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Oxygen consumption in fry and fingerling stages of Indian major carps analysed using indigenously developed respirometer

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ABSTRACT

Experiments were conducted under laboratory conditions for determination of oxygen consumption of advanced fry, fingerlings and advanced fingerlings of Indian major carps, catla *Catla catla* (Hamilton, 1822); rohu *Labeo rohita* (Hamilton, 1822); and mrigal *Cirrhinus mrigala* (Hamilton, 1822) in freshwater medium of total alkalinity varying between 150-154 mg l⁻¹, total hardness 130-140 mg l⁻¹, pH 7.5-8.0, carbon dioxide 5.6-12.0 mg l⁻¹ and temperature 31-35°C. Experiments were conducted in acrylic respirometers designed and developed for this purpose. The oxygen consumption values for advanced fry, fingerlings and advanced fingerlings of catla were 634±9, 565±27 and 516±28; rohu 549±26, 459±41 and 374±38 and mrigal 532±24, 449±28 and 343±30 mg kg body wt⁻¹ h⁻¹ respectively. In all stages, oxygen consumption values of catla varied significantly (p<0.05) from rohu and mrigal, whereas no significant differences were noticed between rohu and mrigal. Oxygen consumption was found to be more in all the three developmental stages of catla compared to corresponding stages of rohu and mrigal. In all the fishes, oxygen consumption was found to be higher in advanced fry stage than fingerling and advanced fingerling stages. The lower critical tolerance limits of oxygen in water for survival of advanced fingerlings of catla, rohu and mrigal were found to be 0.4, 0.32 and 0.32 mg l⁻¹ respectively.

Keywords: Dissolved oxygen, Indian major carps, Lower critical tolerance level, Oxygen uptake by fish, Respirometer

Fishes utilise dissolved oxygen in water for respiration and discharge carbon dioxide as a waste product of metabolism which remains in the medium in a dissolved form (Jhingran, 1991). Oxygen consumption is a critical parameter often used as an index of metabolism and for defining the energy budget of the animal. Lack of oxygen is often reported as a cause for mass mortality in wild and farm reared fishes (Moore, 1942). Dissolved oxygen is considered as a major parameter which directly determines the carrying capacity as well as optimal stocking density of fish in culture systems (Parker, 2002).

Several workers have studied the quantitative relationship between body weight and oxygen uptake in carps (Singh, 1977; Roy and Munshi, 1984; Tabinda *et al.*, 2003; Das *et al.*, 2005; Aravindakshan *et al.*, 2011). Divakaruni and Sharma (1990) studied oxygen consumption of fertilised eggs and early developmental stages of *Labeo rohita* and found that, after hatching, the rate of oxygen consumption increases with progression of development of larvae. Das *et al.* (2005) analysed oxygen consumption rates in *L. rohita* fry (10 days old) under different temperature regimes. As per FAO (1985), fry and fingerlings have a higher metabolic rate, particularly fry stage.

In the present study, an attempt was made to investigate the oxygen consumption rate in advanced fry, fingerlings and advanced fingerlings of the Indian major carps (IMC): catla *Catla catla*, rohu *L. rohita* and mrigal *Cirrhinus mrigala*, under laboratory conditions employing indigenously designed and developed respirometer at ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA), Bhubaneswar. The study also aimed to find out the lower critical tolerance levels of oxygen for advanced fingerlings of catla, rohu and mrigal.

Advanced fry, fingerlings and advanced fingerlings of IMCs collected from the fish farm at Puranapradhan Village, Khordha District, Odisha were brought to ICAR-CIFA, Bhubaneswar and were acclimatised to laboratory conditions. The fishes were acclimatised separately (species-wise and stage-wise) in glass aquaria (30 l). The size details of the fishes used for the experiments are presented in Table 1. Experiments were conducted during 21 July - 27 August 2016. The experimental setup is shown in Fig. 1.

Two acrylic respirometers were designed and developed for this experiment (Mohapatra and Sahoo, 2016). The dimensions of the respirometers were 10"x10"x10" and 11"x11"x11" with 18 and 22 l water

Table 1. Size details (Mean±SE) of fishes used for the experiments

Species	Stage	Advanced fry		Fingerlings		Advanced fingerlings	
		Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
<i>L. rohita</i>		2.88 ± 0.94	0.60 ± 0.41	6.88 ± 0.67	3.54 ± 0.88	9.72 ± 1.57	9.24 ± 2.74
<i>C. mrigala</i>		3.47 ± 0.39	0.44 ± 0.10	4.69 ± 0.50	1.05 ± 0.27	12.0 ± 0.77	10.14 ± 2.10
<i>C. catla</i>		0.29 ± 0.03	0.87 ± 0.34	8.56 ± 0.91	6.94 ± 2.45	11.27 ± 0.78	17.68 ± 2.81

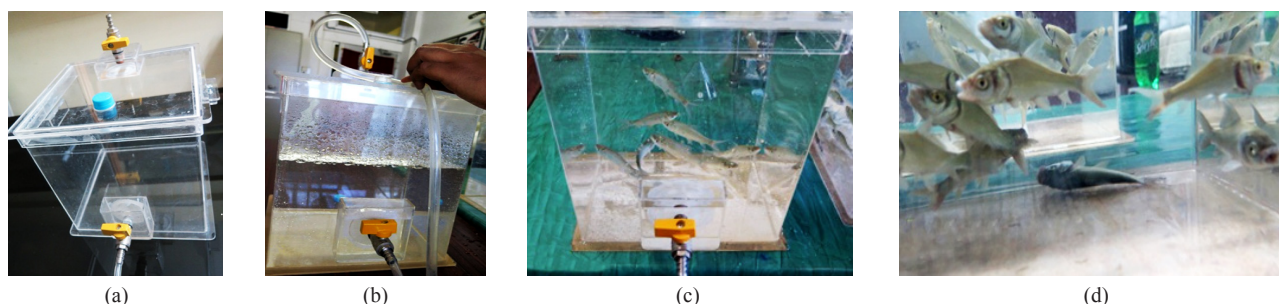


Fig. 1. (a) Acrylic respirometer, (b) Initial filling of water in the respirometer, (c) Respirometer operation with rohu, (d) Experiment for finding out the lower critical limit of oxygen in water for fish

storage capacities respectively. Each respirometer comprised a transparent water tank with outlet hub having drainage valve, transparent covering lid with inlet hub provided with inlet valve and airway cap. The airway cap was provided in the lid to make a way for air to pass into the tank while draining water out of the tank or during filling of water. Water can be filled or drained manually at desired intervals and the inlet as well as the outlet hubs were fixed with screens to prevent escape of fishes. The respirometer with 18 l capacity was used for fry stage and 22 l capacity for fingerlings as well as advanced fingerlings.

Operation of the respirometer involved filling the tank with oxygenated water, stocking the fishes, covering with the lid, water sampling for oxygen estimation at the start and at the end of the experiment. The initial water sample was collected for estimation of dissolved oxygen through the outlet of the respirometer and refilling was done through water inlet simultaneously. Then the water flow through the inlet system was stopped and the airway cap was made air tight. After a definite period of time, the airway cap was opened to collect water sample through the outlet for estimation of dissolved oxygen. Difference between the final and initial oxygen content of the water was calculated. After completion of the experiment, total body weight of the test animals in respirometer was recorded using a digital monopan balance.

The oxygen consumption of fishes was calculated using the formula (Mohapatra and Noble, 1993):

Oxygen consumption ($\text{mg kg body wt}^{-1} \text{ h}^{-1}$) =

$$\text{IO-FO (mg l}^{-1}\text{)} \times \frac{\text{V (ml)}}{1000 \text{ (ml)}} \times \frac{1000 \text{ g}}{\text{W (g)}} \times \frac{60 \text{ min}}{\text{T (min)}}$$

where, IO = Initial oxygen value (mg l^{-1})

FO = Final oxygen value (mg l^{-1})

V = Volume of water in the respirometer (ml)

W = Total weight of fish experimented (g)

T = Time gap between initial and final sampling of oxygen (min)

The dissolved oxygen content in water samples was estimated following Winkler's method (APHA-AWWA-WPCF, 1989). The temperature of water was measured using a thermometer. Total alkalinity, total hardness and carbon dioxide of the water were estimated following standard procedures.

Oxygen consumption of advanced fry, fingerlings and advanced fingerlings of IMC were estimated separately and recorded. For each stage of each species, the experiments were repeated three times and average value and standard error were calculated (Table 2). Standard statistical methods (two way ANOVA) were applied for finding out the level of significance between the species as well as between the stages by taking into consideration the oxygen consumption data for various stages of respective species.

The lower critical tolerance levels of oxygen for advanced fingerlings of each species of IMC were

Table 2. Oxygen consumption ($\text{mg kg body wt}^{-1} \text{ h}^{-1}$) in different stages of Indian major carps

Stages of fish	Rohu	Catla	Mrigal
Advanced fry	549±26 ^b	634±9 ^a	532±24 ^b
Fingerlings	459±41 ^b	565±27 ^a	449±28 ^b
Advanced fingerlings	374±38 ^b	516±28 ^a	343±30 ^b
Combined (Advanced fry to advanced fingerlings)	461±82 ^b	572±55 ^a	441±85 ^b

Values are expressed as Mean ± SD.

Values with same superscripts in a row do not differ significantly ($p < 0.05$)

estimated separately and recorded. For this, the parameters like initial time of sampling and corresponding initial dissolved oxygen value were estimated for each species in the respirometer. After a gap of one hour, the dissolved oxygen content was again estimated by drawing water sample from the respirometer and refilling it with same volume of water through the airway. The final water sample for dissolved oxygen from the respirometer was collected, when the fish inside started showing signs of loss of equilibrium due to oxygen stress. The time was noted and the dissolved oxygen content was estimated.

The physico-chemical parameters of water in the respirometer recorded during the experimental period were: water temperature - 31-35°C, total alkalinity -150-154 mg l⁻¹, total hardness -130-140 mg l⁻¹, pH -7.5-8.0 and carbon dioxide -5.6-12.0 mg l⁻¹. The demand for dissolved oxygen for an aquatic organism depends upon the species, its physical state, water temperature and other factors like presence of pollutant stress. Scientific studies conducted earlier suggest that a minimum of 4-5 mg l⁻¹ of dissolved oxygen is essential for support of life for diverse fish population (Jhingran, 1991). Carbon dioxide quickly combines in water to form carbonic acid which is a weak acid. The concentration of carbonic acid varies depending on the pH and alkalinity of water. If the water is alkaline (high pH), carbonic acid will act to neutralise it and if the water is already acidic (low pH), the carbonic acid will make things worse by making it more acidic. In the present study, the experiments were started in respirometers holding water having initial oxygen levels above 4.0 mg l⁻¹ with alkaline pH.

In advanced fry stage, the estimated average oxygen consumption was higher in catla (634±9 mg kg body wt⁻¹ h⁻¹) than rohu (549±26 mg kg body wt⁻¹ h⁻¹) and mrigal (532±24 mg kg body wt⁻¹ h⁻¹). Similarly in fingerling stage, oxygen consumption was higher in catla (565±27 mg kg body wt⁻¹ h⁻¹) than rohu (459±41 mg kg body wt⁻¹ h⁻¹) and mrigal (449±28 mg kg body wt⁻¹ h⁻¹). Oxygen consumption was higher in advanced fingerlings of catla (516±28 mg kg body wt⁻¹ h⁻¹) than rohu (374±38 mg kg body wt⁻¹ h⁻¹) and mrigal (343±30 mg kg body wt⁻¹ h⁻¹). Oxygen consumption was found to be more in all stages of catla as compared to similar stages of rohu and mrigal. In IMC, oxygen consumption was found higher in advanced fry stage than the fingerling and advanced fingerling stages. In all stages, oxygen consumption values of catla differed significantly (p<0.05) from rohu and mrigal, but, no significant differences were found between rohu and mrigal.

Fry and fingerlings of fishes, particularly the fry stage, have much higher metabolic rate, as compared to later stages (FAO, 1985). The oxygen consumption rate and energy demand of silver carp *Hypophthalmichthys molitrix* fry is 5-10 times higher than the summer fingerlings and it is even much higher than that of two year old fingerlings (FAO, 1985). Status of other species is also similar to that of silver carp. In the present study, oxygen consumption of fry of IMCs was higher than the fingerlings and advanced fingerlings. Oxygen consumption rate of fishes (425-1060 g) viz., *C. catla*, *L. rohita*, *C. mrigala*; *H. molitrix*, *C. carpio* and *P. gonionotus* ranged between 19.74 and 70.58 mg kg fish⁻¹ h⁻¹ during transportation (Aravindakshan *et al.*, 2011). The surface dwelling fish, catla consumed more oxygen, *i.e.*, 70.58 mg kg fish⁻¹ h⁻¹ in comparison to column dweller (rohu 68.9 mg kg fish⁻¹ h⁻¹) and bottom dweller (mrigal 35.8 mg kg fish⁻¹ h⁻¹). Similar results were also obtained for different stages (surface, column and bottom dwellers) of IMCs, in the present set of experiments. The actual average oxygen consumption showed a clear-cut downward trend from surface dwelling fishes *via* column dwelling to bottom dwelling fishes.

Das *et al.* (2005) experimented with 10 days old *L. rohita* fry (average size 0.385 g) for mean oxygen consumption rates at 26, 31, 33 and 36 °C and found that the values were 58.02, 66.04, 76.28 and 93.27 mg kg⁻¹ h⁻¹ respectively. Padmavati *et al.* (2002) studied the oxygen consumption in *C. mrigala* and *L. rohita* in freshwater medium at 30°C using Fry's respirometer and reported values of 295.12 and 92.68 mg kg⁻¹ h⁻¹ under anorexia and hypoxia respectively. In *L. rohita*, the mean oxygen consumption was 297.16 and 104.4 mg kg⁻¹ h⁻¹ under anorexia and hypoxia respectively. In the present study, oxygen consumption value obtained for rohu advanced fry was 269 mg kg⁻¹ h⁻¹ which is in agreement with the earlier findings of Padmavati *et al.* (2002).

The lower critical tolerance levels of oxygen in water for advanced fingerlings of IMCs were estimated separately and presented in Table 3. The limits were 0.32 mg l⁻¹ for rohu and mrigal and 0.4 mg l⁻¹ for catla. It was reported that rohu and mrigal were more tolerant to oxygen stress in water than catla. Before reaching this stage, all fishes showed signs of distress with higher opercular movement inside the respirometer. Findings of the present study is in agreement with that of Tabinda *et al.* (2003) who reported that *L. rohita* fingerlings seem to be the most tolerant species having highest oxygen consumption rates and better survival at low oxygen concentration in water.

Table 3. Lower critical level of dissolved oxygen (mg l^{-1}) in water for survival of advanced fingerlings of IMCs

Species	Total wt. of fish (g)	Volume of water (l)	Initial O_2 level of water (mg l^{-1})	O_2 level in water after 1 h of experimentation (mg l^{-1})	O_2 level in water at the time of equilibrium loss of fish in respirometer (mg l^{-1})	Duration between initial and final O_2 data recording (min.)
Rohu	143.4	22	5.4	1.4	0.32	145
Mrigal	129.5	22	5.2	2.0	0.32	130
Catla	94.5	22	5.1	2.4	0.40	108

Acknowledgements

The authors are thankful to the Project Coordinator, All India Coordinated Research Project on Plasticulture Engineering and Technology (AICRP on PET), Ludhiana, Punjab for financial support and the Director, ICAR-CIFA, Bhubaneswar for providing facilities for the experiments.

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Date of Receipt : 08.09.2016

Date of Acceptance : 29.12.2016