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Rate of Oxygen Consumption in Fingerlings of Major Carps at Different Temperatures

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Abstract: Different species of carp fishes have different rates of oxygen consumption which varies with the change in temperature. Oxygen consumption studies were carried out on fingerlings (seed) of *Labeo rohita, Cirrhina mrigala, Catla catla, Hypophthalmicthys molitrix* and *Ctenopharyngiodon idella* at four different temperatures i.e., 15, 20, 25, 30°C in laboratory conditions. Labeo rohita seems to be the most tolerant species having highest oxygen consumption rates and better survival at low available oxygen concentration in water. *Catla catla* (at 15 and 30°C) and *Hypophthalmicthys molitrix* (at 20°C and 25°C) are least tolerant species with highest oxygen consumption rates. Rate of oxygen consumption is greater in *Labeo rohita* at 15, 20 and 25°C but highest in *Cirrhina mrigala* at 30°C. *Labeo rohita* seems to be the most tolerant species having highest oxygen consumption rates and better survival at low available oxygen concentration in water. *Ctenopharyngiodon idella* and *Cirrhina mrigala* are moderately tolerant species among the fish species under study.

Key words: Fingerlings, Carp fishes, Oxygen consumption and temperature

Introduction

The fish body is designed for life in a buoyant environment that displaces its body mass. Water, while far denser than air reduces the friction on the fish body reducing energy costs of locomotion. Swimming, in general, requires less energy than terrestrial locomotion (Pianka, 1994). The fusiform shape and slime layer typical of fish serves to further reduce friction and its related energy costs. Therefore, countercurrent blood circulation in fish gills and red muscle offers efficient O_2 uptake (Ricklefs, 1993).

Fish muscle is constructed differently than terrestrial animal muscle. It is composed largely of two types: aerobic red muscle and anaerobic white muscle. The metabolic requirements for each type are different. Red muscle is used for constant swimming activity. It is supplied with oxygen for respiration by a well-developed vascular system. In contrast, white muscle is a high power, short-term system used in bursts of speed (Evans, 1993). White muscle uses myoglobin to bind oxygen within muscle cells.

The gill filaments of bony fishes (also known as a primary lamellae) are complex structures, which have a large surface area. Of each are numerous smaller secondary lamellae. Tiny blood capillaries flow through the secondary lamellae of each gill filament. The direction of blood flow is opposite to that of water flow. This ensures that as the blood flows along each secondary lamella, the water flowing beside it always has a higher oxygen concentration than that in the blood. In this way oxygen is taken up along the entire length of the secondary lamellae. Not all fishes rely totally on their gills to breathe. Some species when they are young absorb a large proportion of their oxygen requirements through the skin. Other species have well developed lungs for breathing air and will in fact drown if they do not have access to the surface (Helfman *et al.,* 1997; Lagler *et al.,* 1962; Michael, 1998).

The metabolic rate of fish is usually measured by their rate of respiration i.e., their rate of oxygen consumption, which depends upon the temperature of surrounding water. The oxygen consumption rate increases with rise in temperature and decreases with decrease in temperature. The rate of oxygen consumption in fishes varies from specie to specie. Different species of carp fishes have different rates of oxygen consumption that varies with change in temperature of its surrounding water. Rise in temperature of surrounding water increases the rate of oxygen consumption, which results in low dissolved oxygen even to the sublethal level.

The sub lethal low oxygen concentration may cause increased respiratory and metabolic activity, alteration in blood chemistry, cardiac changes, mobilization of anaerobic energy pathways, upsets in acid base balance, reduced growth and decreased swimming capacity (Barton and Taylor, 1996). Under extreme conditions, fish may take advantage of oxygen-rich surface film water. However, chronic DO requirements are far more important to long term maintenance of healthy fish communities than acute tolerances (Barton and Taylor, 1996).

Transporting fish in water overlaid with pure gaseous oxygen is a worldwide practice. Changes in oxygen, carbon dioxide, ammonia, pH (acidity) and bacterial numbers occur in container water during transport. During a typical shipment, container water remains supersaturated with oxygen and has a constant increase of the two important toxic wastes, carbon dioxide and ammonia. Some carbon dioxide escapes into the oxygen gas layer; the shallower the water the more carbon dioxide escapes. Little ammonia is released into the oxygen layer because of its strong attraction to water. Ammonia is the principle form of nitrogen waste released by fishes and more is released on a per weight basis from smaller individuals of a species than from larger one (Greking, 1955). The more animals loaded into a transport unit, the quicker the water will become polluted with toxic ammonia and carbon dioxide. The pH tends to drop during the transport period because carbon dioxide produces an acidic effect. Fish secretions and excretions provide food for bacteria, which multiply in large numbers within the water.

The susceptibility of aquatic animals to handling and transport stress must always be considered. Certain delicate species always will be difficult to handle unless substantial genetic modifications occur. Both delicate and hardy species can sometimes decline in condition and vigor during transport. Prolonged starvation lowers handling resistance, as does exposure to natural toxins or other forms of stress.

Animals should not be transported unless they have an acceptable standard of vitality. Neither should animals be transported when conditions range beyond those likely to be tolerated. When weak or unduly stressed animals are transported, there will be a physiological or anatomical breakdown and the animals will die immediately or has what is popularly known as a delayed mortality. Such a physiological or anatomical breakdown can cause a decrease in disease resistance and a pre-disposal to microbial disease.

Reducing the water temperature in the sealed transport container slows many biological processes and causes the animals to produce less waste. Chilling also causes a greater oxygen saturation of the water and reduces the oxygen requirement of transported animals. The optimum temperature is that which produces the most favorable water environment without being too low for the species to tolerate.

The osmotic pressure of the external environment may influence the intake of many undesirable pollutants by animals in transport. If a balanced pressure is maintained fluid intake is reduced and the aquatic animals body is less stressed (Norton and Davis, 1977).

The excitability of animals during handling causes a variety of stress manifestations. An immediate effect is a larger oxygen requirement. Latent physiological changes induced by the stress of handling and water quality alteration have been the subject of greater interest during last two decades (Calliouet, 1968; Davis and Parker, 1983; Mazeaud and Mazeaud, 1981; Spotts and Lutz, 1981; Tomasso *et al*., 1980).

Breeding of carp fishes in Punjab is carried out by induced spawning at different hatcheries (public and private) and seed of these fishes is supplied to the fish farmers at fingerling stage. Fingerlings are supplied and transported to the farmers in polyethylene bags containing water at ambient temperature with approximate quantity of oxygen. About 70 hatcheries (public and private) in Punjab not only meet the requirements of fish farmers in the province of Punjab but also supplied them to the other provinces. It has been observed that during transportation mortality rate of fingerlings increases due to oxygen depletion and sometimes the whole flock died before reaching to final destination. Such cases are more often when fingerlings are transported to distant places. Mortality of the fingerlings during transportation not only results in financial losses but also losses in terms of lapse in growth period. This could be overcome if the exact demand of dissolved oxygen and temperature of specific fish specie is known. This would help in maintaining the temperatures and oxygen requirements while transportation even to distant places.

The present study was envisaged to determine the rate of oxygen consumption per hour of carp fishes most commonly cultured in aquaculture ponds of Punjab. The study was carried out at a temperature range from 15-30°C, the normal ambient temperature found in Punjab during winter and summer seasons. This temperature range was also selected to determine the oxygen consumption rate in carp fishes at lower and higher temperatures.

The information on oxygen consumption is not only useful in comparative physiology but also helps in fish culture and fishery management. This provides insights in solving the problems associated with rearing fish or transporting live fish (Froese, 1988).

Materials and Methods

Oxygen consumption studies were carried out on fingerlings (seed) of five most commonly cultured pond fish species in Punjab in a polyculture system. These fishes were *Labeo rohita, Cirrhina mrigala, Catla catla, Hypophthalmicthys molitrix* and *Ctenopharyngiodon idella*. Fish fingerlings (5-10 g each) were obtained from

Central Fish Seed Hatchery, Lahore and acclimatized in glass aquaria to minimize the handling stress. The animals were not fed for three days before the start of experiment. The prolonged starvation lowers handling resistance as do exposure to natural toxins or other forms of stress. The excitability of animals during handling causes a variety of stress manifestations. An immediate effect is a larger oxygen requirement (Calliouet, 1968; Davis and Parker, 1983; Johnson and Cichra, 1983; Johnson *et al.,* 1984; Johnson, 1979; Mazeaud and Mazeaud, 1981; Spotts and Lutz, 1981; Tomasso *et al*., 1980)

Airtight glass bottles (4 liter capacity each) filled with water having 20 animals were used for each set of species and temperature. The experimental set was run in duplicate. The bottles were fitted with probe of oxygen meter and thermometer

Studies were carried out at four different temperatures, i.e., 15, 20, 25 and 30°C. Temperature of the experimental bottles was maintained using ice bath or heating arrangements in the laboratory.

Weighing of the animals was made using Mettler electronic balance. Fishes were introduced into the sealed glass bottles and initial oxygen concentrations were recorded. The rate of oxygen consumption was measured using YSI-5736 model dissolved oxygen meter. Oxygen concentrations (mg) were recorded after every hour for each species. Rate of oxygen consumption was calculated in mg g^{-1} body mass of fish.

Results and Discussion

The data collected during the course of study is presented and discussed. Rate of oxygen consumption at 15°C is reported in Table 1 followed by Fig. 1.

Rate of oxygen consumption increased in the following order in the fingerlings of five experimental fishes.

Catla catla < *Cirrhina mrigala* < *Ctenopharyngiodon idella* < *Hypophthalmicthys molitrix* < *Labeo rohita.*

Table 1: Rate of oxygen consumption mg h^{-1} in fingerlings at 15°C

	Hours vs oxygen consumption (mg)							
Species	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
L. rohita	0.145	0.416	0.538	0.66	0.718	0.824	0.97	1.076
C. mrigala	0.186	0.316	0.542	0.616	0.672	0.756	0.85	0.952
C. catla	0.066	0.17	0.25	0.314	0.404	0.476	0.538	-----
C. idella	0.19	0.856	0.49	0.546	0.556	-----	-----	-----
H. molitrix	0.118	0.396	0.426	-----	-----	-----	-----	-----

Table 2: Rate of oxygen consumption mg h^{-1} fingerlings at 20°C

	Hours vs oxygen consumption (mg)							
Species	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
L. rohita	0.284	0.71	-----	-----	-----	-----	-----	-----
C. mrigala	0.4	0.632	0.726	-----	-----	-----	-----	-----
C. catla	0.16	0.638	-----	-----	-----	-----	-----	-----
C. idella	0.454	0.711	0.775	-----	-----	-----	-----	-----
H. molitrix	0.318	0.348	-----	-----	-----	-----	-----	-----

The maximum oxygen consumption at 15°C was found in *L. rohita and C. mrigala.* The rate of oxygen consumption is moderate in *C. catla,* whereas *C. idella* and *H. molitrix* were died after 5.0 h. This would mean that *L. rohita* and *C. mrigala* could survive for a longer time at 15°C. Therefore, while transportation such temperature shall be maintained for the safe arrival of these species at their final destination.

The results of oxygen consumption at 20°C is reported in Table 2 and illustrated in Fig. 2. From the Table 2 it can be seen that only two species *C. mrigala* and *C. idella* can withstand 20°C but only for a short period of time while other species were found to be less tolerant. The rate of oxygen consumption in these species is as follows:

Hypophthalmicthys molitrix < *Cirrhina mrigala* < *Catla catla* < *Ctenopharyngiodon idella* < *Labeo rohita*

The rate of oxygen consumption at 25°C of that *L. rohita* and *C. mrigala* was maximum upto 3.0 h suggesting the tolerance of these species at high temperature. *C. catla* also have the high oxygen consumption rate but it could not survive after 2.0 h. (Table 3 followed by Fig. 3). The oxygen consumption rate at 25°C follows the following order in the five species.

Hypophthalmicthys molitrix<*Cirrhina mrigala*<*Catla catla* <*Ctenopharyngiodon idella*<*Labeo rohita*

It is worth mentioning here that while transportation the fish farmers usually ignore the effect of temperature on the survival of fishes. In Punjab or else where in other provinces of Pakistan the ambient temperature is usually higher than 25°C. The lower temperature is hardly maintained during transportation, which results in great economic losses. Biological processes are usually slow down at lower temperature, which results in the lower production of waste, one of the main causes of fish mortality. It is also reported that chilling causes a greater oxygen saturation of the water and reduces the oxygen

Table 3: Rate of oxygen consumption mg h^{-1} in fingerlings at 25°C

	Hours vs oxygen consumption (mg)							
Species	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
L. rohita	0.47	0.756	0.814	-----	-----	-----	-----	-----
C. mrigala	0.744	0.666	0.844	-----	-----	-----	-----	-----
C. catla	0.272	0.682	-----	-----	-----	-----	-----	-----
C. idella	0.475	0.751	------	-----	-----	-----	-----	-----
H. molitrix	0.324	0.342	------	-----	-----	-----	-----	-----

Table 4: Rate of oxygen consumption mg h^{-1} in fingerlings at 30°C

	Hours vs oxygen consumption (mg)							
Species	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
L. rohita	1.92	1.976	-----	-----	-----	-----	-----	-----
C. mrigala	0.516	0.556	0.594	-----	-----	-----	-----	-----
C. catla	1.868	2.1	-----	-----	-----	-----		-----
C. idella	2.38	2.54	-----	-----	-----	-----	-----	-----
H. molitrix	0.414	0.42	-----	-----	-----	-----	-----	-----

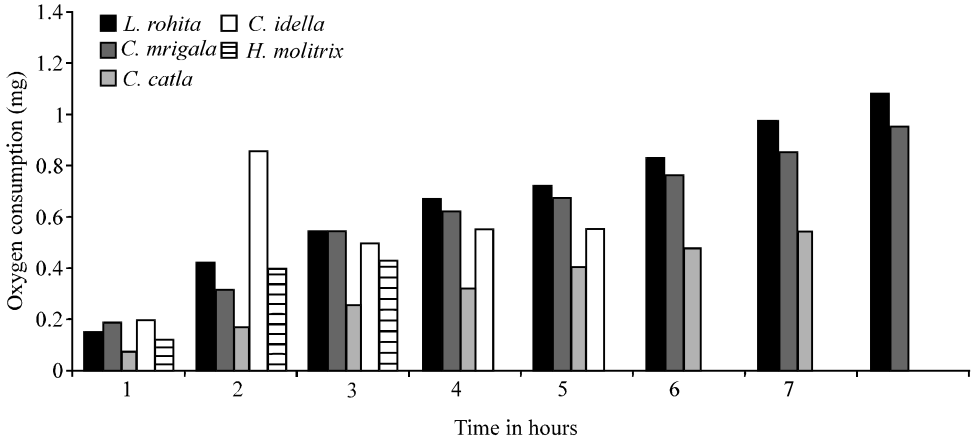

Fig. 1: Rate of oxygen consumption (mg) per hour in fingerlings at 15°C

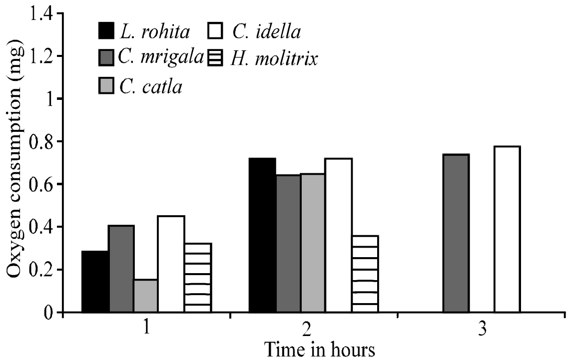

Fig. 2: Rate of oxygen consumption (mg) per hour in fingerlings at 20°C

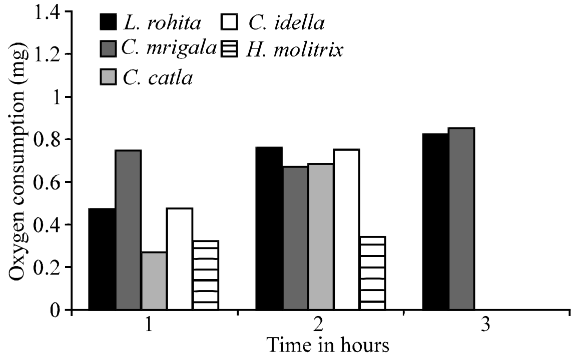

Fig. 3: Rate of oxygen consumption (mg) per hour in fingerlings at 25°C

requirement of transported fishes (Calliouet, 1968; Davis and Parker, 1983; Johnson *et al.,* 1984; Johnson, 1979; Mazeaud and Mazeaud, 1981; Spotts and Lutz, 1981). Evans (1993) and Sehreek and Moyle (1990) reported that oxygen uptake rates of fishes during exercise is slightly higher than resting rates. They also suggested that lower activity levels require less oxygen.

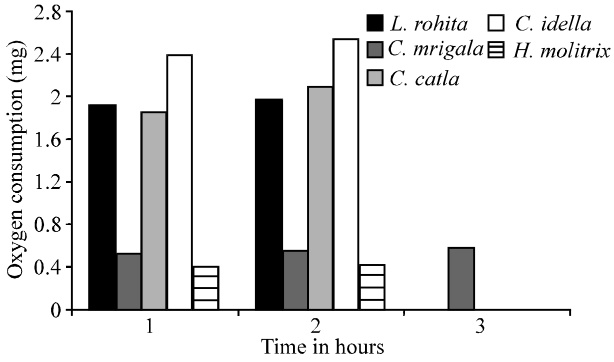

Fig. 4: Rate of oxygen consumption (mg) per hour in fingerlings at 30°C

The results of oxygen consumption at 30°C is reported in Table 4 and Fig. 4 The oxygen consumption rate of *L. rohita* and *C. idella* was quiet higher which proves their tolerance at higher temperature but even than they could not survive for longer periods. The rate of oxygen consumption of other species was found to be insignificant. The oxygen consumption rate follows the following pattern:

Catla catla<Labeo rohita<Ctenopharyngiodon idella< Hypophthalmicthys molitrix<Cirrhina mrigala

Management approaches for transportation (use of additives): Of the various substances that can be added to transport water, salts are likely to provide the most benefit. Sodium chloride is often used because of its osmoregulatory benefit to freshwater species (Wedemeyer, 1972). Post-transport acclimation in salted water also has proved beneficial (Hattingh *et al.,* 1975; Nikinamaa *et al.*, 1983:). Hunn (1982) suggests that total salts in freshwater transport should not exceed 0.75%.

Calcium has been shown to decrease the permeability of gills to water in freshwater fishes (Auld, 1973; Hunn, 1982) and its salts are occasionally used as additives.

Various anesthetics have been used in attempts to relax the animals and thereby lower metabolic rates (Davis and Parker, 1983; Plumb *et al.*, 1983). The compounds used most in the U.S re MS-222 and quinaldine, but their use is not widespread, particularly in sealed containers.

Other additives sometimes are used to check build-up of bio toxins or microbial agents. Clinoptiloite has had limited use in sealed freshwater containers. Its purpose is to remove ammonia, but the quantity required for a desired effect (1-2% of water volume) produces a strong turbidity. Also, it is ineffective when used with sodium chloride. Tris buffer (Tris-hydroxymethyl-aminomethane) has been used to stabilize pH and curtail the development of free carbon dioxide (McFarland and Norris, 1958; Turner and Bower, 1982), but the quantities required and its cost discourage its use. Contrary to popular belief, additions of bacteriostats and antibacterial agent do not necessarily prevent bacterial development in transport containers.

From these results it can be concluded the fingerlings are highly vulnerable to high temperatures. While transportation of fishes low temperature should be maintained to avoid mortality. It is also suggested that additives must be added to attain better survival rate.

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