Journal of Fisheries International 8 (2): 46-51, 2013
ISSN: 1817-3381

Effect of Two Culture Systems on the Haematology and Growth of the African Mud Catfish, *Clarias gariepinus* (Siluriformes: Clariidae)

Felix Olusegun Akinwumi, Abiodun Eniade and Bola Adewumi
Department of Environmental Biology and Fisheries, Adekunle Ajasin University,
Akungba Akoko, Ondo State, Nigeria

Abstract: The haematological and growth parameters of the African mud catfish, *Clarias gariepinus* fed with imported pelleted feeds (Durantee) and raised separately in In-Door Concrete (IDC) and out-door Earthen (ERT) ponds for a period of 12 weeks at the fish farm of the Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba Akoko, Nigeria were assessed in this study. The water quality of the two rearing systems was also studied on a weekly basis. Blood samples were collected from the fish samples by puncturing the caudal peduncle with heparinized plastic syringe. The values of the haematological parameters were measured using standardized and approved methods. The water parameters studied in IDC showed that the temperature (28.543±0.20°C) dissolved oxygen (0.734±0.38 mg L^{-1}) salinity (0.223±0.03%) conductivity (0.002±0.00 MΩ cm^{-1}) total dissolved solids (275.750±31.26 ppm) and nitrate (2.520±1.45 ppm) statistically differed ($p<0.05$) to 27.321±0.71°C, 7.118±0.46 mg L^{-1}, 0.099±0.00%, 0.004±0.00 MΩ cm^{-1}, 102.580±2.53 and 0.000±0.00 ppm obtained, respectively in ERT. However, the values of pH (7.062±0.13) nitrite (0.500±0.26 ppm) and total hardness (40.000±6.96 ppm) in IDC were not significantly different ($p>0.05$) to the values 7.128±0.14, 0.000±0.00 ppm and 39.000±0.00 ppm obtained, respectively in ERT. The packed cell volume (34.600±3.297%) red blood cell (3.430±0.424×10^9 g dL^{-1}) lymphocyte (55.900±5.010%) haemoglobin (11.155±1.213 g dL^{-1}) thrombocyte (12.700±1.989%) white blood cell (121700.000±34012.759×10^9 g dL^{-1}) mean corpuscular volume (105.852±5.544 fl) mean corpuscular haemoglobin (33.800±1.874 pg) and mean corpuscular haemoglobin concentration (32.035±1.100 g dL^{-1}) of the catfish in IDC were not statistically different ($p>0.05$) compared to 28.400±2.956%, 2.670±0.394×10^9 g dL^{-1}, 51.200±3.723%, 8.640±0.953 g dL^{-1}, 15.400±2.522%, 197300.000±37057.028×10^9 g dL^{-1}) 112.935±7.594 fl, 34.423±2.578 pg and 30.394±0.780 g dL^{-1} obtained, respectively in fish raised in ERT but the values obtained for neutrophils (31.400±6.462% in ICD) and (30.400±4.507% in ERT) showed significant variations ($p<0.05$). The study also showed that the fish population in IDC attained statistically higher average weight (0.58 kg) compared to the fish in ERT (0.44 kg). It is recommended that closed fish culture should be encouraged in order to reduce pressure on land and deforestation usually associated with earthen pond construction.

Key words: Fish culture, in-door pond, earthen pond, haematology, fish growth, water quality

INTRODUCTION

Fish live in very intimate contact with the aquatic environment and are therefore very susceptible to the physical and chemical changes which may be reflected in their blood components. Blood is a good indicator to determine the health of an organism and also in diagnosing the functional status of the exposed animal to toxicants (Joshi *et al*., 2002; Okechukwu *et al*., 2007). Maheswaran *et al*. (2008) reported that a number of haematological indices, such as haematocrit, haemoglobin red blood cells among others are useful in the assessment of the functional status of the oxygen carrying capacity of the blood stream. Luskova (1997) observed that changes in the haematological level of fish depend on species, age, the cycle of the sexual maturity of spawners and diseases status.

Stress induced changes in the blood characteristics of *C. gariepinus* as a result of exposure to environmental pollutants, diseases or attack by pathogens have been reported (Onusiriuka and Ufodike, 2000; Ezeri, 2001; Gabriel *et al*., 2001; Alwan *et al*., 2009). These indices have been employed in effectively monitoring the responses of fish stressors and thus its health status under such adverse conditions. Fish are known to be in close relationship with the aqueous environment, hence

Corresponding Author: Felix Olusegun Akinwumi, Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria

Table 1: Statistical inference of haematological status of both sexes *Clarias gariepinus* in in-door and earthen ponds

	Analysis of Variance (ANOVA)	
Parameters	p = 0.05	Inferences
PCV (%)	0.832	p>0.05 (Not significant)
RBC ($\times 10^9$g dL^{-1})	0.729	p>0.05 (Not significant)
HB (g dL^{-1})	0.895	p>0.05 (Not significant)
Thrombocyte (%)	0.111	p>0.05 (Not significant)
WBC ($\times 10^9$g dL^{-1})	0.063	p>0.05 (Not significant)
Lymphocyte (%)	0.221	p>0.05 (Not significant)
Neutrophil (%)	0.035	p<0.05 (Significant)
MCV (fl)	0.131	p>0.05 (Non significant)
MCH (pg)	0.152	p>0.05 (Not significant)
MCHC (g dL^{-1})	0.693	p>0.05 (Not significant)

The mean difference is significant at 0.05 level

the blood will reveal conditions within the body of the fish long before there is any visible manifestation of disease (Musa and Omoregie, 1999; Okechukwu *et al*., 2007).

The production environment for aquaculture in Nigeria is rapidly growing, especially in the South-Eastern and South-Western parts of the country. Many large scaled and small scaled aquaculture ventures are springing up, investing massively in both extensive earthen pond culture system and the semi-intensive and intensive concrete pond culture systems. The culture systems are being used to produce several thousand tonnages of fish per annum. However, a lot of differences in fish colouration, health and behavioural physiology have been observed in the fish reared under different fish culture systems. Wilson and Taylor (1993) observed that slight changes in the micro or macro environmental conditions could result to changes in physiological well-being, quality of growth and protein profile in the animal flesh. However, the database of empirical studies of the Nigerian fish culture environment, particularly on the closed system, is just growing; hence this study.

This study was designed to show the effect of two semi-closed culture methods on the stability of *Clarias gariepinus*, one of the commercially important freshwater fish in the tropics, in captivity. It was undertaken to assess the values of the water quality in the reservoirs, blood parameters and growth of the members of the fish raised separately in In-Door Concrete (IDC) and Earthen (ERT) ponds (Table 1).

MATERIALS AND METHODS

Sample collection: Samples of *C. gariepinus* consisting of 50 adults (mean weight 375.43 g; mean length 42.62 cm) and another batch of 50 adults (mean weight 225.32 g; mean length 36.43 cm) were harvested from IDC and ERT ponds, respectively of the fish farm of the Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria. The fish were fed with foreign pelleted feed (Durantee) at 5% of body weight and raised separately for 12 weeks in the ponds. The growths were assessed by the records of weekly body weight gain using Hanna Top loader scale (0.05 kg sensitivity model: 2834024). Growth results and the physico-chemical parameters of the rearing water were taken on weekly basis. The physico-chemical water parameters such as pH, water temperature, dissolved oxygen, salinity and hardness were determined *in situ* on weekly basis using hydro lab electronic water probe meter (model: Hanna HI 98106).

Blood collection and haematological analysis: Fish were tranquilized with 150 mg L^{-1} solution of tricane methanesulphate (ms-222) and blood samples were collected from both males and females by puncturing the caudal peduncle with heparinized plastic syringe, fitted with 21-gauge hypodermic needle and preserved in disodium salt of Ethylene Diamine Tetraacetic Acid (EDTA) bottles for analysis. The microhaematocrit method was used for the determination of Packed Cell Volume (PCV) (Blaxhall and Daisley, 1973). Haemoglobin (cyamethaemoglobin) and red blood cell concentrations were determined by the methods described by Jain (1986) while the White Blood Cell (WBC) count was determined using Neubauer haemocytometer (Shah and Altindag, 2005). The derived haematological indices of Mean Corpuscular Volume (MCV) Mean Corpuscular Haemoglobin (MCH) and Mean Corpuscular Haemoglobin Concentration (MCHC) were calculated using standard formula (MCV = PCV/RBC×10, MCH = HB/RBC×10 and MCHC = (Hb in 100 mg)/PCV×100, respectively).

The data obtained were subjected to Analysis of Variance (ANOVA) using SPSS 17.0 software package at 0.05 significance level and the results are presented as mean±SE (Standard Error).

RESULTS AND DISCUSSION

The mean values of the water quality parameters for both IDC and ERT ponds during the rearing period are shown in Table 2. The data in the tables show that there were significant differences ($p<0.05$) in the water parameters of IDC in comparison to ERT. Higher values were recorded for the temperature (28.543±0.20°C) salinity (0.223±0.03%) and total dissolved solids (275.750±31.26 ppm) in IDC than in ERT (27.321±0.71°C, 0.099±0.00% and 102.580±2.53 ppm, respectively) but the values recorded for the dissolved oxygen (7.118±0.46 mg L^{-1}) and conductivity (0.004±0.00 MΩ cm^{-1}) in the earthen were higher than in

Table 2: Water quality parameters in concrete and earthen reservoirs

	Concrete pond		Range		Earthen pond		Range	
Parameters	Mean±SE	SD	Min.	Max.	Mean±SE	SD	Min.	Max.
Temperature (°C)	28.543±0.200	10.70	24.714	26.740	27.321±0.71	2.46	20.480	30.700
Dissolved oxygen (Mg L^{-1})	0.734±0.380	1.31	0.000	4.250	7.118±0.46	1.60	5.490	10.130
pH	7.062±0.130	0.46	5.970	7.740	7.128±0.14	0.47	6.050	7.780
Salinity (%)	0.223±0.030	0.10	0.050	0.390	0.099±0.00	0.01	0.080	0.120
Conductivity (MΩ cm^{-1})	0.002±0.000	0.00	0.001	0.006	0.004±0.00	0.00	0.001	0.005
Total dissolved solids (ppm)	275.750±31.26	108.28	85.000	395.000	102.580±2.53	8.75	93.000	1.200
Nitrite (ppm)	0.500±0.260	0.91	0.000	3.000	0.000±0.00	0.00	0.000	0.000
Nitrate (ppm)	2.50±1.4500	5.03	0.000	20.000	0.000±0.00	0.00	0.000	0.000
Total hardness (ppm)	40.000±6.960	24.12	0.000	80.000	39.000±0.00	0.00	39.000	39.000

Table 3: Statistical inference of water quality parameters of *Clarias gariepinus* in in-door concrete and earthen ponds

	Analysis of Variance (ANOVA)	
Parameters	p = 0.05	Inference
Temperature (°C)	0.024	p<0.05 (Significant)
Dissolved oxygen (mg L^{-1})	0.000	p<0.05 (Significant)
pH	0.710	p>0.05 (Not significant)
Salinity (%)	0.000	p<0.05 (Significant)
Conductivity (MΩ cm^{-1})	0.001	p<0.05 (Significant)
Total dissolved solids (ppm)	0.000	p<0.05 (Significant)
Nitrite (ppm)	0.069	p>0.05 (Not significant)
Nitrate (ppm)	0.002	p<0.05 (Significant)
Total hardness (ppm)	0.887	p>0.05 (Not significant)

The mean difference is significant at 0.05 level

the in-door concrete pond (0.734±0.38 mg L^{-1} and 0.002±0.00 MΩ cm^{-1}, respectively). However, the values of the pH (7.062±0.13) nitrite (0.500±0.26 ppm) and total hardness (40.000±6.96 ppm) in IDC showed no statistical difference (p>0.05) compared to the values 7.128±0.14, 0.000±0.00 and 39.000±0.00 ppm obtained, respectively in ERT (Table 3).

The values of the physico-chemical parameters obtained in this study are generally within the recommended ranges required for good fish production. Ayanwale *et al.* (2012) recorded conductivity (100.60±32.01 to 338.00±140.81) alkalinity (132.40±46.36 to 228.00±28.88 mg L^{-1}) hardness (39.60±7.81 to 110.00±16.25 mg L^{-1}) dissolved oxygen (3.30±0.77 to 6.66±2.71 mg L^{-1}) and nitrate (1.21±0.68 to 9.24±2.55 mg L^{-1}) values in selected freshwater reservoirs. Studies have recommended a temperature range of 25-32°C (Afzal *et al.*, 2007) a minimum constant value of 4.0 mg L^{-1} dissolved oxygen (Ufodike and Garba, 1992) 39.60±7.81 to 110.00±16.25 mg L^{-1} water hardness (Mateen *et al.*, 2004) 9.8-49 mg L^{-1} nitrate (Brunson *et al.*, 1994) 20-30 mg L^{-1} alkalinity (Wurts and Durborow, 1992; Goshu and Akoma, 2010) and 120-340 sec conductivity (Kolo, 1996) for good performance of fishes.

Water quality is a critical consideration, especially when planning for high aquaculture production. Boyd and Tucker (1998) reported that the environment of fish is a complex system consisting of several water quality variables but only a few of them play decisive role. The researchers observed that the critical parameters that affect the general condition and performance of cultured organisms include temperature, concentration of dissolved oxygen, suspended solids, ammonia, nitrite, carbon-iv-oxide, pH and alkalinity. However, the researchers observed that dissolved oxygen is the most important and critical parameter that requires a continuous monitoring in aquaculture production systems because as the dissolved oxygen concentration decreases, respiration and feeding activities also decrease. Temperature influences the respiratory metabolism and the activity level of all biochemical processes in organs and tissues. Liu *et al.* (2011) reported physiological malfunctioning when fish were not living in the suitable temperature range. Nouanthavong and Preston (2011) observed a lower water temperature in the intensive (in-door) tanks than in the natural (out-door) ponds. The researchers also observed that there were no differences in the average pH but ammonia-N was much higher (100 times) in the water in the intensive tanks than in the natural ponds. The optimal range of pH in normal water is 6.5-8 while <5 and >10 could be lethal to fish and prawns (Ikuta *et al.*, 1992). The researchers reported that when fish were exposed to a low pH, chloride cell in the gill tissue absorbed bicarbonate (HCO_3) ion from the outside to neutralize the hydrogen (H^+) ion flowing in the body, resulting to the loss of sodium (Na^+) and chloride (Cl^-) ion from the body fluids. However, fish have the ability to regulate their acid-base balance in order to maintain normal pH of their body fluids under acidic ambiance (Iwata *et al.*, 1990).

The results obtained in this study showed that there were no significant differences (p>0.05) in the haematological parameters of *C. gariepinus* raised in both IDC and ERT reservoirs, except for the neutrophils which elicited statistical differences (p<0.05) (Table 4 and 5). Also, the results showed that gender did not significantly affect the haematological characteristics of the fish raised in the IDC and ERT. Although, higher Packed Cell Volume (PCV) Haemoglobin (Hb), Thrombocytes, White Blood Cell count (WBC) lymphocyte, Mean Corpuscular Volume

Table 4: Haematological parameters of female *Clarias gariepinus* in in-door concrete and earthen ponds

	Female (concrete pond)		Female (earthen pond)	
Parameters	Mean±SE	SD	Mean±SE	SD
PCV (%)	34.400±5.12	11.46	29.600±5.14	11.48
RBC ($\times10^9$ g dL^{-1})	3.260±0.65	1.46	2.600±0.68	1.53
HB (g dL^{-1})	10.996±1.57	3.50	9.020±1.65	3.68
Thrombocyte (%)	17.400±2.42	5.41	15.800±3.41	7.68
WBC ($\times10^9$ g dL^{-1})	188600.000 ±51501.07	115159.89	226200.000 ±84478.24	108400.65
Lymphocyte (%)	64.200±3.28	7.33	50.600±3.04	6.80
Neutrophil (%)	18.400±4.71	10.53	27.600±5.05	11.28
MCV (fl)	111.144±7.25	16.21	121.792±12.13	27.12
MCH (pg)	35.816±2.84	6.34	36.912±3.78	8.45
MCHC (g dL^{-1})	32.122±0.54	1.22	30.376±1.08	2.41

Table 5: Haematological parameters of male *Clarias gariepinus* in in-door concrete and earthen ponds

	Male (concrete pond)		Male (earthen pond)	
Parameters	Mean±SE	SD	Mean±SE	SD
PCV (%)	34.800±4.76	10.64	27.200±3.50	7.82
RBC ($\times10^9$ g dL^{-1})	5.600±0.61	1.36	8.260±0.14	0.56
HB (g dL^{-1})	11.313±2.04	4.56	8.260±1.14	2.56
Thrombocyte (%)	8.00±0.95	2.12	15.000±4.11	9.19
WBC ($\times10^9$ g dL^{-1})	54800.000 ±17769.08	39732.86	168400.000 ±58410.00	130609.34
Lymphocyte (%)	47.600±8.23	18.41	51.800±7.28	16.27
Neutrophil (%)	44.400±9.01	20.16	33.200±7.88	17.61
MCV (fl)	100.560±8.47	18.94	104.078±8.55	19.13
MCH (pg)	31.784±2.40	5.35	31.934±3.54	7.91
MCHC (g dL^{-1})	31.954±2.27	5.06	30.412±1.31	2.93

The mean difference is significant at 0.05 level

(MCV) and Mean Corpuscular Haemoglobin (MCH) were recorded in the female fish than in the males but the values were not statistically different (p>0.05), except in the values obtained for the neutrophils.

There has been no general agreement on the haematological values in fish. Prasad and Mukthiraj (2011) recorded RBC (2.04±0.43) WBC (2.18±0.84) Thrombocytes (4.54±4.65) Hb (6.40±0.26) PCV (23.78±3.80) MCV (116.78±18.58) MCH (31.47±3.12) and MCHC (2.81±0.42) in *Oreochromis mossambicus*. Nikolov and Boyadzieva-Doichinova (2010) demonstrated that the red blood cell counts were constant in the three species of freshwater fishes (*Carassius gibelo*, *Alburnus alburnus* and *Scardinius erythrophthalinus*). Onunkwo *et al.* (2007) reported a higher thrombocyte values (21.65-47.24) than the red blood cells (2.42-3.22) in *Tilapia guineensis*. Ajiboye and Faturoti (2011) obtained Hb (7.06) PCV (37.53) RBC (1.39) and WBC (19.39) in *Synodontis nigrita*.

Male and female fish have been reported to differ in their blood variables (Gabriel *et al.*, 2001; Dacie and Lewis, 1991). Collazos *et al.* (1998) observed that the high levels of red blood cells, haemoglobin and packed cell volume usually associated with female fish might be caused by high metabolic activities. The researchers also attributed the high levels of the total leucocytes, neutrophils and monocytes in female fish to the excited reproductive and defence activities during the breeding season. Variations in the blood tissues of fish have been attributed to environmental stress (Orun *et al.*, 2003) peculiarities of species (Collazos *et al.*, 1998) season (Orun *et al.*, 2003) breeding habits (Cech and Wohlschlag, 1981) physico-chemical indices (Onunkwo *et al.*, 2007) and biochemical metabolism (Adeyemo *et al.*, 2003).

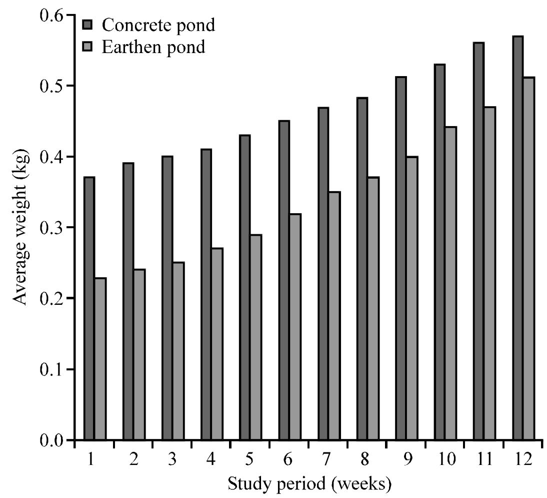

Fig. 1: Weekly growth index measured by average weight measurements

The results in this study revealed that the population of fish in IDC showed higher growth rate than in ERT, especially the male population (Fig. 1). This result is in agreement with Nounthavong and Preston (2011), Sophin and Preston (2001) and Edwards *et al.* (1988) who reported faster growths in weight and length and weight/length ratio in the intensive system than in the natural system. Boyd and Tucker (1998) reported that the provision of the optimum range of the physical, biological and chemical parameters in the rearing water will determine the totality of growth and welfare of cultured organisms.

CONCLUSION

This study demonstrated that the blood parameters and growth of fish were enhanced in both the in-door concrete and out-door earthen ponds. However, *C. gariepinus* grew faster in the in-door concrete than the earthen (natural) system. The results obtained in the study could serve as valuable information for fish biologists, aquaculturists and environmentalists in pond water management and growth monitoring of cultivable organisms.

REFERENCES

Adeyemo, O., S.A. Agbede, A.O. Olaniyan and O.A. Shoaga, 2003. The haematological response of *Clarias gariepinus* to changes in acclimation temperature. Afr. J. Biomed. Res., 6: 105-108.

Afzal, M., A. Rab, N. Akhtar, M.F. Khan, A. Barlas and M. Qayyum, 2007. Effect of organic and inorganic fertilizers on the growth performance of bighead Carp (*Aristichthys nbilis*) in polyculture system. Int. J. Agric. Biol., 9: 931-933.

Ajiboye, A. and E. Faturoti, 2011. Growth performance of *Synodontis nigrita* raised on different dietary crude protein levels. Int. J. Aquatic. Sci., 2: 27-35.

Alwan, S.F., A.A. Hadi and A.E. Shokr, 2009. Alterations in haematological parameters of freshwater fish, *Tilapia zilli* exposed to Aluminium. J. Sci. Appli., 3: 12-19.

Ayanwale, A.V., M.A. Minnin and K.I. Olayemi, 2012. Physico-chemical properties of selected fish ponds in Nigeria: Implications for artificial fish culture. Webmed Central Biology, 3: WMC003751. http://www.webmedcentral.com/article_view/3751.

Blaxhall, P.C. and K.W. Daisley, 1973. Routine haematological methods for use with fish blood. J. Fish Biol., 5: 771-781.

Boyd, C.E. and C.S. Tucker, 1998. Pond Aquaculture Water Quality Management. Kluwer Academic Publishers, Boston, MA., USA., ISBN-13: 9780412071812, Pages: 700.

Brunson, M.W., C.G. Lutz and R.M. Durborow, 1994. Algae Blooms in Commercial Fish Production Ponds. Southern Regional Aquaculture Center, USA, Pages: 466.

Cech, J.J. and D.E. Wohlschlag, 1981. Seasonal patterns of respiration, gill ventilation and haematological characteristic in the striped mullet *Mugil cephalus*. Bull. Mar. Sci., 31: 112-119.

Collazos, M.E., E. Ortega, C. Barriga and A.B. Rodriguez, 1998. Seasonal variation in haematological parameters in male and female *Tinca tinca*. Mol. Cell. Biochem., 183: 165-168.

Dacie, J.V. and S.N. Lewis, 1991. Practical Haematology. 5th Edn., Churchhill, Livingstone, Edinburgh, Pages: 390.

Edwards, P., C. Polprasert, V.S. Rajput and C. Pacharaprakiti, 1988. Integrated Biogas Technology in the Tropics 2. Use of slurry for fish culture. Waste Manage. Res., 6: 51-61.

Ezeri, G.N.O., 2001. Haematological response of *Clarias gariepinus* to bacterial infection and prophylactic treatment with antibiotics. J. Aqua. Sci., 16: 22-24.

Gabriel, U.U., J.K. Alagoa and M.E. Allison, 2001. Effects of disposed crude oil water dispersion on the haemoglobin and haematocrit of *Clarias gariepinus*. J. Aquatic. Sci. Env. Manage., 5: 9-11.

Goshu, G. and O.C. Akoma, 2010. Comparative study of physico-chemical characteristics of some on-farm research ponds, Ethiopia. Trop. Freshwater Biol., Vol. 19.

Ikuta, K., T. Shikama, S. Oda and N. Okumoto, 1992. Acid tolerance of eyed embryos and larvae in salmonid fishes. Bull. Natl. Res. Inst. Aquac., 21: 39-45.

Iwata, M., Y. Shimoyama, N. Sakai, K. Suzuki, H. Ida, K. Muto and U. Akutsu, 1990. Effects of sulfuric acid stress on osmoregulatory ability of Japanese char (*Sulvelinus leucomaenis*). Bull. Natl. Res. Inst. Aquac., 18: 31-37.

Jain, N.C., 1986. Schalm's Veterinary Haematological. 4th Edn., Lead and Febiger, Philadephia, Pages: 1221.

Joshi, P.K., M. Bose and D. Harish, 2002. Haematological changes in the blood of *Clarias batrachus* exposed to mercuric chloride. J. Ecotoxicol. Environ. Monit, 12: 119-122.

Kolo, R.J., 1996. The limnological studies of Shiroro Lake and its major tributaries. Ph.D. Thesis, Submitted to the Department of Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology, Minna, Nigeria.

Liu, J., M. Duan, L. Qu, L. Zhang and G. Feng *et al*., 2011. Effects of temperature, salinity, illumination and copper on oxygen consumption of juvenile Chinese sturgeon, *Acipenser sinensis*. Int. Aquatic. Res., 3: 107-115.

Luskova, V., 1997. Annual cycles and normal values of haematological parameters in fishers. Acta Sci. Nat. Brno, 31: 70-78.

Maheswaran, R., A. Devapaul, S. Muralidharan, B. Velmurugan and S. Ignacimuthu, 2008. Haematological studies of fresh water fish, *Clarias batrachus* (L.) exposed to mercuric chloride. Int. J. Integ. Biol., 2: 49-54.

Mateen, A., M. Afzal and I. Ahmad, 2004. Effects of hardness on the growth performance of Rohu (*Labeo rohita*) and its hybrid. Inter. J. Agric. Biol., 6: 71-73.

Musa, S.O. and E. Omoregie, 1999. Haematological changes in the mudfish, *Clarias gariepinus* (Burchell) exposed to malachite green. J. Aquat. Sci., 14: 37-42.

Nikolov, B. and D. Boyadzieva-Doichinova, 2010. Parameters of the red blood cell count in three species of carp fishes. Bulg. J. Agric. Sci., 16: 307-310.

Nouanthavong, T. and T.R. Preston, 2011. Comparison of natural pond system with an intensive (indoor) system for raising Cachama (*Colossoma macropomu*) and Tilapia (*Oreochromis niloticus*). Livestock Res. Rural Dev., Vol, 23,

Okechukwu, E.O., J. Auta and J.K. Balogun, 2007. Effects of acute nominal doses of chlorpyrifos-ethyl on some haematological indices of african catfish *Clarias gariepinus*-Teugels. J. Fisheries Int., 2: 190-194.

Onunkwo, D.N., E.J. Ansa, J.Y. Opara, K.N. Owhonda and O.A. Akinrotimi *et al*., 2007. Effects of transportation stress on haematological parameters of blackchin tilapia *Sarotherodon melanotheron*. J. Anim. Vet. Adv., 6: 841-845.

Onusiriuka, B.C. and E.B.C. Ufodike, 2000. Effects of sublethal concentrations of Akee apple, *Bligha Sapida* and sausage plant *Kigella africana* on tissue chemistry of the African catfish *Clarias gariepinus*. J. Aqua. Sci., 15: 47-49.

Orun, I., M. Dorucu and H. Yazlak, 2003. Haematological parameters of three cyprinid fish species from karakaya dam lake, Turkey. J. Biological Sci., 3: 320-328.

Prasad, G. and S. Mukthiraj, 2011. Effect of methanolic extract of *Andrographis paniculata* (Nees) on growth and haematology of Oreochromis mossambicus (Peters). World J. Fish Marine Sci., 3: 473-479.

Shah, S.L. and A. Altindag, 2005. Alterations in The Immunological Parameters of Tench (*Tinca tinca* L. 1758) after acute and chronic exposure to lethal and sublethal treatments with mercury, cadmium and lead. Turk. J. Vet. Anim. Sci., 29: 1163-1168.

Sophin, P. and T.R. Preston, 2001. Effect of processing pig manure in a biodigester as fertilizer input for ponds growing fish in polyculture. Livestock Res. Rural Dev., Vol. 3.

Ufodike, E.B. and A.J. Garba, 1992. Seasonal variation in limnology and productivity of a Tropical Highland fish pond in Jos Plateau, Nigeria. J. Aquatic. Sci., 7: 29-34.

Wilson, R.W. and E.W. Taylor, 1993. The physiological responses of freshwater rainbow trout, *Oncorhynchus mykiss*, dining acutely lethal copper exposure. Comp. Physiol., 163: 38-47.

Wurts, A.W. and R.M. Durborow, 1992. Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds. SRAC Publication, USA.