Journal of Fisheries and Aquatic Science, 2012
ISSN 1816-4927 / DOI: 10.3923/jfas.2012.

Growth Response of Tambaqui (*Colossoma macropomum*) Fingerlings to Salt (Sodium Chloride) Supplemented Diets

P. Keshavanath, C.A. Oishi, F.A. Leao da Fonseca, E.G. Affonso and M.P. Filho
Aquaculture Division, National Institute of Research in the Amazon, Post Box No. 478, CEP 69060-001 Manaus, AM, Brazil

Corresponding Author: P. Keshavanath, Aquaculture Division, National Institute of Research in the Amazon, Post Box No. 478, CEP 69060-001 Manaus, AM, Brazil

ABSTRACT

The influence of dietary salt (sodium chloride) on growth, feed digestibility and body composition in tambaqui (*Colossoma macropomum*) fingerlings was investigated, by feeding triplicate groups of fish (av. wt. 1.1 g) maintained in 500 L circular tanks with diets containing different levels of sodium chloride (0.0, 0.5, 1, 1.5 and 2%). The diets were fed at 4% body weight, twice daily in equal halves, six days a week, for 60 days. Fish receiving diets containing 1.5 and 2% salt exhibited significantly higher ($p<0.05$) final body weight and specific growth rate (% day^{-1}). The percent weight gain by fish in these treatments above the control at the termination of the experiment was 26.64 and 26.99, respectively. Fish fed 1.5% salt recorded the best FCR and significantly higher ($p<0.05$) PER. The apparent digestibility values of dry matter and protein were positively affected ($p<0.05$) by dietary salt treatment, while carcass composition was not affected. This study showed the beneficial effect of diets supplemented with 1.5 and 2% sodium chloride on the growth of tambaqui fingerlings.

Key words: Dietary salt, *Colossoma macropomum*, growth, apparent digestibility, carcass composition

INTRODUCTION

Use of salt in fish diets is a common practice in Asia (Veerina *et al*., 1993; Yakupitiage, 1993). Freshwater environment is hypo-osmotic for fish and there is a diffusive ion loss and osmotic water gain across the large surface area of the gill and gut epithelium. Osmoregulation is energy consuming. In fish it is carried out mainly via branchial chloride cells. Euryhaline fish in different environmental salinities induce activation of their ion transport mechanism, usually accompanied by changes in oxygen consumption, causing variations in the energy demands for osmoregulation. Since minerals absorbed from the water do not always meet the total metabolic requirements in fish, their supplementation through the diet promotes growth (Hepher, 1988). Providing sufficient amount of salt through feeds can spare energy that is used for osmoregulation, thereby reducing stress and allowing more energy for growth (Gatlin *et al*., 1992).

Boeuf and Payan (2001) reviewed the literature on salinity influence on growth in fish and concluded that salinity is also a key factor in controlling growth. They observed that the changes in growth rate that depend on salinity result from an action on metabolic rate, food intake and food conversion. Better growth at intermediate salinities (8-20 psu) is very often but not systematically, correlated to a lower standard metabolic rate. *Tilapia rendalli* exhibited significantly higher growth and nutrient digestibility when cultured in 10‰ salinity (Kang'ombe and Brown, 2008). Imanpoor *et al.* (2011) reported that weight gain, specific growth rate, final biomass and feed conversion rates in goldfish (*Carassius auratus*) were significantly affected ($p<0.05$) at 12‰ salinity and 31°C temperature.

Wide variation exists with regard to the level of salt that influences growth in different species of fish. Even though the effects of dietary salt have been investigated in species such as Japanese eel (Arai *et al.*, 1974), rainbow trout (MacLeod, 1978), carps (Nandeesha *et al.*, 2000; Gangadhara *et al.*, 2004), European sea bass (Eroldogan *et al.*, 2005), Asian sea bass (Harpaz *et al.*, 2005; Arockiaraj and Appelbaum, 2010), silver catfish (Garcia *et al.*, 2007) and gilthead seabream (Appelbaum and Arockiaraj, 2009), no such study has been conducted on tambaqui (*Colossoma macropomum*), a highly valued fast growing food fish which is a native species of the rivers, floodplains, lakes and flooded forests of Amazon and Orinoco basins of Brazil. Salt addition to fish diets could lead to reduced production cost due to improved growth rate and shorter duration of culture, thereby saving on the quantity of feed required.

This study evaluated the influence of graded levels of dietary sodium chloride on growth, feed digestibility and body composition in tambaqui fingerlings.

MATERIALS AND METHODS

The work was conducted between May and July, 2009 employing tambaqui seed obtained from a local fish farm in Manaus. The seed were held for acclimation in the wet laboratory of the Aquaculture Division of the National Institute of Research in the Amazon in two 1000 L tanks for 15 days and fed twice daily by hand to satiation with the control diet used in this experiment. The percentage of feeding was standardized at 4% based on consumption by fish during this period.

Diets: Four experimental diets (T_1 to T_4) were formulated with the same content of powdered ingredient mixture (Table 1). They were supplemented with 0.5, 1.0, 1.5 and 2.0% of laboratory grade sodium chloride. A diet formulated similarly with no salt supplementation (T_0) served as the control. The feed mixture was hand kneaded with 300 mL water per kg ingredient powder and processed through a pelletizer to create pellets of 1 mm size. The pellets were dried in a thermostatic oven at 40°C. They were then packed in air-tight plastic bags and kept at room temperature until use.

Experimental set-up: After acclimation, 20 fingerlings each of tambaqui (*C. macropomum*), of average weight 1.1 g and 2.80-3.17 cm length were distributed randomly into the flow-through system consisting of fifteen 500 L circular tanks (three tanks per treatment) containing 300 L of water each. The water flow rate was adjusted to 200 mL per min which resulted in daily water exchange of 96% in the experimental tanks. The tanks were continuously aerated from a central aerator, using one aerator stone per tank. The fish were fed twice daily (09.00 and 16.00 h) six days a week, at 4% of body weight in 2 equal halves, over the experimental duration of 60 days. Fish biomass was measured every 15 days and the amount of feed given was recalculated based on the new body weight at each sampling.

Monitoring water quality: Water quality parameters viz., temperature, dissolved oxygen (DO), pH and conductivity were monitored in the tanks every week, while carbon dioxide (CO_2),

Table 1: Ingredient proportion and proximate composition (%) of diets

	Diets				
Item	T_0	T_1	T_2	T_3	T_4
Ingredients					
Fish meal (68.56% CP)	20	20	20	20	20
Soybean meal (Full fat-54.69% CP)	20	20	20	20	20
Wheat bran (10.78% CP)	20	20	20	20	20
Meat and bone meal (55.92% CP)	10	10	10	10	10
Wheat flour (18.86% CP)	10	10	10	10	10
Maize (9.94% CP)	18.0	17.5	17.0	16.5	16.0
Vitamin-mineral premix*	2	2	2	2	2
Salt (NaCl)	0.0	0.5	1.0	1.5	2.0
Total	100	100	100	100	100
Proximate composition					
Moisture	8.52	10.98	8.86	10.04	9.48
	(0.07)	(0.10)	(0.06)	(0.16)	(0.12)
Crude Protein	33.92	33.06	34.38	33.33	33.24
	(0.20)	(0.08)	(0.16)	(0.30)	(0.14)
Lipid	4.0	4.2	4.0	3.9	4.3
	(0.04)	(0.08)	(0.14)	(0.20)	(0.11)
Ash	10.65	11.37	11.69	12.28	12.53
	(0.29)	(0.10)	(0.08)	(0.16)	(0.32)
Fibre	1.74	1.26	1.42	1.68	1.15
	(0.08)	(0.10)	(0.18)	(0.20)	(0.06)
P:E	0.093	0.091	0.095	0.092	0.093

Values in brackets are SE, *kg mixture contains Vitamins: A: 6000000 IU, B1: 5000 mg, B2: 1120 mg, B3: 30000 mg, B5: 30000 mg, B6: 8000 mg, B8: 2000 mg, B9: 3000 mg, B12: 20000 mcg, C: 500 mg, D3: 2250000 IU, K3: 3000 mg, E: 75000 mg, Minerals: $ZnSO_4$: 150000 mg, $MnSO_4$: 60000 mg, Kl: 4500 mg, $FeSO_4$: 100000 mg, $CoSO_4$: 2000 mg, Na_2SeO_3: 400 mg

alkalinity, total ammonia and nitrite-nitrogen were measured every 15 days. DO and conductivity were monitored using a combined digital YSI 85 meter (YSI incorporated Yellow Springs, Ohio USA), whereas a digital YSI 60 meter was used to measure temperature and pH. CO_2 and alkalinity were analyzed as per APHA (1992), while ammonia concentration was determined colorimetrically at 530 nm wavelength, by indophenol method (Verdouw *et al.*, 1978). Nitrite concentration was estimated by the method described by Boyd and Tucker (1992).

Digestibility measurement: At the end of the growth experiment, 10 fish each from the replicate tanks were held in 15 cylindrical 200 L fibre glass tanks and fed once daily at 09.00 h with the respective 5 diets *ad libitum* in triplicate for 30 days, 6 days per week. The uneaten food was let out after 2 h of feeding every day. Every morning prior to feeding fecal matter was collected and dried in an oven. The fecal matter collected over the entire period from the respective tanks was pooled and analyzed for proximate composition. Digestibility estimates were made as per De Silva *et al.* (1990), with fibre as an internal marker.

Chemical analyses: Ingredients, diets, fecal samples and fish carcass were analyzed for proximate composition (AOAC, 1995) as follows: moisture content by oven drying at 105°C for

24 h; crude protein (N×6.25) by micro-Kjeldahl digestion and distillation after acid digestion using a Kjeltec 1026 distilling unit together with a Tecator digestion system (Tecator, Sweden); crude lipid by Soxhlet ether extraction; crude fibre by acid/alkali digestion; ash by ignition at 550°C in a muffle furnace to a constant weight. Nitrogen-free extract (NFE) was computed by subtracting the sum values for crude protein, lipid, ash, crude fibre and moisture from 100. Gross energy was calculated using the conversion factors of 5.64, 9.44 and 4.11 Kcal g^{-1} for protein, lipid and carbohydrate, respectively (NRC, 1993). Three fish from each tank were sampled at the termination of the feeding experiment for proximate composition of carcass.

Growth and feed utilization indices: Fish performance in terms of specific growth rate (SGR % day^{-1}), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) was calculated using the following formulae:

$$\text{Specific growth rate (SGR; \% day}^{-1}) = \frac{(\ln W_t - \ln W_i)}{T} \times 100$$

where, W_t is weight of fish at time t, W_i is weight of fish at time 0 and T is the culture period in days:

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed consumed (g)}}{\text{Weight gain (g)}}$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

Statistical analysis: The data were analyzed by one-way Analysis of Variance (ANOVA) using Origin 6.1 software. Mean differences between treatments were tested for significance at $p<0.05$ by Tukey test and comparison was made by Duncan's multiple range test (Duncan, 1955).

RESULTS

The average values of the water quality parameters varied narrowly among treatments during the experimental period (Table 2). The range of values were: water temperature: 26.06-26.11°C,

Table 2: Average values of water quality parameters in the experimental tanks

	Treatment				
Parameter	T_0	T_1	T_2	T_3	T_4
Temperature (°C)	26.09	26.06	26.11	26.08	26.06
Oxygen (mg L^{-1})	7.53	7.52	7.40	7.40	7.46
pH	5.10	5.28	5.12	5.19	5.33
Conductivity (μS cm^{-1})	29.24	32.05	32.38	32.19	30.75
Carbon dioxide (mg $CaCO_3$ L^{-1})	0.99	1.13	1.00	1.09	1.07
Alkalinity (mg L^{-1})	0.22	0.23	0.24	0.22	0.26
Ammonia (mg L^{-1})	0.11	0.10	0.12	0.07	0.14
Nitrite nitrogen (mg L^{-1})	0.16	0.15	0.13	0.12	0.15

Table 3: Growth parameters, diet digestibility and body composition of tambaqui fingerlings fed salt supplemented diets

	Treatment				
Parameter	T_0	T_1	T_2	T_3	T_4
Initial mean length (cm)	2.98±0.14[a]	3.08±0.12[a]	3.00±0.16[a]	2.99±0.06[a]	3.00±0.15[a]
Final mean length (cm)	6.19±0.19[b]	6.54±0.25[b]	6.10±0.14[b]	6.43±0.1[b]	6.79±0.16[a]
Initial mean weight (g)	1.1±0.03[a]	1.1±0.01[a]	1.1±0[a]	1.1±0.01[a]	1.1±0.01[a]
Final mean weight (g)	3.98±0.21[b]	4.29±0.29[b]	4.13±0.1[b]	4.76±0.16[a]	4.77±0.22[a]
Net weight gain (g)	2.88±0.12[b]	3.19±0.19[b]	3.03±0.16[b]	3.66±0.1[a]	3.67±0.15[a]
Weight gain (%) over control	--	10.38	5.19	26.64	26.99
SGR (% day^{-1})	2.18±0.04[b]	2.28±0.09[b]	2.21±0.04[b]	2.45±0.05[a]	2.47±0.07[a]
FCR	2.35±0.12[a]	2.19±0.2[a]	2.22±0.07[a]	2.02±0.13[b]	2.18±0.11[a]
PER	1.25±0.06[b]	1.34±0.12[b]	1.31±0.04[b]	1.45±0.09[a]	1.35±0.07[b]
Feed digestibility (%)					
Dry matter	87.56±0.29[b]	91.58±0.33[a]	91.19±0.88[a]	91.47±0.54[a]	92.28±0.25[a]
Protein	94.95±0.35[b]	96.85±0.06[a]	96.67±0.27[a]	95.82±0.12[a]	97.06±0.14[a]
Fat	97.89±0.33[a]	98.40±0.14[a]	97.24±0.43[a]	98.11±0.22[a]	97.98±0.16[a]
Body composition (%)					
Dry matter	91.57±0.45[a]	91.47±0.46[a]	92.10±0.26[a]	92.13±0.4[a]	91.30±0.19[a]
Crude protein	60.12±0.21[a]	60.27±0.23[a]	60.37±0.16[a]	61.00±0.51[a]	61.20±0.44[a]
Lipid	11.90±0.46[a]	12.13±0.23[a]	11.70±0.26[a]	12.37±0.2[a]	12.20±0.32[a]
Ash	15.17±0.47[a]	15.60±0.4[a]	14.87±0.54[a]	15.37±0.15[a]	14.73±0.23[a]

Values are as Mean±SE, Values with same superscript in each row are not significantly different (p>0.05)

dissolved oxygen 7.40-7.53 mg L^{-1}, pH 5.10-5.33, conductivity 29.24-32.38 (µS cm^{-1}), free carbon dioxide 0.99-1.13 mg L^{-1}, alkalinity 0.22-0.26 mg $CaCO_3$ L^{-1}, ammonia 0.07-0.14 mg L^{-1} and nitrite-nitrogen 0.12-0.16 mg L^{-1}.

On termination of the growth experiment, the average weight of individual fish in different treatments ranged between 3.98 g (T_0) and 4.77 g (T_4). The best performance of fish in terms of final body weight and SGR (% day^{-1}) was recorded with diets having 1.5 and 2.0% salt supplementation. Fish under T_1 and T_2 treatments (0.5 and 1.0% added salt) did not differ significantly ($p<0.05$) from that of the control (with no added salt). Fish fed 1.5% salt recorded the best FCR and significantly higher ($p<0.05$) PER (Table 3).

The apparent digestibility values of protein and dry matter were significantly ($p<0.05$) affected by the dietary salt treatments, while fish carcass composition was not affected ($p>0.05$). The values (%) of protein and lipid ranged from 60.12 to 61.20 and 10.90 to 12.37, respectively (Table 3).

DISCUSSION

Water quality parameters in the experimental tanks were within the acceptable optimum range for tambaqui, with no drastic variation among the treatments. Fish fed diets containing 1.5 and 2.0% salt exhibited significantly higher growth. The percentage weight gain by fish in these treatments over the control at the termination of the experiment was 26.64 and 26.99, respectively. Fish receiving 1.5% salt incorporated diet recorded the best FCR and significantly higher ($p<0.05$) PER. This indicates that 1.5% dietary salt is sufficient to enhance growth in juvenile tambaqui. Shiau and Lu (2004) determined the dietary sodium requirement of juvenile hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) in freshwater and reported that addition of 0.2% significantly ($p<0.05$) improved growth and feed efficiency. Through regression analysis of weight gain data, gill Na^+–K^+ ATPase activity and whole body Na+ retention, they concluded that the adequate dietary Na+ concentration for tilapia is about 0.15%. Pyle *et al.* (2003) demonstrated that dietary Na+ could be very important for physiological demands in rainbow trout. Na+ and K+ are essential minerals in animals because of their role in electrolyte and acid-base balance (Shiau and Lu, 2004). Dietary supplemented salt can act as a ready reserve to meet the osmoregulatory requirement of freshwater fishes. The passive outward flux of ions such as Na+ and Cl- to the external medium, via the gills, feces and renal system in freshwater fish is overcome by active uptake of ions from the water and/or from the diet (Evans *et al.*, 2005).

Earlier research shows wide variation in the effective dose of dietary salt that induces higher growth in different fish species: 2% in juveniles of red drum (Gatlin *et al.*, 1992), 4 or 5% in trout and carp (Ogino and Kamizono, 1975; Tacon and De Silva, 1983) 12% in rainbow trout (Salman and Eddy, 1988; Smith *et al.*,1995), 1.5% in mrigal and common carp (Nandeesha *et al.*, 2000), 1% in rohu (Gangadhara *et al.*, 2004), 5% in European sea bass (Eroldogan *et al.*, 2005), 1.2% in silver catfish fingerlings (Garcia *et al.*, 2007), 1.5, 6 and 12% in gilthead sea bream juveniles (Appelbaum *et al.*, 2008; Appelbaum and Arockiaraj, 2008; Appelbaum and Arockiaraj, 2009) and 8% in Asian sea bass (Arockiaraj and Appelbaum, 2010).

Inclusion of salt above the optimum level results in a deterioration of all the growth performances (Smith *et al.*, 1995). Low digestibility and faster evacuation of food have been associated with high levels of dietary sodium chloride (Salman and Eddy, 1988). MacLeod (1978) reported that the addition of excessive salt to the diet could have an adverse effect on food intake, digestion and/or absorption, because of the change in the gastric/intestinal environment and may even have pathological effects, ultimately leading to growth reduction. No adverse effect was detected with even the highest salt dose tested in the present experiment, fish survival being cent percent in all treatments.

Changes in carcass composition following feeding of salt has been reported in species such as rainbow trout, common carp and rohu (Ogino and Kamizono, 1975; Tacon *et al.*, 1984; Gangadhara *et al.*, 2004); however, such an effect was not found in tambaqui (Table 3). This could be related to difference in the size of fish used in different studies. Tambaqui in the present study weighed only 3.98 (T_0) to 4.77 g (T_4) at the end of the growth experiment as against larger sizes of fish in other studies. Nonetheless, salt addition influenced dietary dry matter and protein digestibility. Therefore, the higher growth of tambaqui recorded with the salt supplemented diets could be primarily attributed to the diets serving as a ready source of Na^+ Cl^- for osmoregulatory requirement and the energy thus saved being channeled for growth. Better digestibility of dry matter and protein from these diets would also have contributed to growth.

CONCLUSION

Based on the results obtained, it may be concluded that 1.5% dietary salt supplementation is effective in enhancing juvenile tambaqui growth.

ACKNOWLEDGMENTS

The first author is grateful to the Third World Academy of Sciences, Italy for the TWAS-UNESCO Associateship and CNPQ (National Council for Science and Technology, Brazil) and FAPEAM (Amazon State Research Foundation) for funding support. We thank Maria Ines de Oliveira Pereira for chemical analyses of the samples.

REFERENCES

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

APHA, 1992. Standard Methods for the Examination of Water and Waste Water. 18th Edn., American Public Health Association Washington, USA.

Appelbaum, S. and A.J. Arockiaraj, 2008. Israeli researchers test viability of using brackish inland waters for rearing gilthead sea bream. Hatchery Int., 9: 22-23.

Appelbaum, S. and A.J. Arockiaraj, 2009. Cultivation of gilthead sea bream (*Sparus aurata* Linnaeus, 1758) in low salinity inland brackish geothermal water. AACL Bioflux., 2: 197-203.

Appelbaum, S., A.J. Arockiaraj and C. Imanraj, 2008. Cultivation of gilthead sea bream (*Sparus auratus* L.) in low saline inland water of southern part of Israel desert. Aquacult Asia, 13: 33-36.

Arai, S., T. Nose and H. Kawatsu, 1974. Effect of minerals supplemented to the fish meal diet on growth of eel *Anguilla japonica*. Tansuika Suisan Kenkvusho Kenkvu Hokoku, 24: 95-100.

Arockiaraj, A.J. and S. Appelbaum, 2010. Effect of brine salt rich diets on growth performances and survival of Asian seabass (*Lates calcarifer*) juveniles reared in freshwater systems. AACL Bioflux, 3: 27-33.

Boeuf, G. and P. Payan, 2001. How should salinity influence fish growth. Comp. Biochem. Physiol., 130: 411-423.

Boyd, C.E. and C.S. Tucker, 1992. Water quality and pond soil analyses for aquaculture.. Alabama Agricultural Experimental Station, Auburn University, AL, USA, pp: 183.

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

Eroldogan, O.T., M. Kumlu, M. Kýr and G.A. Kiris, 2005. Enhancement of growth and feed utilization of the European sea bass (*Dicentrarchus labrax*) fed supplementary dietary salt in freshwater. Aquacult. Res., 36: 361-369.

Evans, D.H., P.M. Piermarini and K.P. Choe, 2005. The multifunctional fish gill: Dominant site of gas exchange, osmoregulation, acid-base regulation and excretion of nitrogenous waste. Physiol. Rev., 85: 97-177.

Gangadhara, B., M.C. Nandeesha, P. Keshavanath and T.J. Varghese, 2004. Growth response and biochemical composition of rohu, *Labeo rohita*, fed salt-incorporated diets. J. Applied Aquacult., 16: 169-176.

Garcia, L.O., A.G. Becker, C.E. Copatti, B. Baldisserotto and J. RadünzNeto, 2007. Salt in the food and water as a supportive therapy for *Ichthyophthirius multifiliis* infestation on silver catfish, *Rhamdia quelen*, fingerlings. J. World Aquacult. Soc., 38: 1-11.

Gatlin, D.M., D.S. Mackenzie, S.R. Craig and W.H. Neill, 1992. Effects of dietary sodium chloride on red drum juveniles in waters of various salinities. Prog. Fish Cult., 54: 220-227.

Harpaz, S., Y. Hakim, T. Slosman and O.T. Eroldogan, 2005. Effects of adding salt to the diet of Asian sea bass *Lates calcarifer* reared in fresh or salt water recirculating tanks, on growth and brush border enzyme activity. Aquaculture, 248: 315-324.

Hepher, B., 1988. Nutrition of Pond Fishes. Cambridge University Press, Cambridge, UK., pp: 388.

Imanpoor, M.R., E. Najafi and M. Kabir, 2011. Effects of different salinity and temperatures on the growth, survival, haematocrit and blood biochemistry of goldfish (*Carassius auratus*). Aquacult. Res., 43: 332-338.

Kang'ombe, J. and J.A. Brown, 2008. Effect of salinity on growth, feed utilization and survival of *Tilapia rendalli* under laboratory conditions. J. Applied Aquacult., 20: 256-271.

MacLeod, M.G., 1978. Relationships between dietary sodium chloride, food intake and food conversion in the rainbow trout. J. Fish Biol., 13: 71-78.

NRC, 1993. Nutritional requirements of fishes. National Academy Press. Washington, DC, USA, pp: 114.

Nandeesha, M.C., B. Gangadhara, T.J. Varghese and P. Keshavanath, 2000. Effect of dietary sodium chloride supplementation on growth, biochemical composition and digestive enzyme activity of *Cyprinus carpio* (Linn.) and *Cirrhinus mrigala* (Ham.). J. Aquacult. Tropics, 15: 135-144.

Ogino, C. and M. Kamizono, 1975.. Mineral requirements in fish. I. Effects of dietary salt mixture level on growth, mortality and body composition in rainbow trout and carp. Bull. Japanese Soc. Sci. Fish., 41: 429-434.

Pyle, G.G., C.N. Kamunde, D.G. McDonald and C.M. Wood, 2003. Dietary sodium inhibits aqueous copper uptake in rainbow trout (*Oncorhynchus mykiss*). J. Exp. Biol., 206: 609-618.

Salman. N.A. and F.B. Eddy, 1988. Effect of dietary sodium chloride on growth, food intake and conversion efficiency in rainbow trout, *Salmo gairdneri* (Richardson). Aquaculture, 70: 131-144.

Shiau, S.Y. and L.S. Lu, 2004. Dietary sodium requirement determined for juvenile hybrid tilapia (*Oreochromis niloticus x O. aureus*) reared in fresh water and seawater. Br. J. Nutr., 91: 585-590.

Silva, De S.S., K.F. Shim and A.K. Ong, 1990. An evaluation of the method used in digestibility estimation of a dietary ingredient and comparisons on external and internal markers and time of faeces collection in digestibility studies in the fish *Oreochromis aureus*. Reprod. Nutr. Dev., 30: 215-226.

Smith, N.F., F.B. Eddy and C. Talbot, 1995. Effect of dietary salt load on trans-epithelial Na+ exchange in freshwater rainbow trout (*Oncorhynchus mykiss*). J. Exp. Biol., 198: 2359-2364.

Tacon, A.G.J. and S.S. De Silva, 1983. Mineral composition of some commercial fish feeds available in Europe. Aquaculture, 31: 11-20.

Tacon, A.G.J., D. Knox and C. B. Cowey, 1984. Effect of different dietary levels of salt mixtures on growth and body composition in carp. Bull. Japanese Soc. Sci. Fish., 50: 1217-1222.

Veerina, S.S., M.C. Nandeesha, K.G. Rao and S.S. De Silva, 1993. Status and technology of Indian major carp farming in Andhra Pradesh, India. Asian Fisheries Society, Indian Branch, Mangalore, pp: 30.

Verdouw, H., C.J.A. VanEchteld and E.M.J. Dekkers, 1978. Ammonia determination based on indophenol formation with sodium salicylate. Water Res., 12: 399-402.

Yakupitiage, A., 1993. On-Farm Feed Preparation and Feeding Strategies for Carps and Tilapias. In: Farm-Made Aquafeeds. New, M.B., A.G.J. Tacon and I. Csavas (Eds.)., FAO-RAPA/AADCP, Bangkok, Thailand, pp: 87-100.