

Variations in Oxygen Carrying Capacity of *Sarotherodon melanotheron* Blood in Different Acclimation Media

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Abstract: Variations in Oxygen Carrying Capacity of *Sarotherodon melanotheron* was investigated. The fish were acclimated using three media (brackish water, gradual reduction in salinity and fresh water) for a period of seven days. The results indicated various levels of reduction ($p < 0.05$) exhibited by both juveniles and adults, before and after acclimation in different media. For fish acclimated in brackish water, Oxygen Carrying Capacity for juveniles (OCC) reduced from 5.17 ± 0.87 to 4.70 ± 0.59 , vol. % adult fish from 8.46 ± 0.75 to 8.17 ± 1.01 vol.%. While in gradual acclimation, juveniles from 5.11 ± 0.95 to 3.83 ± 0.7 vol. % adults from 8.44 ± 0.72 to 6.02 ± 0.73 vol. %. And in fresh water, juveniles 3.74 ± 0.87 to 2.57 ± 0.94 vol. %; adults fish from 8.64 ± 0.66 to 5.87 ± 0.70 vol.%. These variations in oxygen carrying capacity were more pronounced in fish acclimated in fresh water and least variation in fresh brackish water. Results from this study suggests that acclimation, a common procedure, in brackish water fish farming exerts some degree of influence oxygen carrying capacity of the fish and hence the need to reckon with then when reporting oxygen and metabolic related activities of this species.

Key words: Variations in oxygen, acclimation media, *Sarotherodon melanotheron*, Nigeria

INTRODUCTION

Oxygen carrying capacity in fish is the amount of oxygen that can be maximally carried by unit volume of blood (Nikinmaa, 2001). The oxygen capacity of whole blood comprises of oxygen in solution in the blood plus oxygen in combination with haemoglobin (Bone *et al.*, 2004). In general, more than 90% of oxygen transported from the respiratory epithelia to the tissue capillaries is transported by haemoglobin that is contained within the erythrocyte (Brauner and Randall, 1998). Aerobic metabolism requires a supply of oxygen to the tissues and adequate elimination of acid and products like carbon-dioxide to prevents undue acidification of tissues. According to Pelster (2001) metabolic and ventilatory activities are tightly coupled in most fishes. In addition, the low solubility of oxygen in body fluids is compensated by the presence of respiratory pigments like haemoglobin, which increase the oxygen-carrying

capacity of blood or haemolymph by one or two order of magnitude (Fago *et al.*, 1997). The optimal use of these respiratory pigments often requires loading and unloading of the oxygen in a very narrow range of oxygen partial pressures (Pelster and Rendall, 1998). Studies on the structure and functions of the respiratory pigment haemoglobin have revealed a striking flexibility in its intrinsic oxygen binding characteristics even among closely related species, caused by replacements in various amino acid residues of the protein moiety of these pigments (Jensen *et al.*, 1998). Also, the haemoglobin may show large variability in their sensitivity to effectors like protons, organic phosphates, environmental conditions, internal organizations and various fish management procedures in aquaculture (Angelichs *et al.*, 1987; Pelster, 2001).

One of the management techniques commonly used in aquaculture is acclimation, which is a prerequisite for stocking of ponds both for culture and experimental

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purposes (Akinrotimi, 2006). Acclimation involve the modification of biological functions especially those of physiological structures to maintain or minimize deviation from homeostasis despite change in some environmental quality such as temperature, salinity, light, pH, hardness or toxicant concentration, has been reported by Gabriel *et al.* (2007) to cause some distortions in blood parameters of fish. Alkahem *et al.* (1998) observed that alterations in natural and chemical composition of aquatic environment to alter the behaviour, biochemistry and physiology of fish which intrinsically may have effects on its haematological properties and invariably affects its oxygen carrying capacity. According to Nikinmaa (2001) the amount of oxygen carried by unit volume of blood is determined by the number of erythrocytes, the oxygen-binding properties of haemoglobin and the prevailing environmental conditions of the fish.

Since oxygen carrying capacity of fish reflects the metabolic conditions of fish more quickly than other commonly measured parameters and since they respond quickly to changes in environmental and handling procedures in aquaculture (Alkinson and Judd, 1978), they have been widely used for the description of fish health (Blaxhall, 1972); for monitoring stress responses (Soivio and Oikari, 1976) and for predicting systematic relationships and the physiological adaptations of fish (Atamanalp and Yanik, 2002).

Available information in the literature on the oxygen carrying capacity of fish under various circumstances, include that of Rainbow trout-*salmo gairdneri* (Smith and Jones, 1982; Nikinmaa, 1982; Cossins and Richardson, 1985; Primm *et al.*, 1986) Common Carp-*cyprinus carpio* (Holk, 1996) hag fish-*myxine glutinosa* (Muller *et al.*, 2003). Striped bass-*morone saxatilis* (Nikinmaa *et al.*, 1984) sea lamprey-*lampetra fluviatilis* (Nikinmaa and Mattsof, 1992) European eel-*Anguilla anguilla* (Wood and Johnse, 1973; Pelster, 1995), but none is available on *S. melanotheron* a popular culture fish in the brackish water zone of Nigeria.

MATERIALS AND METHODS

Three hundred and twenty adult *Sarotherodon melanotheron* (Mean length 13.14 ± 0.38 SD; mean weight 45.26 ± 0.26 SD) and 320 juveniles (mean length 9.22 ± 0.245 and mean weight 28.12 ± 0.345) were harvested during the low tide from the recruitment ponds of African Regional Aquaculture Centre Brackish water fish farm, Buguma, Rivers State, Nigeria. they were immediately transferred to the heathery unit, where they were acclimated in nine

rectangular tanks of 0.36 m^3 , using three different methods with three tanks each. Brackish water Gradual acclimation (reduction in salinity from 12‰) and direct transfer to fresh water, for a period of seven days. The fish were stocked at the rate of 70 fish per tank and were fed twice daily at 1% body weight. Half of the water in the tanks containing brackish (control) and fresh water were exchanged on the third day. While in trails involving gradual acclimation the water was replaced daily with a view to reduce the salinity levels.

During the experiment the following water quality parameter were monitored temperature, hydrogen ion concentration (pH) Dissolved oxygen (Do) salinity, ammonia nitrogen and nitrite nitrogen temperature were taken using mercury in glass thermometer ($^{\circ}\text{C}$). pH was determined by the use of a pH meter (Model HI 9812, Hannah products, Portugal). Salinity was measured by hand held refractometer (model HRN-2N, Atago Products, Japan). Dissolve oxygen in the experimental tank were determined twice at the beginning and at the end of the experiment by the Winkler method (APHA, 1985). The experimental fish was sexed by the examination of the number of orifices (openings) in the genital papilla.

Blood was sampled from a total of 108 fish, 54 males and 54 females. After collection the sample were preserved in EDTA bottles and labeled for easy identification and transferred to the department of medical laboratory Rivers State University of Science and Technology Port Harcourt for haematological analysis.

The blood were analysed based on the methods of Blaxhall and Daisley (1973), Haemoglobin (Hb) was done by the cyanomethaemoglobin method while oxygen carrying capacity of the fish blood was calculated by multiplying the haemoglobin content by 1.25, oxygen combining power of Hb/g (Johansen, 1970).

RESULTS

The result of the physico-chemical parameters of water, indicated, no significant difference in the parameter, except in salinity values in gradual acclimation, which was reduced from 12.08 ± 0.4 to 0.20 ± 0.11 (Table 1). The mean values of oxygen carrying capacity of fish, before and after acclimation, showed a trend which indicated reduction, in all acclimation media, which was more observable in fish acclimated in fresh water, (Table 2). For each acclimation medium stage and sex of fish, there is generally a reduction in the value of their oxygen carrying capacity before and after acclimation, in brackish water juveniles males value decreased from

Table 1: Physico-chemical parameters of tanks in which *S. melanotheron* were acclimated for seven days

Parameters	Before acclimation			After acclimation		
	BR	GR	FR	BR	GR	FR
Temperature (°C)	28.11±0.25	27.02±0.72	27.46±0.18	27.61±0.38	27.68±0.56	27.49±0.61
pH	6.56±0.18	6.72±0.67	7.06±0.46	6.50±0.28	6.58±0.31	6.94±0.41
N-NH ₃ (mg L ⁻¹)	0.49±0.08	0.45±0.07	0.28±0.02	0.57±0.02	0.54±0.02	0.49±0.03
N-NO ₂ (mg L ⁻¹)	0.0042±0.02	0.004±0.01	0.00±0.01	0.0048±0.06	0.0045±0.02	0.0018±0.11
Dissolved oxygen (mg L ⁻¹)	5.97±0.35	5.95±0.04	6.84±0.36	4.99±0.12	4.86±0.14	5.12±0.26
Sulfide (mg L ⁻¹)	0.03±0.01	0.03±0.02	0.01±0.01	0.04±0.02	0.01±0.01	0.01±0.01
Salinity (‰)	12.01±0.32	12.08±0.41	0.08±0.36	12.21±0.66	0.20±0.11	0.02±0.01

Key: BR-(Brackish water); Gr-(Gradual Reduction Insalinity) Fr-(Fresh Water)

Table 2: Mean values of oxygen carrying of *Sarotherodon melanotheron* in different acclimation media

Acclimation Media	Fish size	Before acclimation			After acclimation		
		Mean	Min	Max	Mean	Min	Max
Brackish water	Juveniles	5.17±0.87	3.76	6.23	4.70±0.59	3.64	5.76
Brackish water	Adults	8.46±0.75	6.76	9.38	8.17±1.01	5.01	9.15
Fresh water	Juveniles	3.74±0.87	3.78	6.24	2.57±0.94	1.26	3.74
Fresh water	Adults	8.64±0.66	6.81	9.37	5.87±0.70	4.27	6.93
Gradual acclimation	Juveniles	5.11±0.95	3.38	6.25	3.83±0.74	2.75	4.97
Gradual acclimation	Adults	8.44±0.72	6.78	9.25	6.02±0.73	4.26	7.01

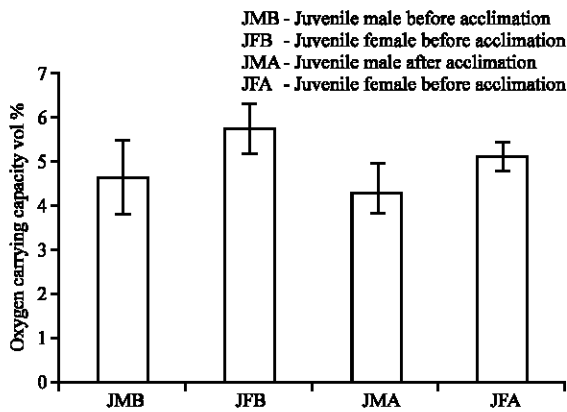


Fig. 1: Oxygen carrying capacity of Male and Female juvenile *Sarotherodon melanotheron* before and after acclimation in brackish water

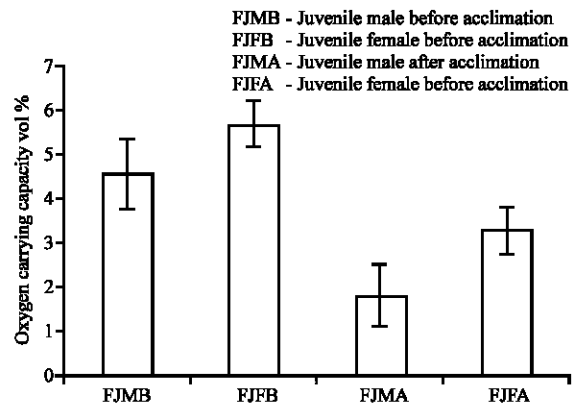


Fig. 3: Oxygen carrying capacity of Male and Female juvenile *Sarotherodon melanotheron* before and after acclimation in fresh water

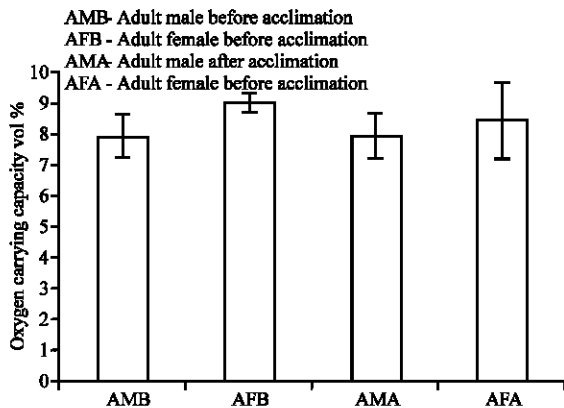


Fig. 2: Oxygen carrying capacity of Male and Female adult *Sarotherodon melanotheron* before and after acclimation in brackish water

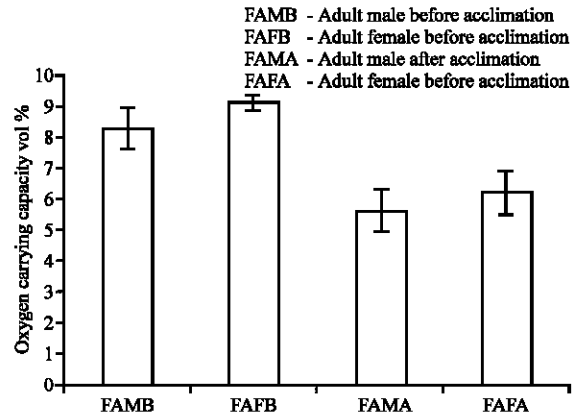


Fig. 4: Oxygen carrying capacity of Male and Female adult *Sarotherodon melanotheron* before and after acclimation in fresh water

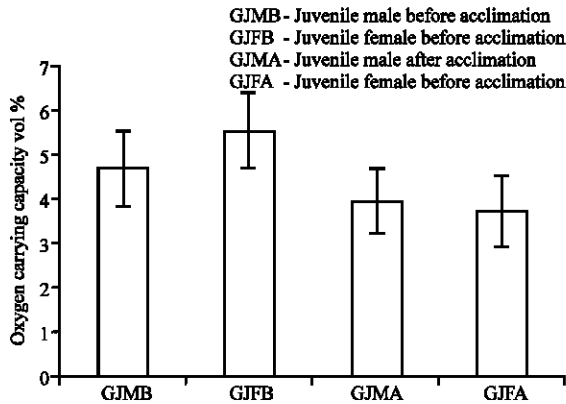


Fig. 5: Oxygen carrying capacity of Male and Female juvenile *Sarotherodon melanotheron* before and after gradual acclimation

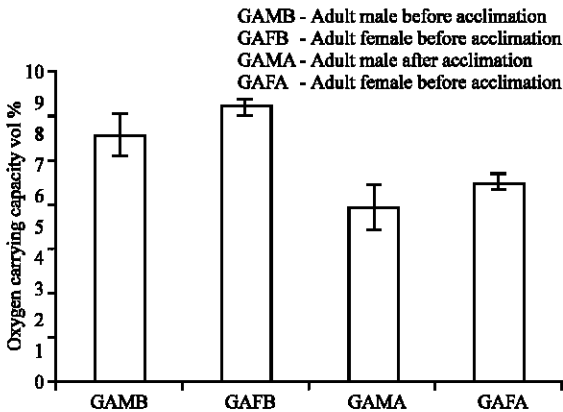


Fig. 6: Oxygen carrying capacity of Male and Female adult *Sarotherodon melanotheron* before and after gradual acclimation

4.63±0.81 to 4.29±0.53 vol.%; juveniles females from 5.72±0.54 to 5.12±0.29 vol.% (Fig. 1), for adults; male 7.93±0.69 to 6.93±0.70 vol.%; female 9.00±0.28 to 8.42±1.23 vol. % (Fig. 2). In fresh water, the value of juvenile males decreased from 4.52±0.49 vol. % (Fig. 3). While adults fish values in fresh water, indicated that in the males decreased from 8.20±0.67 to 5.60±0.61 vol.% females, 9.07±0.21 to 6.15±0.70 vol. % (Fig. 4). In gradual acclimation the value for juveniles male reduced from 4.693±0.83 to 3.95±0.71 vol. %, female from 5.53±0.91 to 3.70±0.79 vol. % (Fig. 5). And adults male value decreased from 7.95±0.71 to 5.59±0.79; a female adults reduced from 8.94±0.22 to 6.46±0.26 vol. % (Fig. 6).

DISCUSSION

Blood is a tissue which performs important roles in the organism, it transports oxygen and nutritive

compounds (Bukowska *et al.*, 2002). Fishes show an interesting diversity of approach to the problem of acquiring and transporting oxygen to the tissues in an aquatic environment. Fish are so intimately associated with their aqueous surrounding, in that any alterations in the physical and chemical changes in the environment are rapidly reflected as measurable physiological changes in the fish (Musa and Omoregie, 1999). Therefore, blood is a pathophysiological reflector of the whole body and hence are important in diagnosing the structural, functional and metabolic of fish exposed to various degree of stress, as a result of handling, transportation, toxicants and acclimation (Adhikari *et al.*, 2004; Akinrotimi *et al.*, 2007; Anyanwu *et al.*, 2007). Acclimation is the sum total of the adjustments which fish make to short and long term changes in their environment, the changes are in response to alterations in oxygen level, salinity, confinement and stocking density. The changes are complex mixtures of adjustments in hormones, metabolic pathways, enzymes and haematological parameters (Adeyemo *et al.*, 2003).

Haematological parameters are very sensitive to stress of any kind. The decrease observed in the oxygen carrying capacity of *S. melanotheron* in all acclimation media, is as a results of confinement stress, similar observations was made by Gabriel *et al.* (2004) on *Clarias gariepinus*, subject to acclimation stress. The observed difference in oxygen carrying capacity between juveniles and adult fish may be due to red cell number and haemoglobin concentration which tends to increase with length, size and age of fish (Das, 1965). The pronounced reduction in the oxygen carrying capacity value, observed in the fish acclimated in fresh water, this is due to the sudden change in environment of the fish from brackish to fresh water which leads to impaired osmoregulation, reduction in the production of Red Blood Cell (RBC) and disruption of iron-synthesizing mechanism (Gabriel *et al.*, 2007). The RBC are produced in the haemopoietic tissue, situated in the Spleen and Kidney (Health, 1991). According to Hibiya (1982) the most important function of RBC is the transport of haemoglobin which carries oxygen to all tissues in the body. Therefore, the reduction in the number of RBC automatically translates to a reduction in oxygen carrying capacity of *S. melanotheron*. This is in agreement with the findings of Adhikari *et al.* (2004) who observed a reduction in oxygen carrying capacity of *Labeo rohita* exposed to cypermethrin in the laboratory.

Kind *et al.* (2002) found that Australian lung fish *Neoceratodus forsteri* adjusted oxygen affinity during exposure to hypoxia, but not beyond the point where low oxygen in the water stimulated air breathing. Hence it is obvious that oxygen carrying capacity of fish, depends on external environment and internal organs of the fish.

CONCLUSION

In fish blood, oxygen is carried in physical solution and also in combination with haemoglobin, so physiologically, haemoglobin is crucial to the survival of *S. melanotheron*, as its role is directly related to the oxygen binding capacity of blood. This study suggests that drastic change in fish environment affects blood composition of the fish, which invariably affects its oxygen carrying capacity, which reduces its metabolic activity, leading to low productivity in aquaculture, this is because metabolic processes involve complex positional and temporal signals in which cells in the tissues communicate with each other, these processes are very precise and can therefore, be extremely sensitive to disruption by xenobiotic compounds and stressful environmental conditions. Therefore, the changes observed in oxygen carrying capacity of this species, in this study is a result of biological variability and sensitivity to the influences of acclimation.

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