Journal of
Fisheries and Aquatic Science

ISSN 1816-4927

Academic Journals Inc.

www.academicjournals.com

Journal of Fisheries and Aquatic Science 6 (5): 545-554, 2011
ISSN 1816-4927 / DOI: 10.3923/jfas.2011.545.554

Growth and Blood Chemistry of Selected Clariid Catfishes Fed Phosphorus Supplemented Diets

Adebayo Israel Adekunle
Department of Forestry, Wildlife and Fisheries Management, Faculty of Agricultural Sciences, University of Ado Ekiti, Ekiti State, Nigeria

ABSTRACT

Phosphorus is important for optimal growth and health of cultivated fish. This study investigates the effect of phosphorus supplemented diets on growth and blood chemistry of *Heterobranchus bidorsalis*, *Clarias gariepinus* and their hybrid, *H. bidorsalis* x *C. gariepinus*. Eleven isonitrogenous (40% Crude Protein) diets were formulated with graded phosphorus inclusion levels at 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8 and 2% for diets (DI to XI), respectively using dicalcium phosphate. Each diet was fed to triplicate groups of ten catfish mean weight (g) for *H. bidorsalis* (10.80±0.20), *C. gariepinus* (10.07±0.50) and their Hybrid (10.00±0.30) for 12 weeks in a laboratory based 3×11 factorial experiment. Growth responses were evaluated, while mineral composition of fish was analyzed using AOAC method. Phosphorus in Blood Serum (PBS) of the fishes was determined after the experiment. Data were analyzed using ANOVA test. The best result was at 0.8% P inclusion level (DV), where Final Mean Weight Gain and Net Protein Utilization were significantly ($p<0.05$) highest in *C. gariepinus* (40.07±0.24 g, 7.60±0.00), but statistically the same in *H. bidorsalis* (28.89±0.24 g, 4.53±0.00) and their Hybrid (26.95±0.24 g, 4.24±0.00), respectively. The mineral composition of fish carcass shows that P intake was significantly ($p<0.05$) highest (28.54±0.02) mg g^{-1} in *H. bidorsalis* and least in Hybrid (21.84±0.02). PBS was statistically ($p<0.05$) highest in Hybrid (6.31±0.01 mm^3) and least in *H. bidorsalis* (5.39±0.01 mm^3). The results show that P is essential for growth and body mineralization, while haematological values provided baseline information on the relevance of inorganic P supplement in the diets of the clariid fishes.

Key words: Growth, clariid catfishes, dicalcium phosphate, blood chemistry, phosphorus in fishes

INTRODUCTION

Meeting nutritional requirements is essential for finfish, although minerals are required in minute amounts compared with protein, lipid and carbohydrate, they are critically important and deficiency in one or more of these micronutrients is perhaps the direst of mistake in diet formulation. For most minerals, excess can be equally detrimental, resulting in toxicity. That is, minerals are potentially lethal when present in amounts slightly above or below the requirement and accurate supplementation are therefore imperative for proper diet formulation (NRC, 1993).

Dietary demand for Phosphorus was recognized in early finfish nutrition and research is ongoing (Lall, 2002; Sugiura *et al.*, 2007). Phosphorus and its compounds are the substances that aquatic animals require in large proportions to build up the bones and scales in combination with Calcium. This mineral is a vital component of organic phosphates such as adenosine triphosphate (ATP), phospholipids, Coenzymes and DNA which have major roles in the metabolism of carbohydrates, fats and amino acids (Goda, 2007; Davis and Gatlin, 1991; NRC, 1993). Minimal quantities of phosphorus are available to fresh water species as their concentrations in fresh water are lower than 0.1 ppm, as a result, the soluble phosphorus available to aquatic species is less than 1 percent of that provided by the feeds (El-Haroun, 2007). There are many factors influencing the absorption, distribution and excretion of phosphorus in fish. Regardless of the form in which phosphorus is ingested, its absorption is dependent on solubility at the point of contact with the absorbing membranes; hence mineral sources that are soluble at luminal pH are potentially more available. The dietary phosphorus is supplied by plant as well as ingredients from animal sources used in feed preparation and also by the inorganic phosphate (Bury *et al*., 2003). The source of minerals in the diet can affect the performance of the fish (McDowell, 2003). According to Storebakken *et al*. (2000), the relative bioavailability of minerals and the amount in the supplement are important factors to consider when choosing a mineral supplement for fishes.

Inorganic sources synthesized from natural mineral sources are not bonded to a carrier molecule unlike the organic sources and are fed as the naturally occurring mineral complex (McDowell, 2003). Inorganic phosphates offer the combination of a consistently high total phosphorus content and excellent digestibility and are therefore widely used as supplemental phosphorus (Sugiura *et al*., 2000). Most inorganic phosphates used for this purpose are sodium phosphate, defluorinated phosphate, monocalcium phosphate and dicalcium phosphate. Klis and Versteegh, 1996) reported that the bioavailability of P from inorganic phosphates ranges from 55 to 92%. Gomes *et al*. (1993) reported that the relative availability for monoammonium and monocalcium phosphates were 81 and 82%, respectively. Gomes *et al*. (1993) were based on the 100% availability of P from dicalcium phosphate that was used in this study.

Little information is available on the effect of dietary phosphorus supplementation on chemical composition of the blood of fish (Chen *et al*., 2003). Preliminary reports have shown that fish blood is rich in total phosphorus (Chen *et al*., 2003). These findings were of interest since rainbow trout had been reported to grow to maturity on meat-based diets that are very rich in phosphorus (Heath, 1990). In this respect, fish seem unique in their nutritional requirement.

The favoured catfishes in Nigeria aquaculture include: *Clarias gariepinus* and *Heterobranchus bidorsalis*. The yearnings of farmers to have a farmed catfish that combines the fast growth traits of *Heterobranchus* spp. and early maturing traits of *Clarias gariepinus* led to the development of a hybrid *Heteroclarias* spp. There has been an increase in fish farming activities in Nigeria in the last few years with intensive culture of catfishes. With this development, various forms of malformation and poor growth have been observed in many farms which may be traced to mineral deficiencies especially, phosphorus. This study was therefore aimed at determining the optimal level of dietary phosphorus supplementation in the diets of *Heterobranchus bidorsalis, Clarias gariepinus* and their Hybrid Heteroclarias, as well as assessing the effect on mineral deposition and blood chemistry of the selected clariid catfishes.

MATERIALS AND METHODS

Experimental set up: The experiment was conducted at Success Fisheries Nig. Ltd, Akure, Ondo state for a period of 84 days. 350 each of artificially bred fingerlings of *H. bidorsalis* (10.80±0.20), *C. gariepinus* (10.07±0.50) and their Hybrid (10.00±0.30) were purchased from a reputable fish farm in Ibadan, Oyo state. Fish were immediately kept in a big plastic pool of 400 L tank each and fed a diet containing 40% protein to acclimatize the fishes to experimental condition for a week before transferring them to the experimental tanks.

Table 1: Gross composition of experimental diets fed to selected clariid catfishes (%)

	Diets										
Ingredients	DI	DII	DIII	DIV	DV	DVI	DVII	DVIII	DIX	DX	DXI
Fish meal	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Soybean meal	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6
G/ nut cake	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Yellow maize	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Cod liver oil	5.1	4.9	4.7	4.5	4.3	4.1	3.9	3.7	3.5	3.3	3.1
[1]Vit/premix	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Methionine	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Cellulose	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Phosphorus (CaHPO4)	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Crude Protein (%)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0

[1]kg^{-1} diet: Vit. A: 1,000,000 IU; Vit. D3: 600,000 IU; Vit. E: 12,000 IU, Vit. K_3: 15 mg; Vit. C: 12,500 mg; Vit. B1: 250mg; Vit. B_2: 1,750 mg; Vit. B_6: 875; Vit. B_1:2 2,500 mg; Ca-D-pantothenate: 5000 mg, Nicotinic acid: 3,750 mg; Folic acid: 250 mg; Co: 24,999 mg; Cu: 1,999 mg; Fe: 11, 249 mg; Se ($Na_2SeO_3.5H_2O$): 75 mg; I (KI): 106 mg; Antioxidant 250 mg

Experimental diets: Experimental diets used for this study are shown in Table 1. The same quantity of ingredients and method of preparation were used. Eleven isonitrogeneous (40% CP) diets were formulated from practical ingredients with different percentage of $CaHPO_4$. Diets were prepared using 2 mm diameter pelleting machine (Hobart mixing machine, model A 200). The resultant pellets were then sun dried for two days and stored separately in airtight polythene bags prior to use. A portion of each eleven experimental diets was removed for chemical analysis.

Feeding procedure: A total of 330 each fingerlings of *H. bidorsalis* (10.80±0.20), *C. gariepinus* (10.07±0.50) and their Hybrid (10.00±0.30) s were randomly stocked into 99 glass aquaria (70×45×40 cm) with 70 L of water at 10 fish per tank according to the thirty three treatments in a factorial experiment. Each diet was fed to satiation twice daily in two equal installments between 09:00-11:00 and 16:00-18:00, for 84 days. Initial and final weights of the experimental fish in each tank were recorded using an electronic balance (Metler PM 480, Delta range). For intermediate weighing, fish were bulk-weighed every 14 days. Air stones were used to aerate the tanks throughout the feeding period.

Growth and nutrient utilization parameters: Growth responses were calculated as described by Olvera-Novoa *et al*. (1990).

Proximate analysis of diets and fish: The eleven diets and fish samples (whole body) from each treatment were prepared in triplicates before and after the experiment and analyzed using standard methods of the Association of Official Analytical Chemists (AOAC, 1990) for protein, fat, ash and moisture. Crude protein was estimated by multiplying nitrogen content by 6.25. Lipid content was determined by ether extraction and ash was determined by combusting samples in a muffle furnace at 600°C for 5 h. Moisture content was estimated by heating samples in an air oven at 105°C for 24 h and computing weight loss.

Feacal collection: Feaces were collected once daily in the morning by siphoning from the 8th week to the 12th week of rearing period for all the treatments. Before feeding in the morning, feaces in the rearing tanks were carefully siphoned and tanks later cleaned before feeding. Feaces were frozen and subsequently pooled and oven dried at 60°C for 48 h.

Mineral analysis: Fish carcass and feaces were analyzed for P, Mg, Ca and Zn as described by (AOAC, 1995) method.

Blood analysis: Blood samples were obtained from 5 fish from each treatment with 1 mL syringe by puncture of the caudal vein. Haematological analyses such as Haematocit (PCV), Red Blood Cell (RBC), White Blood Cell (WBC), Haemoglobin (Hb) were assessed before and after the experiment as described by Jain (1986). Blood Serum Phosphorus (PBS) concentration was determined by the colorimetric method of Chen *et al*. (2003).

Data analysis: Data from each treatment were subjected to one way analysis of variance (ANOVA) test using the Statistical Package for Social Science (SPSS) 1998 version). Individual differences (p = 0.05) among treatment means were separated using Duncan's multiple range test (Duncan, 1955).

RESULTS

Proximate composition of experimental diets: The result of the proximate analysis of experimental diets is shown in Table 2. The crude protein levels of the eleven diets used for this study ranged from 40.1 to 40.3% (D I-XI). The result shows that the fat content is lowest in DII with an insignificant increase from 6.55 in DI to 7.03% DV. Ash content ranged between 11.1-11.6 % among the diets. Fibre content was highest in DX with a value of 2.20% and lowest in DVIII (1.47%). Zn contents of the diets ranged from 1.52 in DI to 1.57 μg g^{-1} in DX. However, the phosphorus and calcium contents were lowest in DI (10.2, 16.3) g kg^{-1} and highest in DXI (15.5, 20.1) g kg^{-1}, respectively. Digestible energy (11.1) in kilo cal kg^{-1} was the same for all the treatments.

Growth and nutrient utilization parameters among the species: Growth and nutrient utilization of the three species were statistically compared as shown in Table 3. There was a

Table 2: Chemical composition of experimental diets fed to selected clariid catfishes (%)

	Diets										
Parameters	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Crude protein (%)	40.10	40.10	40.10	40.10	40.10	40.10	40.00	40.00	40.30	40.00	40.20
Fat (%)	6.55	6.44	7.64	6.88	7.03	6.04	6.25	7.02	6.49	6.84	6.75
Ash (%)	11.10	11.00	11.40	11.00	11.30	11.40	11.10	11.10	11.60	11.30	10.90
Fibre (%)	1.92	2.01	2.14	2.06	2.19	1.94	2.16	1.47	2.04	2.20	2.08
Nitrogen free extract (%)	40.40	40.40	38.80	40.00	39.40	39.50	40.50	40.00	39.50	38.50	40.10
Calculated analysis											
Available phosphorus (g kg^{-1} DM)	10.20	10.40	11.00	11.90	12.30	12.60	13.40	13.90	14.20	14.70	15.50
Calcium (g kg^{-1} DM)	16.30	16.70	16.90	17.20	17.50	17.80	18.60	19.10	19.50	19.80	20.10
Zinc (μg g^{-1} DM)	1.52	1.56	1.55	1.53	1.55	1.54	1.57	1.55	1.57	1.57	1.56
Phytate (mg g^{-1} DM)	5.64	5.62	5.60	5.63	5.64	5.65	5.64	5.66	5.65	5.63	5.64
DE (kcal kg^{-1})	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10

Table 3: Growth of the clariid fishes fed DCP- supplemented diets

	Species		
Parameters	Hetero-clarias (Hybrid)	*H. bidorsalis*	*C. gariepinus*
SGR	1.73±0.01[a]	1.16±0.01[c]	1.63±0.01[b]
FCR	1.93±0.02[b]	2.02±0.02[a]	1.84±0.02[c]
Mean Weight Gain (g)	26.95±0.24[b]	28.89±0.24[b]	40.07±0.24[a]
NPU (%)	4.36±0.00[b]	3.93±0.00[c]	10.84±0.00[a]
PER (%)	4.24±0.00[b]	4.53±0.00[b]	7.60±0.00[a]

FCR: Feed conncersion ration Npu: Net protein utilization, PER: Protein efficiency ration, SGR: Specific growth rate. Means with the same superscripts along the horizontal row are not significantly different (p>0.05)

significant difference (p<0.05) in the parameters evaluated. The final Mean Weight Gain (MWG) was highest in *Clarias gariepinus* with a value of 40.07 g. The final mean weight gains of *H. bidorsalis* (28.89 g) and the hybrid (26.95 g) were closely related but still statistically different. Feed conversion ratio (FCR) was highest in *H. bidorsalis* (2.02). Values for net protein utilization (NPU) and protein efficiency ratio (PER) were statistically highest in *Clarias gariepinus* (10.84, 7.60%), respectively and least in *H. bidorsalis* (3.93%) for NPU and the hybrid (4.24%) for PER.

Proximate analysis of (whole body) of the species: Proximate analysis among the species is presented in Table 4. There were significant differences (p<0.05) among the variables examined. Body crude protein was highest in *C. gariepinus* (65.02%), followed by the hybrid (57.14%) and least in *H. bidorsalis* (46.65%). The fat content was highest in *H. bidorsalis* (3.22%) and least in *C. gariepinus* (1.94%). Moisture and ash contents were highest in the hybrid with the recorded values of 13.37 and 20.79%, respectively. Nitrogen Free Extract (NFE) was significantly (p<0.05) highest in *H. bidorsalis* (19.22%) and statistically the same (5.67, 5.81%) in *C. gariepinus* and Heteroclarias, respectively.

Mineral content of fish carcass: The mineral composition of fish carcass for the three species is presented in Table 5. There was significant difference (p<0.05) in minerals intake in fish. Mg and P intake were highest in *H. bidorsalis* (68.22, 28.54) mg g^{-1}, followed by *C. gariepinus* (53.90, 22.31) mg g^{-1} and least in Heteroclarias (50.17, 21.84 mg g^{-1}), respectively. Highest Ca intake was in *C. gariepinus* (33.05 mg g^{-1}) and statistically the same (28.91, 29.20) mg g^{-1} in hybrid and *H. bidorsalis*, respectively. Zinc intake was highest *H. bidorsalis* (60.97 µg g^{-1}) and least in C. *gariepinus* (48.55 µg g^{-1}).

Mineral in feaces of experimental fishes: The content of respective minerals in feaces of the different species is significantly different (p<0.05) as presented in Table 6. The highest discharged of Ca in the feacel matter was in *C. gariepinus* (38.25 mg g^{-1}) and was statistically the same in *H. bidorsalis* (33.55 mg g^{-1}) and Heteroclarias (33.86 mg g^{-1}), respectively. P discharge was highest in Heteroclarias (32.06 mg g^{-1}), followed by *H. bidorsalis* (29.95 mg g^{-1}) and least in *C.gariepinus* (23.64 mg g^{-1}). *H. bidorsalis* had the highest feacal content of Mg (94.54 mg g^{-1}) and statistically the same (86.08, 85.78) mg g^{-1} in *C.gariepinus* and Heteroclarias, respectively. There was no significant difference (p>0.05) in Zinc discharge between *H. bidorsalis* (95.17 µg g^{-1}) and Heteroclarias (91.74 µg g^{-1}) while the least discharge was in *C.gariepinus* (37.37 µg g^{-1}).

Table 4: Proximate evaluation of the carcass of the fishes after the experiment

	Species		
Parameters	Hetero-clarias (Hybrid)	*H. bidorsalis*	*C. gariepinus*
Moisture (%)	13.37±0.02[a]	11.78±0.02[b]	11.67±0.02[c]
Ash (%)	20.79±0.04[a]	18.80±0.04[b]	15.69±0.04[c]
CP (%)	57.14±0.04[b]	46.65±0.04[c]	65.02±0.04[c]
Fat (%)	2.33±0.04[b]	3.22±0.04[a]	1.94±0.04[c]
CHO (%)	5.81±0.07[b]	19.22±0.07[a]	5.67±0.07[b]

Cp: Condeprotein Means with the same superscripts along the horizontal row are not significantly different (p>0.05)

Table 5: Mineral content of fish carcass after the experiment

	Species		
Parameters	Hetero-clarias (Hybrid)	*H. bidorsalis*	*C. gariepinus*
Ca ($mg\ g^{-1}$)	28.91±0.10[b]	29.20±0.10[b]	33.05±0.10[a]
Zn ($\mu g g^{-1}$)	53.47±0.03[b]	60.97±0.03[a]	48.55±0.03[c]
Mg ($mg\ g^{-1}$)	50.17±0.06[c]	68.22±0.06[a]	53.90±0.0[b]
P ($mg\ g^{-1}$)	21.84±0.02[c]	28.54±0.02[a]	22.31±0.02[b]

Means with the same superscripts along the horizontal row are not significantly different (p>0.05)

Table 6: Mineral in feaces of experimental fishes

	Species		
Parameters	Hetero-clarias (Hybrid)	*H. bidorsalis*	*C. gariepinus*
Ca ($mg\ g^{-1}$)	33.86±0.30[b]	33.55±0.30[b]	38.25±0.30[a]
P ($mg\ g^{-1}$)	32.06±0.12[a]	29.95±0.12[b]	23.64±0.12[c]
Zn ($\mu g g^{-1}$)	91.74±1.23[a]	95.17±1.23[a]	37.37±1.23[b]
Mg ($mg\ g^{-1}$)	85.78±0.01[b]	94.54±0.018[a]	6.08±0.01[b]

Means with the same superscripts along the horizontal row are not significantly different (p>0.05)

Table 7: Haematological values of the experimental species

	Species		
Parameters	Hetero-clarias (Hybrid)	*H. bidorsalis*	*C. gariepinus*
Hb ($g\ dL^{-1}$)	8.44±b0.01[a]	8.13±0.01[b]	8.52±0.01[a]
PCV (%)	24.40±0.05[a]	24.50±0.05[a]	24.36±0.05[a]
WBC ($x10^3 mm^{-3}$)	59.91±4.75[a]	57.59±4.75[b]	56.27±4.75[c]
RBC ($x10^{12}$/L)	2.29±0.04[b]	2.16±0.04[c]	2.32±0.04[a]
PBS (mm^3)	6.31±0.01[a]	5.39±0.01[c]	5.58±0.01[b]
Alb (mm^3)	4.07±0.01[a]	3.07±0.02[c]	3.71±0.01[b]

Means with the same superscripts along the horizontal row are not significantly different (p>0.05)

Blood analysis in experimental fishes: Table 7 shows the result of blood analysis for the fish. Reported values for PCV (24.40, 24.50 and 24.36%) in Heteroclarias, *H. bidorsalis* and *C. gariepinus*, respectively were not significantly different (p>0.05). There was significant difference (p<0.05) in WBC with the highest value in Heteroclarias ($59.91\times10^3\ mm^{-3}$), followed by *H. bidorsalis* ($57.59\times10^3\ mm^{-3}$) and least in *C. gariepinus* ($56.27\times10^3\ mm^{-3}$). RBC had the highest (p<0.05) value in *C. gariepinus* (2.32×10^{12}/L) and least in *H. bidorsalis* (2.16×10^{12}/L). Phosphorus in Blood Serum (PBS) was highest in Heteroclarias (6.31 mm^3) and also least in *H. bidorsalis* (5.39 mm^3). Reported values for Hb (8.44, 8.52) g dL^{-1} in Heteroclarias and *C. gariepinus*, respectively were not significantly different ($p>0.05$).

DISCUSSION

Data from this study showed that the growth response of selected clariid catfishes was significantly affected by the supplementation of dietary available P. Growth of *H. bidorsalis, Clarias gariepinus* and their hybrid improved significantly with increasing supplementation of P (Table 3). According to Sugiura *et al.* (2007), dietary supplementation of Phosphorus improved growth performance in fish. Considering the growth performance in this study, *Clarias gariepinus* exhibited the best feed utilization with recorded best mean weight gain while the least growth response was observed in Heteroclarias. Similar result had been observed in the three common species of Rainbow trout (Wilson *et al.*, 1982). In contrast, no significant changes in growth of red snapper, seabass and Atlantic salmon fed low P diets as reported by Vielma and Lall (1998). Several factors including age, stage of development, diet composition, duration of experiment, health and rearing condition may affect growth (Shearer, 1995).

Dietary P levels had a significant effect on whole body crude protein, fat and ash contents (Table 4). Results indicated an improvement in protein; fat and ash contents in the fish given P supplemented diets with the highest crude protein level, ash and fat in *Clarias gariepinus*, Heteroclarias and *H. bidorsalis*, respectively. Significant improvement of whole body crude protein composition of the fish is an indication of the importance of P in body protein metabolism. Such improvement was observed in Tilapia fed P-supplemented diets (Bury *et al.*, 2003). Similar findings were also reported by NRC 1993); fish given low-phosphorus feed showed reduced protein intake. The supplementation of phosphorus in fish feed, therefore, improves the functioning enzymes in digesting protein and fat (NRC, 1993).

The most relevant and reliable measure for mineral content of fish appears to be whole body mineral content (Shearer, 1995). Result showed that minerals especially Ca and P were best stored in the carcass of *H. bidorsalis* (Table 5). One possible explanation may be its (*H. bidorsalis*) high mineral requirement for bone formation due to its large size at maturity (Lenient *et al.*, 2008). For P, the values are expected to decrease somewhat with fish size, and adequate P levels are more critical for fish in the fingerlings and juvenile stages than in the grow out phase (Sugiura *et al.*, 2007). This is in line with the observation of Andrews *et al.* (1973) who reported that body mineralization is highly correlated with requirement by fish. Hauler and Carter (2001) similarly reported that addition of P supplement in fish feeds improved carcass P uptake by fish. The significant improvement in the carcass Mg and Zn is evidence of positive effect of dietary phosphorus on improved mineralization. The growth response of clariid catfishes in this study indicated that high levels of phosphorus supplements may inhibit Mg and Zn bioavailability. This inhibition could occur due to potential interactions of minerals and the subsequent effects on bioavailability (Abbass, 2007).

The mineral load from the fishes (Table 6) indicated that the fecal mineral contents were high. Losses of phosphorus and calcium varied significantly among the species and appeared to be highest in Heteroclarias and *C. gariepinus*, respectively. The potential high loss of P and Ca may be due to over supplementation of the test diets with dicalcium phosphate above requirement for growth. A similar result was reported by Eya and Lovell (1997) who found 31.2% phosphorus net absorption in channel catfish given basal feed with high dietary phosphorus. In general, bioavailability of phosphorus has been found to be positively correlated with the solubility of the mineral in water. Monobasic phosphates of sodium and potassium are highly available (90-95%) sources of phosphorus for Channel catfish *Ictalurus punctatus* (Lovell, 1978); Common Carp *Cyprinus carpio* (Ogino *et al.*, 1979); red sea bream *Chrysophys major* (Lovell, 1988) and rainbow trout, *Oncorhychus mykiss* (Ogino *et al.*, 1979). Di and tribasic phosphates are highly available to red sea bream (Lovell, 1988). Dibasic calcium phosphate has an availability of 65% for the channel catfish (Lovell, 1988).

The observed improvement in haematological parameters in clariid catfishes in this study conforms to the report of Chen *et al.* (2003) that nutritionally deficient P diets cause decrease in haemoglobin concentration and red blood cell. Haemoglobin is crucial to the survival of fish being directly related to the oxygen binding capacity of blood (Tatina *et al.*, 2010). In this study, close values were observed in blood parameters among the fish species (Table 7), which indicated similar effect of dietary phosphorus on the fishes.

CONCLUSION

It is obvious from results of this study that P is essential for growth, efficient feed utilization and body mineralization of selected clariid catfishes. Since fish must obtain most of the phosphorus from the diet, the optimal amount of phosphorus supplementation in feed is important. In estimating the level of P supplement in the diet, based on general responses such as weight gain and body mineralization as demonstrated in this study, available P should not exceed the dietary requirement and must be carefully balanced to prevent signs of deficiency and minimize the fecal discharge into water. Also, the need for phosphorus supplementation in fish feed must be considered with respect to digestibility of inorganic P source. The primary source of phosphorus used was dicalcium phosphate with high level of digestibility, which provides an indication of its availability to fish.

There is a need for greater understanding of the role of dietary phosphorus in the blood chemistry of fish as serum P level was correlated to the amount of phosphates supplemented for all the species in this study. Further studies in these areas with different sized and aged catfishes will corroborate these findings. It is hereby suggested that knowledge of P bioavailability from different inorganic sources with appropriate method of determining excess P in fish will increase its inclusion in fish feeds.

REFERENCES

AOAC, 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington DC. USA., pp: 200-210.

AOAC, 1995. Official Methods of Analysis. 16th Edn., Association of Official Analytical Chemists, Washington, DC., USA.

Abbass, F.E., 2007. Effect of dietary oil sources and levels on growth, feed utilization and whole-body chemical composition of common carp, *Cyprinus carpio* L. fingerlings. J. Fish. Aquat. Sci., 2: 140-148.

Andrews, J.W., T. Murai and C. Campbell, 1973. Effects of dietary calcium and phosphorus on growth, food conversion, bone ash and haematocrit levels of catfish. J. Nutr., 103: 766-771.

Bury, N.R., P.A. Walker and C.N. Glover, 2003. Nutritive metal uptake in teleost fish. J. Exp. Biol., 206: 11-23.

Chen, C.Y., G.A. Wooster, R.G. Getchell, P.R. Bowser and M.B. Timmons, 2003. Blood chemistry of healthy, nephrocalcinosis-affected and ozone-treated tilapia in a recirculation system, with application of discriminant analysis. Aquaculture, 218: 89-102.

Davis, D.A. and D.M. Gatlin III, 1991. Dietary mineral requirements of fish and shrimp. Proceedings of the Aquaculture Feed Possessing and Nutrition Workshop, Sept. 19-25, American Soybean Association, pp: 49-67.

Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.

El-Haroun, E.R., 2007. Improved growth rate and feed utilization in farmed African catfish *Clarias gariepinus* (Burchell, 1822) through a growth promoter Biogen® supplementation. J. Fish. Aquat. Sci., 2: 319-327.

Eya, J.C. and R.T. Lovell, 1997. Available phosphorus requirements of food-size channel catfish *Ictalurus punctatus* fed practical diets in ponds. Aquaculture, 154: 283-291.

Goda, A.M.A.S., 2007. Effect of dietary soybean meal and phytase levels on growth, feed utilization and phosphorus discharge for Nile tilapia *Oreochromis niloticus* (L.). J. Fish. Aquat. Sci., 2: 248-263.

Gomes, P.C., M.F.M. Gomes, G.J.M.M. deLima and C. Bellaver, 1993. Phosphorus requirement and its availability in monoammonium and monocalcuim phosphates for 21 day old broilers. Rev. Soc. Brasil. Zootecnia, 22: 755-763.

Hauler, R.C. and C.G. Carter, 2001. Reevaluation of the quantitative dietary lysine requirements of fish. Rev. Fish. Sci., 9: 133-163.

Heath, A.G., 1990. Summary and perspective. Am. Fish. Soc. Symp., 8: 183-191.

Jain, N.C., 1986. Schalm's Veterinary Haematology. 4th Edn., Lea and Febiger, Philadelphia, ISBN-10: 0812109422, pp: 149-162.

Klis, J.D.V. and H.A.J. Versteegh, 1996. Phosphorus Nutrition in Poultry. In: Recent advances in Animal Nutrition, Garnsworthy, P.C., J. Wiseman and W. Haresign (Eds.). Nottingham University Press, Nottingham, England, pp: 71-86.

Lall, S.P., 2002. The Minerals. In: Fish Nutrition, Halver, J.E. and R.W. Hardy (Eds.). 3rd Edn., Academic Press, New York, USA., pp: 264-274.

Lenient, M.O.I., J.O. Atteh, J.S. Omotosho and C.T. Madu, 2008. Response of *Heterobranchus longifilis* fingerlings to supplemental dietary vitamin E. J. Fish. Aquatic Sci., 3: 22-30.

Lovell, R.T., 1978. Dietary phosphorus requirement of channel catfish (*Ictalurus punctatus*). Trans. Am. Fish. Soc., 107: 617-621.

Lovell, T., 1988. Nutrition and Feeding of Fish. 1st Edn., Van Nostrand Reinhold, New York, ISBN: 044-2259271, pp: 1-260..

McDowell, L.R., 2003. Minerals in Animal and Human Nutrition. 2nd Edn., Elsevier, Amsterdam, The Netherlands.

NRC (National Research Council), 1993. Nutrient Requirements of Fish. National Academy Press, Washington, DC. USA., pp: 114.

Ogino, C., L. Takeuchi, H. Takeda and T. Watanabe, 1979. Availability of dietary phosphorus in carp and rainbow trout. Bull. Jpn. Soc. Sci. Fish., 45: 1527-1532.

Olvera-Novoa, M.E., G.S. Campros, G.M. Sabido and C.A. Martinez-Palacious, 1990. The use of alfalfa leaf protein concentrates as a protein source in diets of Tilapia (*Oreochromis mossambicus*). Aquaculture, 83: 45-58.

Shearer, K.D., 1995. The use of factorial modeling to determine the dietary requirements for essential elements in fish. Aquaculture, 133: 57-72.

Storebakken, T., S. Refstie and B. Ruyter, 2000. Soy Products as Fat and Protein Sources in Fish Feeds for Intensive Aquaculture. In: Soy in Animal Nutrition, Drackley, J. K. (Ed.)., Federation of Animal Sciences Societies, USA., pp: 127-170.

Sugiura, S.H., F.M. Dong and R.W. Hardy, 2000. A new approach to estimating the minimum dietary requirement of phosphorus for large rainbow trout based on non faecal excretions of phosphorus and nitrogen. J. Nutr., 130: 865-872.

Sugiura, S.H., K. Kelsey and R.P. Ferraris, 2007. Molecular and conventional responses of large rainbow trout to dietary phosphorus restriction. J. Comparat. Physiol. B., 177: 461-472.

Tatina, M., M. Bahmani, M. Soltani, B. Abtahi and M. Gharibkhani, 2010. Effects of different levels of dietary vitamins C and E on some of hematological and biochemical parameters of sterlet (*Acipenser ruthenus*). J. Fish. Aquat. Sci., 5: 1-11.

Vielma, J. and S.P. Lall, 1998. Control of phosphorus homeostasis of Atlantic salmon (*Salmo salar*) in fresh water. Fish Physiol. Biochem., 19: 83-93.

Wilson, R.P., E.H. Robinson, D.M. Gatlin III and W.E. Poe, 1982. Dietary phosphorus requirement of channel catfish, *Ictalurus punctatus*. J. Nutr., 112: 1197-1202.