign and mortality. Duarte *et al.,* (2013) evaluated the effect of low pH exposure on Na^+ regulation in two cichlid fish species of the Amazon, and reported that Discus are better than Angelfish in maintaining ionic balance under acidic, ion-poor conditions. Many fishes are intolerant to low pH, while others, although more tolerant, will avoid low pH if possible (Graham and Hastings, 1984). At low and high pH, impaired fish growth was recorded (Boyd, 1998; Zweig *et al.*, 1999) and biological activities like ingestive variations, reproduction, movement and distribution are greatly influenced by water temperature.

The effect of water pH on fish is related to age and developmental stages. The larval stages are more sensitive to pH changes (Lloyd and Jordan, 1964). The growth results of 4.5 and 6.6 pH suggest that moderate reduction of pH has little or no effect on the growth rate (Mount, 1973). In fish, exposure to low pH has been shown to either reduce growth or have no effect on it (Mount 1973; Leivestad *et al.*, 1976; Menendez 1976; Jacobsen 1977). Sapkale *et al.,* (2013) has investigated the maximum weight gain, feed conversion efficiency, and survival was recorded at pH 7.5. Ndubuisi *et al.,* (2015) showed that reduced pH condition has a depressing effect on the growth rate of *Clarias gariepinus* fry.

The scientific studies of ecological parameters for this native fish Dwarf Gourami is lacking. So, need to find out optimum pH range for growth and survival of Dwarf Gourami under control condition. There for the present study was carried out to find out the effect of water pH on growth and survival of Dwarf Gourami under captivity.

Materials and Methods

The present study was carried out at wet lab of ornamental fish research centre, ICAR-Central Institute of Fisheries Education, Kolkata centre. Dechlorinated purified tap water was used for the experiment was from Nabadiganta Municipal Corporation, Kolkata.

Collection of fish and acclimatization

Fish used for experimental purpose were juvenile Dwarf Gourami *Trichogaster lalius* with an average length 4.63±0.23 cm and average weight 1.43± 0.03 g. The fish were procured from Tanay fish farm, Kolkata and were transported in the polythene bag with oxygen packing to the wet laboratory. Then fishes were carefully transferred to the circular tank (1000 L) and acclimatized under aerated condition for a period of two weeks.

In all treatments, 25% water was exchanged after every three days. During acclimatization, the juveniles were fed with prepared diet containing 35% protein and live food (Tubifex and mix zooplankton).

Experimental Design

The experimental glass tanks were arranged following completely randomized design (CRD). Various treatments of the experiment were T1: 5±0.25, T2: 6±0.25, T3: 8±0.25, T4: 9±0.25, Control (7±0.25). Fishes were randomly distributed in five distinct experiment groups and each treatment has three replications.

Experiment set up

The experiment for effect of water temperature was conducted in 15 rectangular shaped (28 cm x 19 cm x 22 cm) 12 litre capacity glass aquariums. The tank was initially washed and disinfected with potassium permanganate solution. Thirty ten fish per replication were used (total 30 fish per treatment) and filled with chlorine free purified water. Aeration was provided through blower system in all experiment tanks to maintain optimum level of dissolved oxygen, aquarium tanks were covered with fibre hood to avoid temperature fluctuation and jumping of fishes.

Water pH maintenance

For decreasing pH glacial acetic acid was used and 1 N sodium carbonate was used for increasing it. The pH of the tank was measured three times in a day using thermoscientific pH meter.

Experimental diet preparation

For formulation of pelleted diet, ingredients like fish meal, soyabean meal, groundnut oil cake (protein source), rice bran, wheat flour (carbohydrate source), fish oil, soya oil (lipid source) were used. All the ingredients except vitamin mineral premix, fish oil and soya oil were mixed properly in a grinder. The dough was then transfer to an aluminium container and place in an autoclave for steaming for 45 minutes. Then the dough was taken out and cooled at room temperature. The vitamin mineral premix, fish oil and soya oil added as per the formulation and were mixed after cooling. Pellets were prepared using the hand pelletizer having a diameter of 2 mm. Finally they were air-dried for a day and then sealed in polythene bags and kept at 50^0C in order to avoid contamination till the completion of the experiment.

Feeding

Fishes were fed with formulated diet containing 35% crude protein up to satiation level.

Sampling procedure

Sampling was done at one month intervals to assess the body weight, growth response and survival rate of the fish. The total length and body weight was taken with the help of scale and an electrical balance. The dead fishes were removed and number of fishes in each aquarium was recorded counted daily during the 90 days of experiment.

Method to determine LC_{50} and ET_{50}

LC_{50} is the lethal concentration which 50% populations die in a given particular period of time. probit method used assess the LC_{50}. In calculation, both the data of survival percentage and different pH range was transformed into respective probit values and then transformed survival percentage was plotted against the different transformed pH range. Both these data set were used to generate regression equation.

Acclimated chronic exposure (ACE) method was used for assess effect of exposure time (ET50) on survival in pH experiment of fish. for a specific pH were analyzed by plotting daily mortality value against days of exposure to determine patterns in survival and by comparing plots of ET50 for some significant pH treatments over time.

Survival curve were generate using the linear curve-fitting program in Microsoft Excel. The highest r^2 values were used to select the best-fitting models.

Physico-chemical parameter of water

Water quality parameters *viz.* temperature, pH, dissolved oxygen, free carbon dioxide, total hardness, alkalinity, ammonia were estimated at 15 days interval of each treatment during the experiment period.

The temperature of all the experimental tanks were recorded with digital thermometer and pH was measured by thermoscientific digital pH meter.

Dissolved oxygen measured by modified Winkler's method and dissolved free carbon dioxide was measured by titration with N/80 sodium hydroxide using phenolphthalein indicator. Alkalinity was measured by titration with N/50 sulphuric acid using methyl orange and phenolphthalein indicators. Hardness was measured by 0.01M EDTA using EBT indicator (APHA, 2005). Free ammonia concentration was estimated by Ammonia test kit developed by Seachem Laboratories, USA.

Assessment of growth parameter and feeding performance

Sampling was done at one month intervals to assess the body weight and growth response of the fish. The weight was taken in an electrical balance.

Survival rate

At the end of an experiment all the culture tanks were dewatered and the number of experimental fish in each tank was counted and the survival rate (%) was calculated by following formula:

Statistical analysis

The data were statistically analyzed by statistical packages SPSS version 16 in which data were subjected to one way ANOVA and Duncan's multiple range testes was used to determine the significant differences between the mean. Comparisons were made at the 5% probability level and graph prepared by SAS JMP 9 versions.

Results and Discussion

Physico-chemical parameters of water

Physico-chemical parameters of water during experimental period of 90 days such as temperature, pH, dissolved oxygen, total hardness, total alkalinity, free carbon dioxide, ammonia were recorded and average value of all the treatment are presented in the Table3.

The average maximum and minimum water temperature was recorded during experiment 27.4 ± 2.3^0C and 16.1 ± 2.5^0C respectively, alkalinity 130-200mg/L, hardness 112-138mg/L, total ammonia 0.001-0.003mg/L, dissolved oxygen 6.2-7.9mg/L and CO_2 was detected only in T1:5±0.25 and T2:6±0.25 during entire experimental days.

Assessment of growth parameters

Growth parameters of *T. lalius* were shown following results under pH experiments

Percentage weight gain (%)

Percentage weight gain achieved during experiment 2 showed significant difference ($p<0.05$) among the treatments (Table 4, Fig 1). Higher weight gain % obtained in control (40.74±2.22) was significantly different ($p<0.05$) from all the pH treatment groups. Lowest weight gain% was recorded in T1

(14.05±0.44). T2 and T4 showed statistically similar weight gain percentage.

Specific growth rate (SGR %)

Specific growth rate of fishes varied significantly ($p<0.05$) among the treatment groups (Table 4 and Fig 1). Highest SGR obtained in control (0.32±0.02) was significantly different ($p<0.05$) from all the pH treatment groups. Among the treatment groups T3 shoed highest SGR which was statistically similar to T2. Lowest SGR was recorded in T1 (0.19±0.00).

Feed conversion ratio (FCR)

FCR differed significantly ($p<0.05$) among the treatment groups at the end of the experimental duration (Table 4, Fig 1). Lowest FCR was obtained in control (1.02±0.00) and highest was observed in T1 (4.80±0.10). The FCR of both control and T1 were significantly different ($p<0.05$) from other treatment groups.

Feed efficiency ratio (FER)

Significant difference ($P<0.05$) was observed among the treatment groups in FER at the end of experimental period (Table 4; Fig 1). FER was found to be high in control group (0.97±0.01) and lowest FER was obtained in T2. The FER of both control and T1 were significantly different ($p<0.05$) from other treatment groups.

Protein efficiency ratio (PER)

There was significant difference ($P<0.05$) in PER among treatment groups during the experimental period (Table 4 and Fig 1). Higher PER recorded in control group (2.79±0.02) was significantly different ($p<0.05$) compared to other treatment groups. Lowest PER was recorded in T1 (0.59±0.01). The PER obtained in both control and T1 were significantly different ($p<0.05$) from other treatment groups.

Survival rate (%)

Significant difference in survival percentage was observed among the treatment groups at the end of experiment 2 (Table 4 and Fig 1). The highest survival rate of 86.66±3.33 % was recorded in control group (pH 7) which was significantly differed ($p<0.05$) from the rest of the treatment group at the end of experiment. Lowest survival rate (0%) was recorded in T5 (pH 4) and T6 (pH 10) in which 100% mortality happened within a few hours of experiment which is followed by T4 (46.67%).

Effect of pH on survival of *Trichogaster lalius*

Effect of pH on survival was analyzed by plotting survival percentage at the end of 90^{th} day against the pH. For this purpose acidic and alkaline treatment ranges were plotted separately. This curve was used to calculate LC_{50} (on 90^{th} day). For LC_{50}, survivability curve at 90^{th} day against different pH treatment were plotted by two ways (acidic range and alkaline range). In the acidic range, the value of LC_{50} was 5.71 with upper and lower confidence limit of 5.76 and 5.66 respectively. The value of LC_{50} was 8.22 with upper and lower confidence limit of 8.27 and 8.17 respectively.

Effect of exposure time on survival in pH experiment

ET_{50} for pH 5

The value of ET_{50} was 52.48 days with upper and lower confidence limit of 58.88 and 46.77 respectively (Fig 24).

Table.1 Different chemicals and their quantity used for the maintenance of pH

pH range*	Volume of chemical used
5	1.8ml glacial acetic acid
6	900µl glacial acetic acid
7	720µl glacial acetic acid (Control)
8	Tap water
9	6.4ml 1N sodium carbonate

*Tanks were also set at pH 4 and pH 10 for a day

Table.2 Composition of ingredients and diet

Name of Ingredients	Quantity % for feed
Fish meal	27
Soyabean meal	20
Rice bran	20
Groundnut oil cake	14
Wheat flour	12
Carboxy methyl cellulose sodium salt	3
Spirullina power	1
Vitamin mineral premix	1
Fish oil	1
Soya oil	1
Crude Protein	**35.15**
Crude lipid	**5.67**
Gross energy (Kcal 100 g^{-1}) calculated	**427.6**

Contribution to diet (per kg): Vitamin A, 7,00,000 IU; vitamin $D_{3,}$ 70,000 IU; vitamin E, 250 mg; Cobait 150 mg; Copper 1200mg; Iodine 325 mg; Iron 1500mg: Magnesium 5000mg; Potassium 100mg; Sodium 5.9mg; Manganese 1500mg; Sulphar 0.72%; Zinc 9600mg; DL-Methionine 1000mg; Calcium 25.5 %; Phosphorus 12.75 %

Table.3 Physico-chemical parameters of temperature experiment

Treatments	Temperature (^{0}C)	Alkalinity (mg/L)	Hardness (mg/L)	Ammonia (mg/L)	Dissolved Oxygen (mg/L)	CO_2 (mg/L)
pH 7(Control)	21.0-30.2	136-180	118-135	0.01-0.04	6.2-7.9	0.00
pH 5	21.1-30.0	130-180	112-121	0.00	5.8-7.2	3-5
pH 6	21.1-30.1	138-184	120-134	0.00	6.6-7.6	2-3
pH 8	21.0-30.2	140-200	130-138	0.03-0.07	6.3-7.8	0.00
pH 9	21.1-30.1	153-298	116-136	0.04-0.09	5.5-6.8	0.00

Table.4 Growth parameters and survival (mean±SE) of *Trichogaster lalius* under different pH regimes at the end of experiment

Treatment	WG (%)	FCR	FER	SGR	PER	Survival %
Control (7±0.25)	40.74 ± 2.22^{a}	1.02 ± 0.00^{d}	0.97 ± 0.01^{a}	0.32 ± 0.02^{a}	2.79 ± 0.02^{a}	86.66 ± 3.33^{a}
T1(5±0.25)	14.05 ± 0.44^{d}	4.80 ± 0.10^{a}	0.20 ± 0.00^{d}	0.09 ± 0.00^{d}	0.59 ± 0.01^{d}	50.00 ± 0.00^{a}
T2(6±0.25)	25.13 ± 0.30^{c}	2.05 ± 0.01^{b}	0.49 ± 0.00^{c}	0.24 ± 0.02^{b}	1.39 ± 0.00^{c}	36.66 ± 6.66^{b}
T3(8±0.25)	32.93 ± 0.96^{b}	1.50 ± 0.02^{c}	0.66 ± 0.00^{b}	0.25 ± 0.01^{b}	1.90 ± 0.02^{b}	36.66 ± 3.33^{b}
T4(9±0.25)	25.61 ± 0.22^{c}	2.01 ± 0.01^{b}	0.49 ± 0.00^{c}	0.19 ± 0.00^{c}	1.41 ± 0.01^{c}	53.33 ± 3.33^{a}

Fig.1 Growth parameters and survival (mean±SE) of *Trichogaster lalius* under different pH regimes at the end of experiment. (a) Percentage weight gain, (b) Specific growth rate, (c) Feed conversion ratio, (d) Feed efficiency ratio, (e) Protein efficiency ratio, (f) Survival percentage.

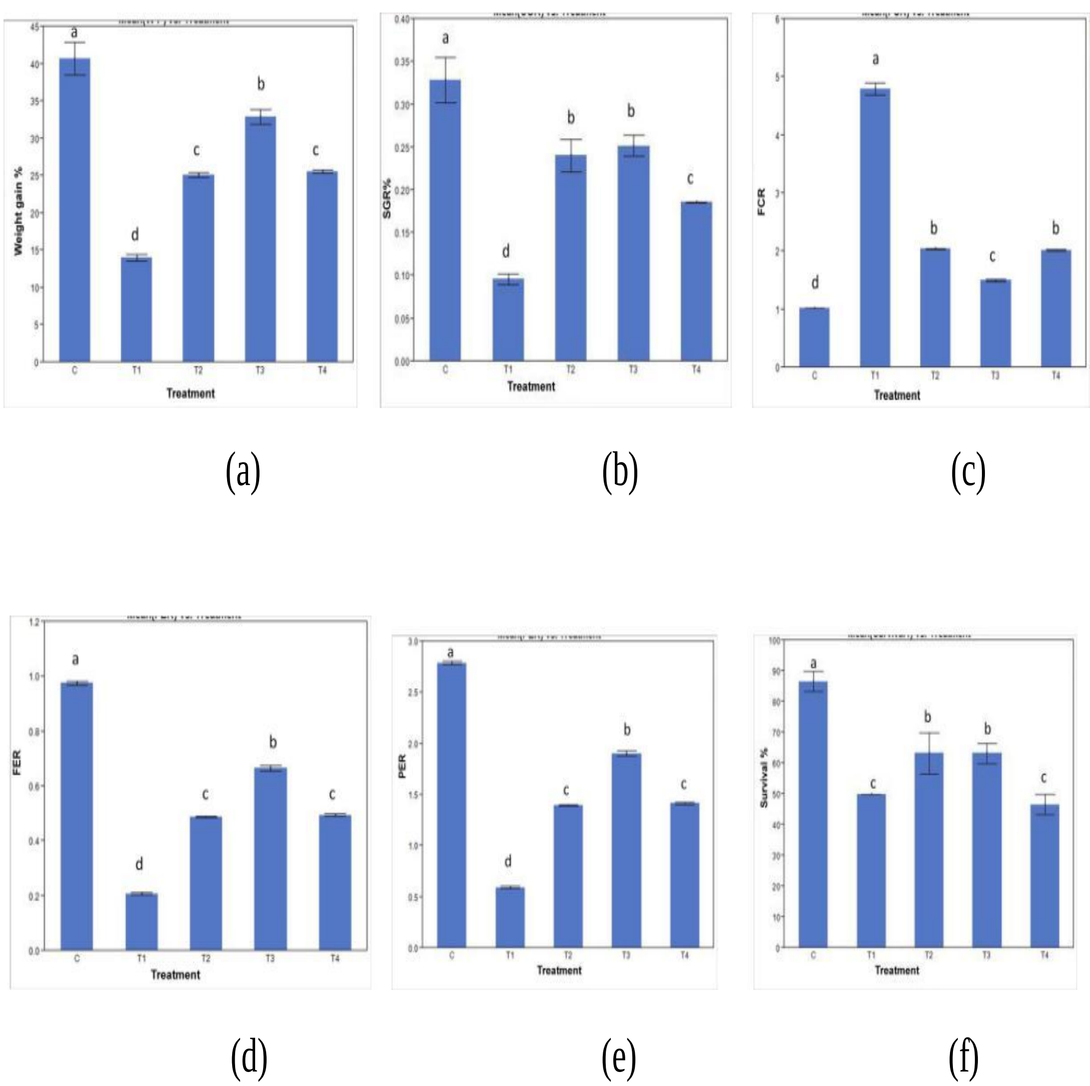
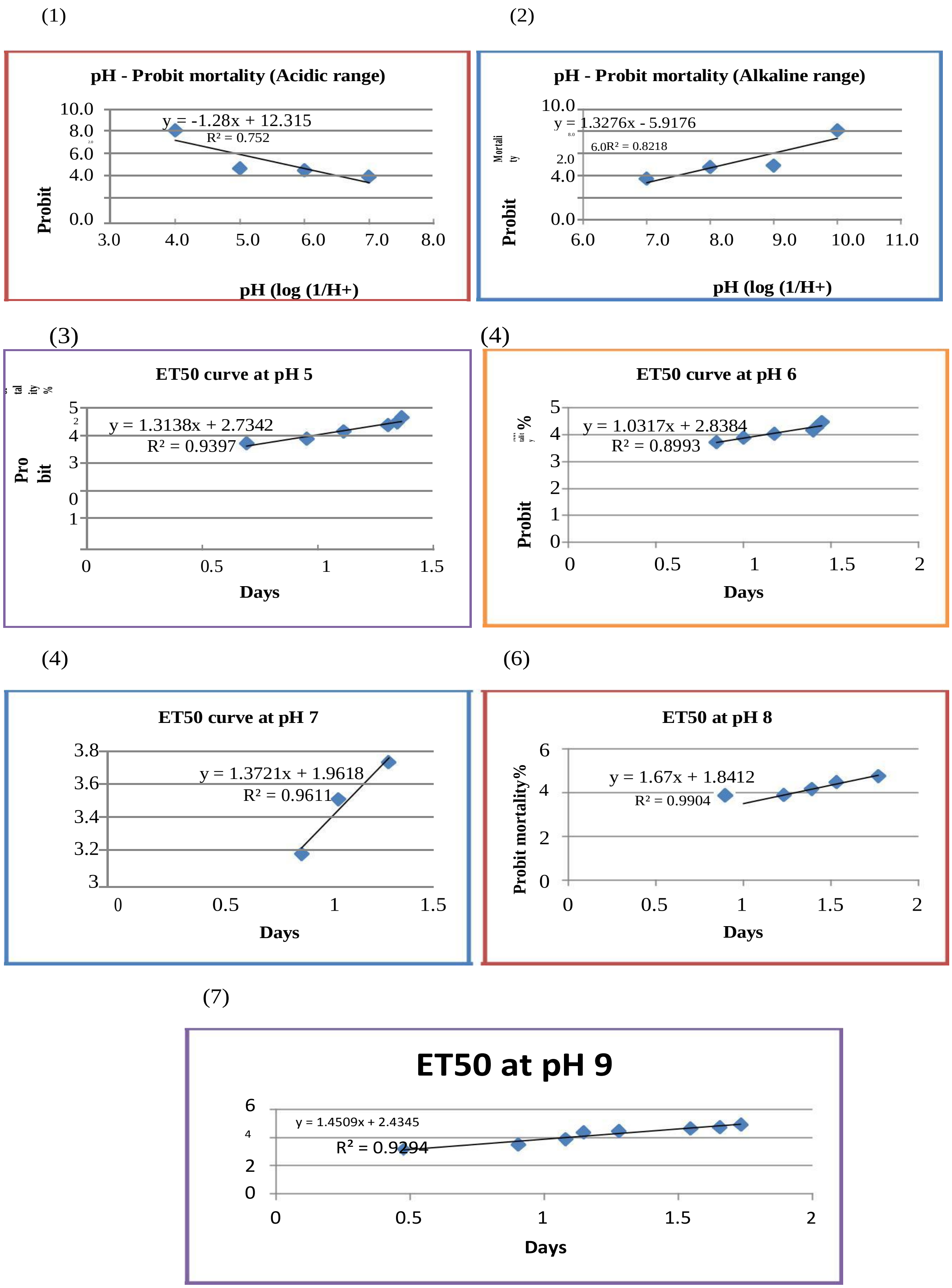


Fig.2 Probit mortality (1.Acidic & 2.Alkaline) (3) ET50 pH5, (4) ET50 pH6, (5) ET50 pH 7, (6) ET50 pH8, (7) ET50 pH9 (*Trichogaster lalius*) under different pH regime



ET_{50} for pH 6

The value of ET_{50} was 123.03 days with upper and lower confidence limit of 141.25-107.15 respectively (Fig 25).

ET_{50} for pH 8

The value of ET_{50} was 77.62days with upper and lower confidence limit of 83.17 - 70.79 respectively (Fig 27).

ET_{50} for pH 9

The value of ET_{50} was 57.54 days with upper and lower confidence limit of 64.56 - 52.48 respectively (Fig 28).

ET_{50} for pH 7 (control)

The value of ET_{50} was 162.18 days with upper and lower confidence limit of 177.82 - 144.54 (Fig 26).

Dissolved oxygen, total alkalinity, total hardness, ammonia values of different treatments were in normal range throughout the experiment period mainly due to continuous aeration, water exchange and syphoning of waste products twice in a week and maintenace of one sponnge filter in every aquarium.

Effect of water pH on survival rate of Trichogaster lalius

Behavioural changes of fishes were slightly prominent at higher pH at 8.0 and 9.0. During the initial stages of experiment, fish exhibited consistent swimming behaviour. As the test period prolonged, activity slightly reduced. The higher pH induced physiological stress was responsible for inconsistent behaviour of fishes in those treatments. As the days progressed, this behaviour was reduced due to acclimatization in the captive environment and artificial food.

The probit method was used to calculate the pH that was lethal to 50% of test fish at the end of the 90-d experiment. LC_{50} upper and lower confidence limits were calculated from the mortality data on 90^{th} days in different treatments (pH). It was observed that value of LC_{50} for acidic range was 5.71 with upper and lower confidence limit of 5.76 - 5.66 and LC_{50} for alkaline range was 8.22 with upper and lower confidence limit of 8.27 - 8.17 respectively. The water pH for 1% and 99% mortality of *Trichogaster lalius* was found to be 7.53 and 3.89 in acidic range and 6.47 and 9.97 in alkaline range respectively.

pH plays an important role in the survival, and growth of *Trichogaster lalius.* pH does not only directly influence the growth and digestive activity of *Trichogaster lalius*, but also its metabolism. Froese and Pauly (2014) reported that enduring range of pH for *Tricogaster lalius* was 6.0-8.0, whereas according to the report of Animal world the ideal water pH for this fish was 6.0-8.0.

In the light of reports from above literature, the result of present experiment is significant in the sense that if the water pH goes below 5.71 and above 8.22, 50% test fishes will die. As the pH increases, the mortality of fish decreased and survival rate was found to increase in acidic range and 1.0% mortality of *Trichogaster lalius* on acidic range was calculated to be at pH 7.53 from the regression curve. Whereas in alkaline range, as the pH decreased the mortality of fish decreases and survival rate was found to increase and 1% mortality was calculated to be at pH 6.47 from the regression curve. So by comparing both raw and analysed data, it can be said that the ideal water pH range *Trichogaster lalius* in captive condition is 6.47 to 7.53. This result supported by seriously fish.com and Dwarf gourami fact sheet reported that pH range 6.0 -7.5 is suitable for *Trichogaster lalius* and 6.5-7.5 by (www.greenaqua.hu).

In this study, mortality of the juvenile *Trichogaster lalius* especially in extreme low pH 4 and high pH 10 (maintain by glacial acetic acid and Sodium hydroxide) also recorded that could be attributed to internal respiration practiced by the juvenile whereby there is a direct contact between the solution and the internal organs of the fish. juveniles were struggled, gulping, irritate swimming, jumping, and high mucus secretion was observed due to this water turn milky colour which led to the immediate destruction of the fry after 4 h post stocking in pH 10 and 3.5 h post stocking in pH 4. Similar similar results were reported in *Clarias gariepinus* hatchlings by Uzoka *et al.,* 2012. Boyd (1982) and Gaunder (2005) had observed that the acid and alkaline death points for fish are about pH 4 and 11 respectively with reproduction and growth diminishing with increasing acidity or alkalinity. In this study, LC_{50} was found at pH 5.71 in acidic range and pH 8.22 in alkaline range which is in agreement with the study of Uzoka *et al*., (2012) in *Clarias gariepinus* fry

Growth performance of Trichogaster lalius in different pH ranges

In the experiment 2 *Trichogaster lalius* juveniles were reared under different pH ranges, control group (pH 7) showed higher growth performance in terms of body weight, weight gain percentage, specific growth rate, FCR, FER, PER than the other pH condition.

In the present study, the effect of pH showed a significant effect on weight gain % and specific growth rate (%) among the treatment groups. Control which was kept on pH 7 and followed by T3 (pH8) showed higher growth rate and SGR% indices as compared to other treatment groups and lower growth was recorded in pH 9.0 and pH 5.0. Similar results were reported by Menendez (1976) in rainbow trout and Rodgers (1984) in brook trout, *Salvelinus fontinalis*. Copatti *et al.,* (2011) reported higher weight gain and SGR % in pH 7.0 than lower pH 5.5 in silver cat fish. The findings of Ndubuisi *et al.,* (2015) supports the above results in which the growth of fry *Clarias gariepinus* was assessed at 11 pH ranges (2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12) in a 14 days trial in which best growth rate was obtained in pH 7.0. The findings of IVOKE *et al.,* (2007) in *Heterobranchus bidorsalis* (male) x *Clarias gariepinus* (female) hybrid juvenile's also supports the results of present study in which optimum pH range for better weight gain and SGR% was reported to be 7.0 to 7.5. The reduction in growth rate was also reported in various fishes exposed to acidic pH of 5.5 (Menendez, 1976; Graig and Baski, 1977). Decrease in the level of oxygen in the blood is pointed out to be the reason for lower growth rate at high pH (Vaala and Mitchell, 1970; Packer and Dunson, 1972) and lower growth rate at lower pH ranges (Robinson *et al.,* 1976). In the present study weight loss observed in pH 8.0 and pH 6.0 may be due to imbalance in homeostasis as reported by Kimmel in 1993 that low or high pH is not directly lethal to fish whereas it will affect growth and reproduction. But according to Mount (1973) a moderate reduction in pH (pH 6) has little or no effect on the growth rate and best SGR.

In the present study, the effect of pH showed better FCR, FER and PER at pH 7.0 but decline at pH 8.0, 6.0 and 5.0. This is supported by the findings of IVOKE *et al.,*

(2007) who reported better FCR, FER and PER at pH 7.0 to 7.5 in hybrid catfish they were efficiently utilising the given feed for growth somatic growth. Sapkale and Singh (2013) reported Better FCR at pH 7.5 in common carp (*Cyprinus carpio*).

Acidic pH induced reduction in feeding and corresponding growth was reported by Beamish (1972) at pH 5.0 in white suckers, *Catostomus commersoni* and similar effects were also reported from studies of D'Cruz *et al.*, (1998).

It is concluded from the present experiment that optimum pH range for culture, growth and survival under captivity of juvenile *Trichogaster lalius* was found to be 6.5 to 7.5. The pH of water above 8.2 and below 5.71 may cause serious stress to fish in captive condition and mortality may cross 50%.

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References

Ayyappan, S., Moza, Usha, Gopalakrishan, A., Meenakumari B., Jena K. J., and Pandey A. K. 2011. Handbook of Fisheries and Aquaculture, Ornamental Fish Breeding and Culture, ICAR, New Delhi, pp. 500-504.

Beamish, R. J., 1972. Lethal pH for the white sucker Catostomus commersoni (Lacepede). *Transactions of the American Fisheries Society*, 101(2): 355-358.

Boyd, C. E., 1982. *Water quality management for pond fish culture*. Elsevier Scientific Publishing Co..

Boyd, C. E., 1998. Water quality for pond aquaculture. International Centre for Aquaculture and Aquatic Environments. Alabama Agricultural Experiment Station, Auburn University, Alabama. *Res. Dev. Ser*, 43: 115-119.

Copatti, C. E., Garcia, L. D. O., Kochhann, D., Cunha, M.A. and Baldisserotto, B., 2011. Dietary salt and water pH effects on growth and Na+ fluxes of silver catfish juveniles. *Acta Scientiarum. Animal Sciences*, 33(3): 261-266.

Craig, G. R. and Baksi, W. F., 1977. The effects of depressed pH on flagfish reproduction, growth and survival. *Water Research*, 11(8): 621-626.

D'Cruz, L. M., Dockray, J. J., Morgan, I. J. and Wood, C. M., 1998. Physiological effects of sublethal acid exposure in juvenile rainbow trout on a limited or unlimited ration during a simulated global warming scenario. *Physiological zoology*, *71*(4): 359-376.

Degani, G. and Schreibman, M. P. 1993. Pheromone of male blue gourami and its effect on vitellogenesis steroidogenesis and gonadotropin cells in pituitary of the female. *J. Fish Biol.* 43: 475-485.

Dey, V. K. 1996. Ornamental fishes and Handbook of Aquafarming. The Marine Products Export Development Authority, Cochin.

Duarte, R. M., Ferreira, M. S., Wood, C. M. and Val, A. L., 2013. Effect of low pH exposure on Na+ regulation in two cichlid fish species of the Amazon. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 166(3): 441-448.

Froese, Rainer and Pauly, Daniel, Eds. (2014). "*Trichogaster Lalius*" In Fishbase. February 2014 Version

Gaunder,H.,Animaldiversity2pp.http:www.animaldiversity, ummzumich.edu / *Clarias gariepinus*. Htmp, Accessed April 05, 2005 (2005)

Graham, J. H. and Hastings, R. W., 1984. Distributional patterns of sunfishes on the New Jersey coastal plain.

Environmental Biology of Fishes, 10(3): 137-148.

IVOKE, N., MGBENKA, B. O. and OKEKE, O., 2017. Effect of pH on the Growth Performance of Heterobranchus bidorsalis (♂) x Clarias gariepinus (♀) Hybrid Juveniles. *Animal Research International*, 4(1).

Jacobsen, O. J., 1977. Brown trout (*Salmo trutta L.)* growth at reduced pH. *Aquaculture*, 11(1): 81-84.

Leivestad, H., Hendrey, G., Muniz, I. P. and Snekvik, E., 1976. Effects of acid precipitation on freshwater organisms. *Impact of acid precipitation on forest and freshwater ecosystems in Norway*, pp. 87-111.

Lloyd, R. and Jordan, D. H., 1964. Some factors affecting the resistance of rainbow trout (*Salmo gairdneri*, Richardson) to acid waters. *Int. J. Air Wat. Pollut*, 8: 393-403.

Menendez, R., 1976. Chronic effects of reduced pH on brook trout (*Salvelinus fontinalis*). *Journal of the Fisheries Board of Canada*, 33(1): 118-123.

Mount, D. I., 1973. Chronic effect of low pH on fathead minnow survival, growth and reproduction. *Water Research*, 7(7): 987-993.

Ndubuisi, U. C., Chimezie, A. J., Chinedu, U. C., Chikwem, I.C. and Alexander, U., 2015. Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *International Journal of Research in Biosciences*, 4(3): 14-20.

Packer, R. K. and Dunson, W. A., 1972. Anoxia and sodium loss associated with the death of brook trout at low pH. *Comparative Biochemistry and Physiology Part A: Physiology*, 41(1): 17-26.

Parra, J. E. G. and Baldisserotto, B., 2007. Effect of water pH and hardness on survival and growth of freshwater teleosts. *Fish osmoregulation. Science Publishers, New Hampshire*, pp.135-150.

Roberts, H. and Palmeiro, B.S., 2008. Toxicology of aquarium fish. *Veterinary Clinics of North America: Exotic Animal Practice*, 11(2): 359-374.

Robinson, G. D., Dunson, W. A., Wright, J.E. and Mamolito, G. E., 1976. Differences in low pH tolerance among strains of brook trout (*Salvelinus fontinalis*). *Journal of Fish Biology*, 8(1), pp.5-17.

Rodgers, D. W., 1984. Ambient pH and calcium concentration as modifiers of growth and calcium dynamics of brook trout, Salvelinus fontinalis. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(12): 1774-1780.

Sapkale, P. H., Singh, R. K. and Desai, A. S., 2013. Effect of different water temperatures and pH on the growth, specific growth rate and feed conversion efficiency of spawn to fry of common carp, *Cyprinus carpio*. *International Journal of Environment and Waste Management*, 12(1): 112-120.

Uzoka, C. N., Nwigwe, H. C., Ihejirika, C. E., Ibe, C. C. and Onwuagba, J. I., 2012. Growth and survival of hatchlings of *Clarias gariepinus* subjected to various pH. *International Journal of Biosciences (IJB)*, 2(10): 35-39.

Vaala, S. S. and Mitchell, R. B., 1970. Blood oxygen-tension changes in acid-exposed brook trout, Proceeding *of Pennsylvania Academy of Sciences*, 44: 41–44.

Welcomme, R. L. ed., 1988. *International introductions of inland aquatic species* (No. 294). Food & Agriculture Org..

Zweig, R. D., Morton, J. D. and Stewart, M. M., 1999. *Source water quality for aquaculture: a guide for assessment*.