THE EFFECT OF SUPPLEMENTAL MANGANESE ON GROWTH PERFORMANCE, FEED UTILIZATION, DIGESTIBILITY AND SOME PHYSIOLOGICAL PARAMETERS OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

HANY I. EL-MARAKBY

Department of Fish Nutrition, Central Laboratory for Aquaculture Research, Abbassa, Abo-Hammad, Sharkia, Egypt.

(Manuscript received 1st October 2006)

Abstract

Basal diet was formulated to contain casein and gelatin as sources of protein and was divided to six equal treatments. Mn was added to each treatment at different levels to be 3, 5, 8, 11, 14 and 17 mg/kg diet. Nile tilapia (4±1 g) were assigned to the six treatments, with three replicates each. Fish were fed frequently a diet of 30% crude protein at a rate of 3% of live body weight. The optimum fish growth was obtained at Mn level of 5-8 mg/kg diet. Feed intake was significantly higher with fish fed 5 mg Mn/kg diet ($P<0.05$). There were no significant changes in feed intake among fish groups fed Mn-enriched diets ($P<0.05$). Subsequently, FCR was significantly higher with fish fed control diet ($P<0.05$), while the lowest one was obtained at Mn levels of 5 and 8 mg/kg diet. The higher PER value was obtained in Mn-enriched diets, while the lowest value was obtained at fish group fed control diet ($P<0.05$).

Moisture content in fish body increased with the increase in dietary Mn. It was significantly higher in fish group fed 14 and 17 mg Mn/kg diet compared to that of fish fed the control diet. The highest crude protein content was obtained at fish group fed 17 mg Mn/kg diet, while the highest content of total lipid was obtained at fish group fed control diet, while the lowest one was obtained at fish group fed 17 mg Mn/kg diet. Ash content was slightly increased with increasing the dietary Mn levels ($P<0.05$). The highest digestibility coefficient of crude protein was obtained in fish group fed 5-11 mg Mn/kg diet ($P<0.05$), the digestibility coefficient of total lipids were higher in fish group fed 8-14 mg Mn/kg diet than the other fish groups ($P<0.05$). The digestibility coefficient of carbohydrate was higher in fish group fed Mn-enriched diets (5-17 mg Mn/kg diet) than the fish group fed control diet.

No definite changes in hemoglobin, hematocrit, glucose, creatinine and uric acid levels due to dietary Mn levels. Also, plasma AST and ALT activities were insignificantly affected by dietary Mn levels in the diet. Mn concentration in plasma was positively correlated with Mn levels in the diet, however, no significant interaction of dietary Mn with Na, K, Mg, Zn and Cu concentrations in plasma.

Key words: Manganese, minerals, Nile tilapia, growth, feed utilization, digestibility, hematology, AST, ALT.

INTRODUCTION

Like all animals, fish require minerals as essential factors in a wide variety of metabolic functions. Because manganese (Mn) content of the water is not sufficient

for the requirement of the fish, diet is considered a more significant source of the element (Srivastava and Agrawal, 1983, NRC, 1993). The most important biological function of Mn is as a cofactor of enzymes, particularly in energy metabolism (Wapnir, 1990). It is a vital factor in lipid and carbohydrate metabolism too. Mn is essential for normal growth, function of the brain, reproduction and prevention of skeletal abnormalities in terrestrial animals. Moreover, Mn as several nutrients can act both as pro- and antioxidants, and it is functional part of the red-ox centers of antioxidant enzymes, and therefore often classified as antioxidant nutrient (Hamre *et al.*, 2004). Further, Mn deficiency in the diet impaired cellular immune response in rainbow trout (Inoue et al. 1998), and was associated with poor growth, depressed feed intake, skeletal abnormalities (dwarfism), eye lens cataracts, and increased mortality (Knox *et al.*, 1981).

Effects of dietary Mn has been examined on fish species such as rainbow trout (Ogino and Yang, 1980, Knox *et al.*, 1981, Satoh *et al.*, 1983a), common carp (Ogino and Yang, 1980, Satoh et al., 1983b), channel catfish (Gatlin and Wilson, 1984) and Atlantic salmon (Maage et al., 2000). These experiments were designed to compare the response of *Oreochromis niloticus* fed basal diets with different concentrations of supplemental Mn.

When a mineral deficiency is suspected, it is necessary to examine specific biochemical or compositional indicators of nutritive status. The first step when a deficiency is suspected, a presumptive diagnosis based on clinical signs of deficiency is considered. This has proven difficult with fish since the signs of most elemental deficiencies i.e. reductions in growth, feed consumption and feed efficiency are nonspecific (Tacon, 1985). However, mineral nutrition has received a little attention and manganese requirement for Nile tilapia has not been clarified. The purpose of this study is to investigate the effect of dietary supplemental manganese levels on growth, feed utilization, and some physiological parameters of Nile tilapia, *Oreochromis niloticus* fingerlings and to which extent it may be toxic to fish.

MATERIALS AND METHODS

Diets:

A manganese free mineral premix was firstly prepared (Table 1). Traces of Mn in casein and gelatin were calculated from NRC (1993), and Mn-sulfate was added to adjust the tested levels. L-cellulose was used as an inert bulkier to adjust the ingredients in the all tested diets. Purified casein/gelatin basal diets were prepared by thoroughly mixing the dry ingredients with oil and then warm water was added until stiff dough resulted then passed through a mincer (2 mm diameter) and dried in a forced convection air drier at 65°C. Each pelleted diet was placed in plastic bags and stored at -10°C.

Fish and husbandry:

Nile tilapia, *Oreochromis niloticus* weighing 3-5 g/fish were obtained from Abbassa Fish Hatchery, Abbassa, Abo-Hammad, Sharkia, Egypt. Fish were acclimated indoor tank for 2 weeks to laboratory conditions. The fish were distributed randomly at a rate of 20 fish per 225-L glass aquarium (225 L). Each aquarium was supplied with compressed air via air-stones from air compressor. The fish were assigned to six groups with three replicates each. The fish groups fed diets containing different levels of manganese 3 (as control diet), 5, 8, 11, 14 and 17 mg Mn/kg diet. Fish were fed frequently a diet containing 30% crude protein (Table 1) at a rate of 3% of live body weight twice daily, 6 days a week for 15 weeks. Faeces and feed residues were removed by siphoning from each aquarium, and a half of aquarium's water was replaced with dechlorinated tap water. Fish in each aquarium was biweekly weighed and subsequently the amount of given feed was calculated. Dead fish were removed and recorded daily. At the end of the experiment, fish were collected, counted and weighed. Growth performance was determined and feed utilization was calculated as following:

Weight gain = final weight – initial weight,

Specific growth rate (SGR) = 100 (ln W_2 – ln W_1) / T, where W_1 and W_2 are the initial and final weight, respectively, and T is the number of days in the feeding period ,

Feed conversion ratio (FCR) = feed intake / weight gain,

Protein efficiency ratio (PER) = weight gain / protein intake,

The condition factor (K) = 100 weight / $(length)^3$

The hepato-somatic index (HSI) = liver weight / fish body weight.

Apparent digestibility coefficient:

Apparent digestibility trial was performed using 0.5% chromic oxide in the diet as an inert marker to evaluate the nutrients digestibility coefficient. Fish faeces were collected by siphoning method, however, after 2 hours of fish feeding, aquaria were cleaned by siphoning the feed residues, then deposited faeces were collected every 20 min. Digestibility coefficient was determined by the following equation:

$$\text{Digestibility coefficient} = 100 - \left(100 \times \frac{\%\ \text{Indicator in feed}}{\%\ \text{indicator in faeces}} \times \frac{\%\ \text{nutrient in faeces}}{\%\ \text{nutrient in feed}}\right)$$

The measurements of chromic oxide concentration in faeces and diets were done spectrophotometrically according to the method of Zivkovic and Nowar (1977).

Analytical methods:

The basal diet and fish samples from each treatment were analyzed using the methods of AOAC (1990) for determination of moisture, crude protein, total lipids and ash.

Blood samples were taken from caudal vein of anaesthetized fish by sterile syringe using EDTA solution as an anticoagulant. The blood samples were used for determining hematocrite (Hct) and hemoglobin (Hb) contents (Van Kampen and Zijlstra, 1961). Plasma was obtained by centrifugation at 3000 rpm for 15 min and nonhaemolyzed plasma was stored in deep freezer for further biochemical analyses. Glucose was determined according to Trinder (1969). Uric acid was measured according to Barham and Trinder (1972). Creatinine was measured colorimetrically as described by Henry (1964). Activities of aspartate amninotransferase (AST) and alanine aminotransferase (ALT) were determined colorimetrically according to Reitman and Frankel (1957). For measuring blood minerals, 0.5 mL plasma was digested with a mixture of conc. HCl: HNO_3 (1:1 v/v) using Mega Microwave Digestion System, and appropriately diluted with deionized water to constant volume. The studied elements were determined using atomic absorption spectrophotometer (Perkin Elmer model 2280). Sodium and potassium were determined by flame photometry (AOAC, 1990).

Statistical analysis:

The obtained data were subjected to analysis of variance according to Snedecor and Cochran (1982). Differences between means were at the 5% probability level using Duncan's new multiple range test (Duncan, 1955).

RESULTS

The mean final weight, weight gain and SGR were shown in Fig. 1 and Table 2. The obtained results showed that fish fed the control diet (3 mg Mn/kg diet) had the lowest growth. Fish fed diets containing 5-8 mg Mn/kg diets had significantly higher growth rate than those fed the control diet. The highest growth was obtained at 5 and 8 mg Mn/kg diet (13.42 and 13.31 g/fish, respectively). There were no significant changes in K factor and HSI, and their ranges were 1.7-1.795 and 2.907-3.373, respectively (Table 2, $P<0.05$). Survival rate of fish groups fed Mn-enriched diets were significantly higher than that fed control diets (Table 2, $P<0.05$). There were no significant changes in survival rate among fish groups fed Mn-enriched diets ($P<0.05$).

Data of feed intake, FCR and PER were shown in Table 3. The feed intake was significantly higher with fish fed 5 and/or 8 mg Mn/kg diets compared with those fish fed the control diet ($P<0.05$). There were no significant changes in feed intake among fish groups fed Mn-enriched diets ($P<0.05$). Subsequently, FCR was significantly higher with fish fed control diet (2.2, $P<0.05$), while the lowest one was obtained at

Mn levels of 5 and 8 mg/kg diet (1.97 and 1.99, respectively). Moreover, the higher PER value was obtained in Mn-enriched diets, while the lowest value was obtained at fish group fed control diet ($P<0.05$).

Table 4 illustrated the changes in the chemical composition of the whole-fish body of Nile tilapia fed different levels of Mn. Moisture content increased with the increase in dietary Mn ($P<0.05$). The highest moisture content was obtained with fish groups fed 14 and 17 mg Mn/kg diet (75.82% and 76.88%, respectively). The moisture content in those two groups of fish were significantly higher than that of fish fed the other diets. The lowest moisture content was obtained at control group (74.26%). Crude protein content in whole-fish body increased significantly with fish fed 17 mg Mn/kg diet compared to fish fed the control diet. Total lipids decreased with the increase of Mn levels in diets ($P<0.05$). The lipid percentages were significantly lower in fish group fed 14 or 17 mg Mn/kg diet compared to the lipid percentage of the fish fed the control diet. Ash content in whole-fish body was slightly increased with increasing the dietary Mn levels ($P<0.05$) with no significant differences among treatments. The highest ash content was obtained at fish group fed 8-17 mg Mn/kg diet (21.08%-21.36%), while the lowest one was obtained at fish group fed control diet (20.36%).

The digestion coefficient values of crude protein, total lipids and carbohydrates are given in Table 5. The highest digestibility coefficient of crude protein was obtained in fish group fed 5-11 mg Mn/kg diet ($P<0.05$), while the lowest digestibility coefficient was obtained in fish group fed 17 mg Mn/kg diet (79.1%). The digestibility coefficient of total lipids were higher in fish group fed 8-14 mg Mn/kg diet than the other fish groups ($P<0.05$). The lowest digestibility coefficient of total lipids was obtained at fish group fed control diet (68.2%, $P<0.05$). The digestibility coefficient of carbohydrates was higher in fish group fed Mn-enriched diets (5-17 mg Mn/kg diet) than the fish group fed control diet (72.3%, $P<0.05$).

No significant changes in hemoglobin, hematocrit levels, glucose, creatinine and uric acid due to dietary Mn levels ($P<0.05$, Table 6). Also, plasma AST and ALT activities were insignificantly affected by dietary Mn levels in the diet ($P<0.05$, Table 6). Mineral contents in plasma were shown in Table 7. Concentrations of sodium, potassium, magnesium, zinc and copper in plasma were insignificantly changed due to the dietary Mn. Manganese concentration was significantly increased by increasing Mn level in the diet. Mn levels in plasma showed a plateau at Mn levels of 14 and 17 mg/kg (87.37 and 96.37 ppm, respectively).

DISCUSSION

The main outcome of the present study was that the variations in dietary Mn had only a minor effect on fish growth performance. The maximum fish growth was obtained at 5-8 mg Mn/kg diet and fish response to the Mn levels in the diet. This result indicates that a level of 5-8 mg Mn/kg diet may be sufficient to cover Mn requirement. In comparisons with Mn requirements reported for other fish species using purified diets, it seems that Nile tilapia has a lower Mn requirement (5-8 mg/kg) than Atlantic salmon (7.5-10.5 mg/kg), common carp (12-13 mg/kg) and rainbow trout (12-13 mg/kg) but higher than that of channel catfish (2-4 mg/kg) (Ogino and Yang, 1980, Satoh et al., 1987, Satoh et al., 2001, Gatlin and Wilson, 1984, Maage et al., 2000). In this study, the poor growth was obtained when Nile tilapia fed basal control diet. In this regard, Rumsey and Ketola (1975) and Bell et al. (1987) observed that Atlantic salmon has shown poor growth when fed purified diets, and Helland *et al.* (1991) suggested that this might have been related to problems with appetite.

In the present study, the survival rate was lower in fish group fed control diet (3 mg/kg diet) than that fed Mn-enriched diets. Abnormal fish growth or body dwarfism was not observed in Nile tilapia fed Mn-deficient (control) diet. This observation was not in agreement with Satoh *et al.*, 1983a,b, Yamamoto et al., 1983 and Maage *et al.*, 2000 who reported that the developmental abnormalities were observed in rainbow trout, common carp and Atlantic salmon fed Mn-deficient diets.

It was noticed that the addition of Mn to fish diets enhanced the feed intake, FCR and PER. This enhancement was correlated with the enhancement in the digestibility of crude protein, total lipids and carbohydrates. These results indicated the necessity of Mn for fish growth and feed utilization. Meanwhile, Mn deficiency in the diet impaired cellular immune response in rainbow trout (Inoue *et al.* 1998), and was associated with poor growth, depressed feed intake, skeletal abnormalities (dwarfism), eye lens cataracts, and increased mortality (Knox *et al.*, 1981).

Hematological tests and analyses of serum constituents have proved useful in the detection and diagnosis of metabolic disturbances (Aldrin *et al.,* 1982). Screening of hematological characteristics is sensitive in assessing fish health, although not very specific. According to Blaxhall and Daisley (1973) such tests should be supplemented with clinical and biochemical analysis for diagnostic purposes. Also, determinations of AST and ALT have proved useful in the diagnosis of liver and kidney diseases in fish (Racicot *et al.*, 1975, Maita *et al.*, 1984). Creatinine and uric acid are considered as good indicators of glomular filtration rate and kidney dysfunction (Lockhart and Metner, 1984, Zaghloul *et al.*, 2000). There were no significant changes in hemoglobin, hematocrit, glucose, creatinine, uric acid, AST and ALT activities in fish plasma due to dietary Mn levels. These results are indicating the healthy status of Nile tilapia in this study irrespective to Mn levels in the diet.

Contents of sodium, potassium, magnesium, zinc and copper in plasma are insignificantly changed, however, Mn content in fish body was significantly increased by increasing dietary Mn to 11 mg/kg diet or above. In this regard, Gatlin and Wilson (1984), Lorentzen and Maage (1999) and Satoh *et al.* (2001) reported that the incorporation of a higher amount of Mn resulted in an increase in whole body and bone Mn content.

From the present study, it could be concluded that the Nile tilapia fingerlings require 5-8 mg Mn/kg dry diet to maintain the optimum growth although there were no clinical symptoms observed at low Mn levels.

Table 1. Composition and proximate chemical analyses (on DM bases) of the experimental diet containing 30% crude protein.

Ingredients	**%**
Casein	28.47
Gelatin	6.85
Dextrin	18.00
Corn starch	14.10
L-cellulose	18.58
Corn oil	3.00
Fish oil	3.00
Vitamin mixture [1]	1.00
Mn-free mineral mixture [2]	4.00
Carboxymethyl cellulose	2.00
Calcium carbonate	1.00
Total	100
Chemical analysis (%)	
Dry matter	91.25
Crude protein	30.2
Ether extract	6.1
Crude fibers	17.45
Nitrogen free extract [3]	40.71
Ash	5.74
Digestible (Kcal/kg)	3001
Gross energy (Kcal/kg) [4]	4725
Energy : Protein ratio	100.6

[1] Each one kg of vitamin mixture contains: vitamin A 72000 IU, E 60 mg, B_1 6 mg, B_3 12000 IU, B_6 9 mg, B_{12} 0.06 mg, C 12 mg, Pantothenic acid 60 mg, Nicotinic acid 120 mg, Folic acid 6 mg, Biotin 0.3 mg, Choline chloride 3 mg.

[2] Each one kg of mineral mixture contains: zinc sulfate heptahydrate 3.0 g, cuprous chloride 0.10 g, calcium phosphate monobasic 135.8 g, calcium lactate 327.0 g, ferric citrate 29.7 g, potassium phosphate dibasic anhydrous 239.8 g, sodium phosphate monobasic 87.2, sodium chloride 43.6 g, aluminium chloride anhydrous 0.15 g, potassium iodide 0.15 g, cobalt chloride 1.0 g, sodium selenite 11 mg and L-cellulose 132.25 g.

[3] Nitrogen free extract (NFE) = 100 – (protein + lipid + ash + fiber)

[4] Gross energy (GE): Calculated as 5.65, 9.45 and 4.2 Kcal/g for protein, lipid and carbohydrates, respectively.

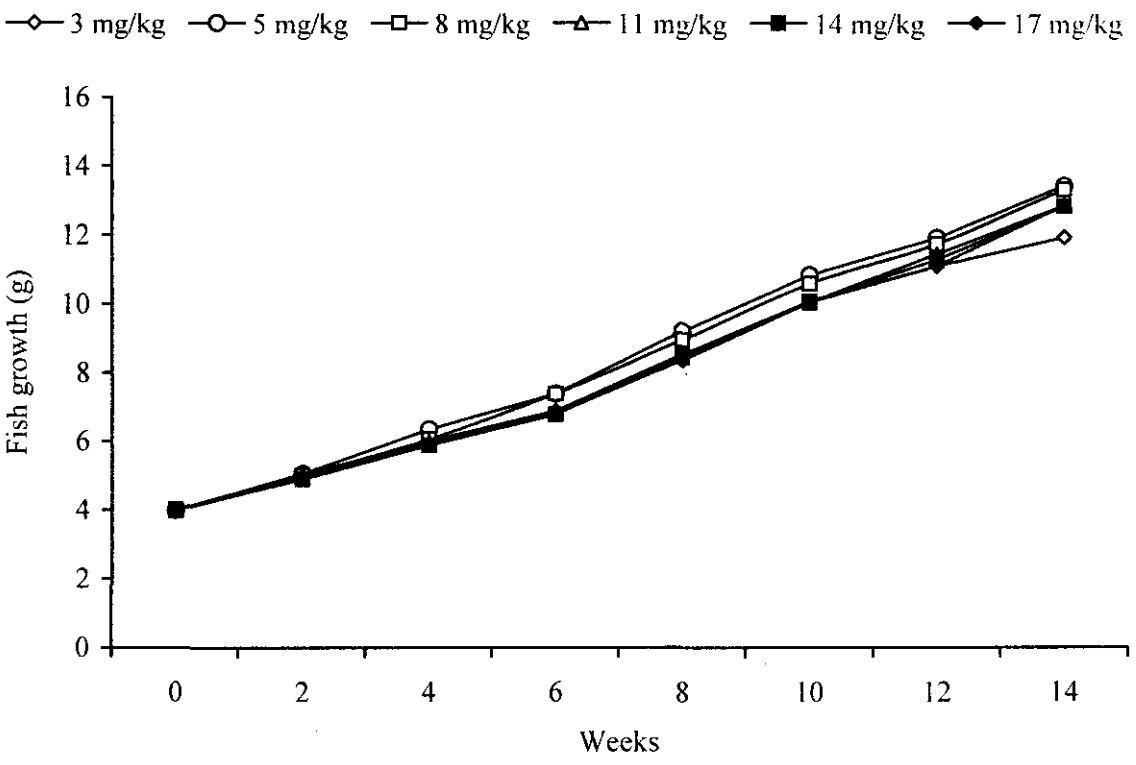

Fig 1. Changes in live body weight (g/fish) of Nile tilapia fed diets containing different dietary manganese levels.

Table 2. Growth performance of Nile tilapia fed diets containing different ldietary Mn.

Items	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	14 mg	17 mg
Initial weight (g/fish)	4.01 ± 0.12	3.99 ± 0.10	4.01 ± 0.17	3.98 ± 0.12	4.00 ± 0.14	4.00 ± 0.12
Final weight (g/fish)	11.92 B ± 0.59	13.42 A ± 0.17	13.31 A ± 0.35	12.84 AB ± 0.21	12.83 AB ± 0.17	12.85 AB ± 0.16
Weight gain (g/fish)	7.91 B ± 0.39	9.43 A ± 0.12	9.30 A ± 0.24	8.86 AB ± 0.14	8.83 AB ± 0.11	8.85 AB ± 0.10
SGR (%/day)	1.037 B 0.052	1.155 A 0.056	1.143 A 0.053	1.116 AB 0.055	1.110 AB 0.057	1.111 AB 0.059
K factor	1.700 A ± 0.013	1.736 A ± 0.014	1.795 A ± 0.020	1.757 A ± 0.739	1.759 A ± 0.011	1.773 A ± 0.015
HS index	3.237 A ± 0.132	3.156 A ± 0.556	2.907 A ± 0.368	3.167 A ± 0.563	3.373 A ± 0.687	3.007 A ± 0.756
Survival rate (%)	96.1 B ± 0.6	100 A ± 0.0	100 A ± 0.0	98.3 AB ± 0.9	98.3 AB ± 0.9	98.3 AB ± 0.9

The same letter in the same row is not significantly different at $P<0.05$.

Table 3. Feed intake, food conversion ratio (FCR) and protein efficiency ratio (PER) of Nile tilapia fed diets containing different levels of dietary Mn.

Items	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	14 mg	17 mg
Feed intake (g feed/fish	17.4 B ±0.52	18.6 A ±0.53	18.5 A ±0.53	18.2 AB ±0.52	18.1 AB ±0.52	18.2 AB ±0.64
FCR	2.20 A ±0.066	1.97 B ±0.061	1.99 B ±0.058	2.05 AB ±0.058	2.05 AB ±0.049	2.06 AB ±0.058
PER	1.64 A ±0.026	1.53 B ±0.031	1.52 B ±0.029	1.47 AB ±0.034	1.48 AB ±0.025	1.47 AB ±0.026

The same letter in the same row is not significantly different at $P<0.05$.

Table 4. Proximate chemical analysis (%, on dry matter basis) of whole body of Nile tilapia fed diets containing different levels of dietary Mn.

Items (%)	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	ng	17 mg
Moisture	74.26 C ± 0.42	75.50 BC ± 0.28	75.39 BC ± 0.64	75.52 BC ± 0.17	75.82 AB ± 0.17	76.88 A ± 0.51
Crude Protein	55.18 B ± 0.66	55.45 B ± 0.61	56.33 AB ± 0.77	56.41 AB ± 0.62	56.92 AB ± 0.45	57.81 A ± 0.51
Total lipids	23.45 A ± 0.78	23.34 A ± 0.48	22.51 AB ± 0.16	22.17 AB ± 0.71	20.88 B ± 0.32	20.75 B ± 0.99
Ash	20.36 A ± 0.34	20.71 A ± 0.13	21.08 A ± 0.52	21.26 A ± 0.51	21.36 A ± 0.04	21.31 A ± 0.48

The same letter in the same row is not significantly different at P<0.05.

Table 5. Apparent digestibility coefficients (%) of Nile tilapia fed diets containing different levels of dietary Mn.

Items	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	14 mg	17 mg
Crude protein	79.7 CD ± 0.21	82.2 A ± 0.29	81.2 AB ± 0.29	80.9 ABC ± 0.26	80.5 BC ± 0.62	79.1 D ± 0.56
Total lipids	68.2 D ± 1.86	75.6 B ± 0.33	79.8 A ± 0.41	80.3 A ± 0.40	80.5 A ± 0.45	71.4 C ± 0.33
Carbohydrates	72.3 A ± 0.60	74.8 AB ± 0.51	77.7 A ± 8.34	75.4 A ± 0.51	74.8 AB ± 0.51	75.6 A ± 0.7

The same letter in the same row is not significantly different at P<0.05.

Table 6. Changes in Hb, Hct, glucose, creatinine and uric acid concentrations in plasma of Nile tilapia fed diets containing different levels of dietary Mn.

Items	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	14 mg	17 mg
Hb	6.03 A ± 0.95	5.63 A ± 0.49	5.17 A ± 0.51	5.51 A ± 0.36	6.54 A ± 0.65	5.42 A ± 0.77
Hct	14.67 A ± 1.86	16.00 A ± 2.08	12.33 A ± 0.33	10.33 A ± 0.33	15.00 A ± 1.73	13.67 A ± 2.33
Glucose (mg/100 ml)	94.87 A ± 14.41	96.92 A ± 6.23	115.67 A ± 10.31	122.1A ± 19.72	129.03 A ± 16.28	119.97 A ± 17.27
Creatinine (mg/100 ml)	3.387 A ± 0.352	2.767 A ± 0.362	3.452 A ± 0.592	2.951 A ± 0.128	3.990 A ± 0.721	3.687 A ± 0.522
Uric acid (mg/100 ml)	1.99 A ± 0.357	1.94 A ± 0.048	2.020 A ± 0.242	2.134 A ± 0.506	2.304 A ± 0.255	2.011 A ± 0.488
AST	62.67 A ± 10.17	45.33 A ± 2.63	51.00 A ± 6.11	57.67 A ± 8.29	56.67 A ± 10.33	57.33 A ± 8.09
ALT	23.33 A ± 6.33	19.67 A ± 1.22	23.33 A ± 1.22	19.33 A ± 1.67	22.00 A ± 2.08	18.67 A ± 2.73

The same letter in the same row is not significantly different at P<0.05.

Table 7. Changes in some elements (ppm) in plasma of Nile tilapia fed diets containing different levels of dietary Mn.

Items (%)	Mn levels (mg/kg diet)					
	Control (3 mg)	5 mg	8 mg	11 mg	14 mg	17 mg
Na	4.463 A ± 0.612	4.783 A ± 0.609	4.210 A ± 0.234	4.940 A ± 0.142	5.213 A ± 0.567	3.697 A ± 0.368
K	388.67 A ± 78.88	531.33 A ± 65.53	304.33 A ± 12.57	329.33 A ± 54.74	417.33 A ± 53.62	355.00 A ± 24.38
Mg	2640.3 A ± 268.6	3851.0 A ± 536.8	4030.0 A ± 473.2	4011.7 A ± 745.8	4292.7 A ± 425.6	4296.7 A ± 659.6
Zn	74.03 A ± 3.98	77.86 A ± 6.41	77.67 A ± 9.06	83.40 A ± 3.31	72.70 A ± 8.84	64.13 A ± 4.53
Mn	39.57 C ± 5.48	46.80 C ± 5.40	47.97 C ± 5.67	66.57 B ± 4.62	87.37 A ± 5.75	96.37 A ± 5.52
Cu	68.03 A ± 7.69	68.63 A ± 13.61	72.97 A ± 6.42	71.53 A ± 6.88	55.07 A ± 6.58	59.87 A ± 5.58

The same letter in the same row is not significantly different at $P<0.05$.

REFERENCES

1. Aldrin, J. F., J. L. Messager and F. Baudin Laurencin. 1982. La biochemie clinique en aquaculture. Interet et perspectives. CNEXO Actes Colloq., 14: 291-326.
2. A. O. A. C. 1990. Official Methods of Analyses. 15*th* edition. K. Helrich (Ed.). Association of Official Analytical Chemist Inc., Arlington, VA.
3. Barham, D. and P. Trinder. 1972. Enzymatic determination of uric acid. Analyzed, 97: 142-145.
4. Bell, J. G., C. B. Cowey, J. W. Adron and B. J. S. Pirie. 1987. Some effects of selenium deficiency on enzyme activities and indices of tissue peroxidation in Atlantic salmon (*Salmo salar*). Aquaculture, 65: 43-54.
5. Blaxhall, P. C. and K. W. Daisley. 1973. Routine haematological methods for use with fish blood. J. Fish Biol., 5: 771-781.
6. Duncan, D. B. 1955. Multiple ranges and multiple (F) test. Biometrics, 11: 1- 42.
7. Galtin, D. M. III and R. P. Wilson. 1984. Studies on the manganese requirement of fingerling channel catfish. Aquaculture, 41: 85-92.
8. Hamre, K., R. Christiansen, R. Waagbø, B. E. Torstensen, B. Lygren, O. Lie, E. Wathne and S. Albrektsen. 2004. Antioxidant vitamins, minerals and lipid levels in diets for Atlantic salmon (*Salmo salar*, L.): effects on growth performance and fillet quality. Aquaculture Nutrition, 10: 113-123.

9. Helland, S., T. Storebakken and B. Grisdale-Helland. 1991. Atlantic salmon, *Salmo salar*. In: Wilson, R. P. (ed.), Handbook of Nutrient Requirements of Finfish. CRC Press, Boca Raton, pp 13-22.
10. Henry, R. J. 1964. Colorimetric determination of total protein. In: Clinical Chemistry. Harper and Row Publ., New York, pp 181.
11. Inoue M., S. Satoh, M. Maita, V. Kiron and N. Okamoto. 1998. Recovery from derangement of natural killer-like activity of leucocytes due to Zn or Mn deficiency in rainbow trout, *Oncorhynchus mykiss* (Walbaum), by the oral administration of these elements. Journal of Fish Diseases, 21: 233-236.
12. Knox, D., C. B. Cowey and J. W. Adron. 1981. The effect of low dietary manganese intake on rainbow trout (*Salmo gairdneri*). Br. J. Nutr., 46: 495-501.
13. Lockhart, W. L. and D. A. Metner. 1984. Fish serum chemistry as a pathology tool. Fisher, 16: 73-86.
14. Lorentzen, M. and A. Maage. 1999. Trace element status of juvenile Atlantic *Salmon salmo* salar L. fed a fish-meal based diet with or without supplementation of zinc, iron, manganese and copper from first feeding. Aquaculture Nutrition, 5: 163-171.
15. Maage, A., B. Lygren and A. F. A. El-Mowafi. 2000. Manganese requirement of Atlantic salmon (*Salmo salar*) fry. Fisheries Science, 66: 1-8.
16. Maita, M., K. Shiomitsu and Y. Ikeda. 1984. Health assessment by the climogram of hemochemical constituents in cultured yellowtail. Bulletin of the Japanese Society of Scientific Fisheries, 51: 205-211.
17. NRC (National Research Council). 1993. Nutrient Requirements of Fish. Committee on Animal Nutrition. Board on Agriculture. National Research Council. National Academy Press. Washington DC., USA. p 114.
18. Ogino, C. and G.Y. Yang. 1980. Nutrient requirements of warmwater fishes and shellfishes. National Academy Press, Washington, DC, 102 pp.
19. Racicot, J. G., M. Gaudet and C. Leray. 1975. Blood and liver enzymes in rainbow trout (*Salmo gairdneri* Ric) with emphasis on their diagnostic use: Study of CCl4 toxicity and a case of Aeinfection. J. Fish Biol., 7: 825-835.
20. Reitman, S. and S. Frankel. 1957. Colorimetric determination of glutamic oxaloacetic and glutamic pyruvic transaminases. Amer. J. Clin. Pathol., 28: 53-56.
21. Rumsey, G. L. and H. G. Ketola. 1975. Amino acid supplementation of casein in diets of Atlantic salmon (*Salmo salar*) fry and of soybean meal for rainbow trout (*Salmo gairdneri*) fingerlings. Can. J. Fish. Res. Board., 32: 422-426.

22. Satoh, S., M. J. Apines, T. Tsukioka, V. Kiron, T. Watanabe, and S. Fujit. 2001. Bioavailability of amino acid-chelated and glass-embedded manganese to rainbow trout, *Oncorhynchus mykiss* (Walbaum), fingerlings. Aquaculture Research, 2001, 32 (Suppl. 1): 18-25.
23. Satoh, S., T. Takeuchi and T. Watanabe. 1987. Availability to carp of manganese in while fish meal and of various manganese compounds. Bulletin of the Japanese Society of Scientific Fisheries, 53(5): 825-832.
24. Satoh, S., H. Yamamoto, T. Takeuchi and T. Watanabe. 1983a. Effects on growth and mineral composition of rainbow trout of deletion of trace elements or magnesium from fish meal diet. Bulletin of the Japanese Society of Scientific Fisheries, 49: 425-429.
25. Satoh, S., H. Yamamoto, T. Takeuchi and T. Watanabe. 1983b. Effects on growth and mineral composition of carp of deletion of trace elements or magnesium from fish meal diet. Bulletin of the Japanese Society of Scientific Fisheries, 49: 431-435.
26. Snedecor, G. W. and W. G. Cochran. 1982. Statistical methods. 6^{th} edition. Iowa State Univ. Press. Amer. IA, USA, pp 593.
27. Srivastava A. K. and S. J. Agrawal. 1983. Changes induced by manganese in fish testis. Experientia, 39: 1309-1310.
28. Tacon, A. G. J. 1985. Nutritional fish pathology. ADCP/Rep/85/22. Food and Agriculture Organization of the United Nations, Rome.
29. Trinder, P. 1969. Determination of glucose concentration in the blood. Ann. Clin. Biochem., 6:24.
30. Van Kampen, E. J. and N. C. Zijlstra 1961. Determination of haemoglobin. Clin. Chem. Acta, 5: 719-720.
31. Wapnir R. A. 1990. Protein Nutrition and Mineral Absorption. CRC Press, Boca Raton, FL., pp 243-257.
32. Yamamoto, H., S. Satoh, T. Takeuchi, T. Watanabe. 1983. Effects on rainbow trout of deletion of Mn or trace elements from fish meal diets. Bulletin of the Japanese Society of Scientific Fisheries, 49: 287-293.
33. Zaghloul, K. H., W. A. Omar, W. Z. A. Mikhail and S. Abo-Hegab. 2000. Ecological and biochemical studies on the Nile fish, *Oreochromis niloticus* (L.), cultured in different aquatic habitats. Egyptian Journal of Zoology, 34: 379-409.
34. Zivkovic and M. S. Nowar. 1977. A simple modification for rapid accurate determination of chromium oxide used in the digestibility trills. Veterinaria, 26:313-318.

تأثير إضافة المنجنيز في العلائق على مظاهر النمو، الإستفادة من الغذاء ، الهضم وبعض الوظائف الفسيولوجية لأسماك البلطي النيلي

هاني ابراهيم المراكبي

قسم تغذية الأسماك- المعمل المركزي لبحوث الاسماك، العباسة- أبو حماد، شرقية

وزعت أسماك البلطي ذات وزن ٤±١ جم الى ستة معاملات بثلاث مكررات لكل منهم. أضيف المنجنيز للعليقة بمستويات مختلفة ٣، ٥، ٨، ١١، ١٤، ١٧ ملجم منجنيز/كجم عليقة. تم تغذية الاسماك على عليقة محتوية على ٣٠% بروتين خام بمعدل ٣% للجسم الحي. تم الحصول على النمو الامثل للاسماك عند مستوى منجنيز ٥-٨ مجم/كجم. الغذاء المأكول كان اكثر معنوية مع الاسماك التي تغذت على ٥ ملجم منجنيز/كجم عليقة. لم يكن هناك فروق معنوية في الغذاء المأخوذ بين مجاميع الاسماك التي تغذت على علائق غنية بالمنجنيز. معامل التحول الغذائي كان أعلى معنويا مع الاسماك التي غذيت على عليقة المقارنة (٣ ملجم منجنيز/كجم عليقة) بينما حصلنا على أقل قيمة عند مستويات ٥-٨ ملجم منجنيز/كجم عليقة. أعلى معامل تحول غذائي تم الحصول عليه في الاسماك التي تغذت على علائق غنية بالمنجنيز بينما القيمة الاقل تم الحصول عليها في مجموعة المقارنة. زاد محتوى الرطوبة لجسم الاسماك معنويا بزيادة المنجنيز بالعليقة وأعلى محتوى رطوبة في مجموعة الاسماك التي غذيت على١٤، ١٧ ملجم منجنيز/كجم عليقة. بينما كان أعلى محتوى للبروتين في المجموعة المغذاه على ١٧ ملجم منجنيز/كجم عليقة. وكان أعلى محتوى من الدهون الكلية في المجموعة غير المعاملة، وأقل محتوى كان في المجموعة المغذاه على ١٧ملجم/كجم. زاد محتوى الرماد قليلا بزيادة مستوى المنجنيز. أعلى مكافىء هضم للبروتين الخام تم الحصول عليه في مجاميع الاسماك المغذاه على ٥-١١ ملجم منجنيز/كجم عليقة، بينما مكافىء الهضم للدهون الكلية كان أعلى في مجاميع الاسماك التي تغذت على ٨-١٤ ملجم منجنيز/كجم عليقةعن المجاميع الاخرى، وفى الكربوهيدرات كان مكافىء الهضم أعلى في مجاميع الاسماك التي غذيت على العلائق المحتوية ٥-١٧ ملجم منجنيز/كجم عليقة عن المجموعة غير المعاملة.

لم يحدث تغير راجع لمستويات المنجنيز في الهيموجلوبين، الهيماتوكريت، الجلوكوز، الكرياتينين ومستويات حمض اليوريك. كذلك نشاط انزيمات AST, ALT كان تأثيرها غير معنوي لاضافة المنجنيز في العليقة. وكان هناك ارتباط ايجابي لتركيز المنجنيز في البلازما ومستويات المنجنيز في العليقة. ولم يكن هناك تداخل معنوي للمنجنيز بالعليقة مع تركيزات الصوديوم، البوتاسيوم، الماغنسيوم، الزنك و النحاس في البلازما.