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Effect of dietary nickel concentrations on the growth and feed conversion efficiency of fish

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Abstract
During this investigation, the growth performance (wet weight and length) of three fish types was studied under the sub-lethal nickel (Ni^{2+}) concentrations of 70.40g, 71.99g and 79.11g for *Catla catla*, *Labeo rohita* and *Cirrhina mrigala*, respectively. The increase in fish weight was monitored in glass aquaria for eight weeks. During these metal-stress trials, fish were kept under constant temperature (30 °C), pH (7.0) and total hardness (200 $mg \cdot L^{-1}$). Physio-chemical variables, e.g. dissolved O_2, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_2, total NH_3 and electrical conductivity of the test mediums used for each growth trial were recorded on a daily basis. An increase/decrease in wet weight, fork and total length of fish were monitored on the Fortifying basis for eight weeks of growth trial. Statistical analysis of the research data showed significant effects of metal stress on wet weights. Among the three treated fish species, *Catla catla* gained significantly maximum weight of 18.28 ± 0.95g, followed by *Labeo rohita* (16.18 ± 0.89) and *Cirrhina mrigala* (15.25 ± 1.15g). Fork and total length increments were observed significantly higher in *Catla catla*, followed by *Labeo rohita* and *Cirrhina mrigala*. However, under the exposure of nickel, all the fish species showed considerably lower weights than the control fish. It was concluded that sub-lethal metal (nickel) exposure to the fish significantly affected the growth performance (weights, fork and total length gains) and feed conversion ratios (FCR) of all the three fish species.

Keywords: Fish health, metal toxicity, nickel, growth and feed conversion

Introduction
Aquatic sources play a vital role in the production of animal proteins in the form of fish and other kinds of seafood to fulfil the food requirement of the progressively increasing population of a country. For fish culture, there is less amount of energy required as compared to other farm animals. Feed conversion ratio (FCR) of fish is at least 1.5 times higher than feed conversion ratio of chicken and is much better than lamb or beef [19] because the use of healthy fish twice a week decreases the risk of heart attack (lower triglycerides) and stroke in human beings [2].

Freshwater bodies in the province of Punjab have been contaminated with a wide range of chemicals, including metals. The environmental conditions are not favorable for aquatic organisms due to the human influence that causes deleterious changes by loading chemicals in the aquatic systems [10].

Being an agricultural country, Pakistan mainly depends upon the water resources (rivers, streams, lakes and ponds) but the quality of water is deteriorating gradually due to untreated industrial wastes and city sewage which is entering into the natural freshwater [16]. Heavy metals (like Zn^{2+}, Pb^{2+}, Cd^{2+}, Ni^{2+} and Mn^{2+}) are present in these wastes that are not only affecting the fish but also causing adverse effects on the planktonic biota of receiving water bodies [16]. There are different sources of heavy metals (e.g. petrol, industrial effluents, and leaching of metal ions from the soil and acid rains) that affect the water quality and aquatic environment [22]. The high concentration of heavy metals creates problems for aquatic organisms and pushed us towards a polluted world [3].

Fish respond to the stress of heavy metals in the same way as other animals response [7]. However, the pollution of heavy metals in freshwater becomes a matter of concern over the last few decades [9, 26]. Water pollutants affect the aquatic organisms in many ways, as several changes in physiological activities, biochemical parameters of tissues and blood of fish occur due to the absorption of toxic metals [5] and these organisms can not escape from the adverse effects of contaminations [11, 21].

The heavy metals enter the fish bodies in three possible ways; through the body surface, gills or digestive tract and highly susceptible to the metals present in wastewater. Heavy metals influence the physiological functions, individual growth rate, blood, tissues, reproduction, feed conversion efficiency and cause mortality in fish [27]. Heavy metal toxicity decreases oxygen consumption by fish [24].

The aim of the present study was to assess the toxicity of polluted water with Nickel (Ni^{2+}) metal against three different fish species. Moreover, we had focused on the growth performance of these fish species under Ni^{2+}-polluted water.

Materials and methods

The experiment to study the "effect of dietary Ni^{2+} concentrations on the growth and feed conversion efficiency of fish" was conducted at Fisheries Research Farms, University of Agriculture, Faisalabad, Pakistan. The fish species (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) were obtained from the Fish Seed Hatchery, Faisalabad and kept under laboratory conditions in 500-liter cement tanks for two weeks for acclimation before the start of the experiment.

After two weeks of acclimation, all three fish species were transferred to the experimental aquaria, separately (70-liter water capacities). All glassware and aquaria used, in these experiments, were washed thoroughly with nitric acid and rinsed with distilled water before use. The glass aquaria were filled with 70-liter dechlorinated tap water. In each aquarium, constant air was supplied through capillary systems. Water temperature (30 °C), pH (7.0) and total hardness (200 mg L^{-1}) of the test media were kept constant. The quality parameters *viz*. water temperature, pH, total hardness, dissolved O_2, CO_2, Na^+, K^+, Ca^{2+}, Mg^{2+}, total NH_3 and electrical conductivity were monitored in water throughout test period daily.

The feed of the desired concentration of nickel was prepared using pure $NiCl_2$ (Fisher) to prepare diet pellets. Fish species in control aquariums were fed with normal feed (without metal). During the 60-day experimental period, the fish was fed daily (six days a week) to satiation at 09.00 and 17.00 with the following feed of digestible energy 2.90 $Kcal^{-1}$ (35 percent digestible protein).

According to the description of [14] the sub-lethal concentration of Ni^{2+} metal (1/3 of LC_{50}) used for these tests were 70.40, 71.99 and 79.9 mg L^{-1} for *C. catla*, *L. rohita* and *C. mrigala*, respectively. The growth trials for each fish species were performed with three replications. Before the experiment, the growth parameter (wet body weight, fork and total length) was measured and recorded.

For the maintenance of pH value of desired concentration of the tested medium, NaOH (for the increase of pH) and HCl (for the decrease of pH) were added. However, for the maintenance of the total hardness, the salts of $CaSO_4$ and $MgSO_4$ while ethylene ediaminete traacetic acid (EDTA) and its sodium salt were used to decrease the hardness of water.

At the end of the 60-day growth trial, the increase/decrease in fish wet weights and feed conversion ratio (FCR) were analyzed.

Statistical analysis

The entire data of metal toxicity as well as growth parameters were analyzed through One-Way ANOVA (analysis of variance) at CI of 95%. Moreover, the mean values of entire data were compared through LSD-test at 0.05% by SPSS software.

Results

The growth experiment of three fish species *viz*. *C. catla*, *L. rohita* and *C. mrigala* were conducted in glass aquarium for eight weeks under constant water temperature (32 °C), pH (7) and total hardness (250 mg L^{-1}). These three fish species fed with diets containing nickel concentration of 70.40, 71.99, 79.9 ug/g. While controlled fish did not receive Ni^{2+} from their diets. The growth performance of *C. catla*, *L. rohita* and *C. mrigala* had been observed daily and presented.

Average wet weight of fish species

Fish was exposed to various concentration of diet-borne Ni^{2+} to determine the growth of fish.

Catla catla

The initial wet weight of *Catla catla* was 18.28 ± 0.95 g. Increment in weight was obtained 1.79 in the sixth week of the whole the experimental period while minimum increment in weight was 0.92 in the first week of trial. Feed intake in all eight weeks fluctuated 0.14 g and 1.56 g during the first and fifth week, respectively. The FCR ratio of *Catla catla* was 1.90 during fifth-week minimum FCR was 0.29 during the sixth week of this experimental period. Whereas in controlled conditions, the initial and final average wet weights of *Catla catla* were 7.87 ± 0.96 g and 27.70 ± 1.21 g, respectively. Maximum and minimum increment in wet weights of *Catla catla* was 0.65 and 3.81, respectively. Highest feed intake and FCR of this fish were 2.87 and 1.02 in the eighth and seventh week, respectively.

Labeo rohita

The average initial wet weight of *Labeo rohita* was 6.61 ± 1.61 g while final wet weight was 16.18 ± 0.89. An average increase in wet weight was maximum of 1.87 in the fourth week. The average feed intake by this fish was 0.62 g and 1.91 g during the first and sixth weeks, respectively. The FCR were 1.17 and 1.56 in the first and sixth weeks of growth trial. Better weight increased in *L. rohita* than *C. catla* and *C. mrigala.* On the other hand, in a controlled environment, it was observed that the highest average wet weight was 27.08 ± 1.21 g in the eighth week. While FCR was maximum 1.00 during the first week and feed intake was 2.87 in 8th week in growth trial duration.

Cirrhina mrigala

Maximum weight was 1.79 gained in the eighth week of whole experimental duration while minimum 0.37 was achieved in the first week. Feed intake and FCR were increased 1.38 and 0.99 in the first and seventh week, respectively (Table 1). Likewise, this fish attained the initial average wet weight of 10.21 ± 1.09 g, and the final average wet weight was 37.78 ± 1.18 g in the controlled conditions. Maximum increment in wet weight was 4.81 g, during which FCR was 0.83 in 7th week while maximum feed intake was 2.87 in 8th week (Table 2).

Table 1: Diet ingredients of fish

Ingredients	Percentage (%)
Fish meal	40.00
Corn gluten (30% CP)	39.27
Rice polish	07.51
Wheat flour	05.00
Oil (Sunflower)	03.22
Vitamin and mineral mixture	05.00
Digestible protein (DP) = 35% Digestible energy (DE) = 2.90 KCal g^{-1}	Major profile (%)
	Lysine = 1.9365
	Methionine = 0.8205
	Ca^{2+} = 2.2659
	PO_4 = 1.2023
	Na^{+} = 0.3244

Table 2: Average increase in wet weights, feed intake and feed conversion ratios of three treated fish species

Metal concentration: 70.40 (mg L^{-1})					Metal concentration: 71.99 (mg L^{-1})				Metal concentration: 79.11 (mg L^{-1})			
Catla catla					*Labeo rohita*				*Cirrhina mrigala*			
Weeks	**Av. Weight (g)**	**Increase in weight (g)**	**Feed intake (g)**	**FCR**	**Av. Weight (g)**	**Increase in weight (g)**	**Feed intake (g)**	**FCR**	**Av. Weight (g)**	**Increase in weight (g)**	**Feed intake (g)**	**FCR**
Initial	7.91 ± 1.46	_	_	_	6.61 ± 1.61	_	_	_	6.17 ± 1.87	_	_	_
Week-1	8.83 ± 1.22	0.92	0.41	0.44	7.14 ± 0.12	0.53	0.62	1.17	6.54 ± 1.13	0.37	0.51	1.38
Week-2	9.94 ± 1.25	1.11	0.53	0.48	7.76 ± 0.36	0.62	0.63	1.20	7.10 ± 1.12	0.56	0.54	0.96
Week-3	11.2 ± 0.96	1.27	1.53	1.20	8.78 ± 0.45	1.20	0.64	0.63	8.21 ± 0.97	1.11	0.93	0.84
Week-4	12.56 ± 0.76	1.35	1.54	1.14	10.65 ± 0.49	1.87	0.61	0.33	9.33 ± 0.89	1.12	0.56	0.50
Week-5	13.98 ± 1.03	1.42	1.56	1.90	11.86 ± 0.78	1.21	0.65	0.54	10.48 ± 0.43	1.15	0.64	0.56
Week-6	15.77 ± 1.13	1.79	0.52	0.29	13.08 ± 1.03	1.22	1.91	1.56	11.80 ± 1.02	1.32	0.51	0.39
Week-7	16.81 ± 1.13	1.40	0.53	0.51	14.46 ± 0.95	1.38	0.59	0.43	13.46 ± 1.00	1.66	0.99	0.60
Week-8	18.28 ± 0.95	1.47	0.54	0.37	16.18 ± 0.89	1.72	0.56	0.32	15.25 ± 1.15	1.69	0.79	0.44
Mean ± SD	12.81 ± 3.65	1.29 ± 0.27	0.89 ± 0.53	0.79 ± 0.56	10.72 ± 3.40	1.19 ± 0.47	0.77 ± 0.45	0.75 ± 0.45	9.81 ± 3.18	1.13 ± 0.48	0.68 ± 0.13	0.70 ± 0.33

FCR = Feed Intake (g) ÷ Increase in weight (g)

Average fork and total length of fish

The table showed an average increase in the fork and total lengths of three fish species grown under a dietary nickel.

Catla catla

The average initial fork and total lengths of *Catla catla* were 87.90 ± 2.12 mm and 90.00 ± 4.10 mm while final fork and total lengths were 100.45 ± 1.27 mm and 101.37 ± 1.95 mm, respectively. During this experimental period, the highest fork and total length were 2.16 mm and 2.10 mm in the sixth week. The controlled *Catla catla* exhibited the maximum fork length 2.95 mm while total length 3.12 mm both in the eighth week.

Labeo rohita

The initial fork and total lengths of *L. rohita* were 74.20 ± 2.10 mm and 76.30 ± 4.16 mm, respectively while final fork and total lengths were 85.37 ± 1.97 mm and 86.37 ± 3.13 mm, respectively. Increment in fork length was 1.90 in the third and fourth weeks while the total length was also 1.90 mm in the fourth week. Conversely, the initial average total and fork lengths of *Labeo rohita* were 75.80 ± 4.29 mm and 77.80 ± 2.99 mm. While at the end of the trial, final average fork and total lengths were 96.10 ± 5.37 mm and 97.25 ± 5.47 mm, respectively. The maximum fork and total length were 4.16 mm and 4.00 mm in the last week.

Cirrhina mrigala

The initial fork length of this fish was 75.10 ± 2.16 mm, and the final fork length was 85.66 ± 1.65 mm. The maximum increase in fork length was 2.12 mm in the eighth week while initial of total length was 78.00 ± 4.16 mm, and the final was 86.35 ± 2.65 mm. The maximum increment was 1.90 mm in the seventh and eighth week during growth trial (Table 3). Instead of all, in the controlled conditions, the final average fork length was 111.26 ± 5.21 mm, and increment was 6.37 mm in the eighth week. While the final average total length of *Cirrhina mrigala* was 111.28 ± 5.31 mm and the highest total length was 4.56 mm in the eighth week during the growth trial period (Table 4).

Table 3: Average increase in wet weights, feed intake and feed conversion ratios of three control fish species

Weeks	Metal concentration: 70.40 (mg L^{-1})				Metal concentration: 71.99 (mg L^{-1})				Metal concentration: 79.11 (mg L^{-1})			
	Catla catla				*Labeo rohita*				*Cirrhina mrigala*			
	Av. Weight (g)	**Increase in weight (g)**	**Feed intake (g)**	**FCR**	**Av. Weight (g)**	**Increase in weight (g)**	**Feed intake (g)**	**FCR**	**Av. Weight (g)**	**Increase in weight (g)**	**Feed intake (g)**	**FCR**
Initial	6.78 ± 0.86	_	_	_	8.09 ± 0.83	_	_	_	10.15 ±1.85	_	_	_
Week-1	7.87 ± 0.96	0.65	0.65	0.87	8.13 ± 0.98	0.69	0.65	1.00	10.21 ±1.90	4.18	0.65	0.16
Week-2	8.72 ± 0.88	0.85	0.71	0.83	8.86 ± 1.09	0.73	0.71	0.97	14.41 ± 0.99	4.20	0.71	0.16
Week-3	10.83 ± 2.45	2.11	0.84	0.39	11.20 ± 0.99	2.34	0.84	0.35	18.73 ± 0.93	4.32	0.84	0.19

Week-4	14.65 ± 1.09	3.82	0.92	0.23	14.11 ± 0.91	2.91	0.93	0.31	22.63 ± 0.88	3.90	0.92	0.23
Week-5	18.56 ± 1.19	3.91	1.33	0.34	16.84 ± 0.79	2.73	1.33	0.48	26.34 ± 0.73	3.71	1.33	0.35
Week-6	21.46 ± 1.20	2.90	1.78	0.61	19.40 ± 0.73	2.56	1.78	0.69	29.97 ±1.19	3.63	1.78	0.49
Week-7	23.89 ± 1.25	2.43	2.50	1.02	23.12 ± 1.11	3.72	2.50	0.67	32.97 ± 1.26	3.00	2.50	0.83
Week-8	27.70 ±1.21	3.81	2.87	0.75	27.08 ± 1.21	3.96	2.87	0.72	37.78 ±1.18	4.81	2.87	0.59
Mean ± SD	16.71 ± 7.35		1.45 ± 0.85	0.63 ± 0.28	16.09 ± 6.81		1.45 ± 0.85	0.64 ± 0.25	24.13 ± 9.43		1.45 ± 0.85	0.37 ± 0.24

FCR = Feed Intake (g) ÷ Increase in weight (g)

Table 4: Average increase in fork and total lengths of three treated fish species during 8-week growth trial

Weeks	Metal concentration: 70.40 (mg L^{-1})				Metal concentration: 71.99 (mg L^{-1})				Metal concentration: 79.11 (mg L^{-1})			
	Catla catla				*Labeo rohita*				*Cirrhina mrigala*			
	Av. Fork length (mm)	Increase in fork length (mm)	Av. Total length (mm)	Increase in total length (mm)	Av. Fork length (mm)	Increase in fork length (mm)	Av. Total length (mm)	Increase in total length (mm)	Av. Fork length (mm)	Increase in fork length (mm)	Av. Total length (mm)	Increase in total length (mm)
Initial	87.90 ± 2.12	_	90.00 ± 4.10	_	74.20 ± 2.10	_	76.30 ± 4.16	_	75.10 ± 2.16	_	78.00 ± 4.16	_
Week-1	88.70 ± 2.06	0.80	90.60 ± 3.35	0.60	74.60 ± 2.08	0.40	76.56 ± 3.78	0.26	75.50 ± 2.00	0.40	78.20 ± 3.95	0.20
Week-2	89.90 ± 1.87	1.20	91.62 ± 3.63	1.02	75.35 ± 1.53	0.75	77.33 ± 3.82	0.77	75.98 ± 2.13	0.48	78.50 ± 4.12	0.30
Week-3	91.91 ± 1.87	2.01	93.42 ± 3.76	1.80	77.25 ± 1.03	1.90	79.13 ± 3.28	1.80	77.18 ± 2.11	1.20	78.90 ± 3.72	0.40
Week-4	93.74 ±1.97	1.83	95.22 ± 3.89	1.80	79.15 ± 1.75	1.90	81.30 ± 4.10	1.90	78.58 ± 1.92	1.40	80.15 ± 3.98	1.25
Week-5	95.14 ± 1.93	1.40	96.57 ± 2.51	1.35	80.35 ± 1.79	1.20	82.30 ± 2.92	1.00	80.00 ± 1.98	1.42	81.25 ± 2.54	1.10
Week-6	97.30 ± 1.97	2.16	98.67 ± 2.59	2.10	81.71 ± 1.28	1.36	83.25 ± 2.68	1.22	81.50 ± 2.23	1.50	82.55 ± 3.75	1.30
Week-7	98.45 ± 1.37	1.15	99.67 ± 3.25	1.00	83.48 ± 2.08	0.77	84.88 ± 3.26	1.63	83.50 ± 1.72	2.04	84.45 ± 2.68	1.90
Week-8	100.45 ± 1.27	2.00	101.37 ± 1.95	1.70	85.37 ± 1.97	1.89	86.37 ± 3.13	1.49	85.66 ± 1.65	2.12	86.35 ± 2.65	1.90
Mean ± SD	93.72 ± 4.46	1.56 ± 0.49	95.23 ± 4.12	1.42 ± 0.51	79.05 ± 4.00	1.39 ± 0.75	80.76 ± 3.67	1.25 ± 0.56	79.22 ± 3.73	1.32 ± 0.62	80.92 ± 2.98	1.04 ± 0.68

Discussion

The three fish species (*C. catla, L. rohita* and *C. mrigala*) were exposed to chronic sub-lethal levels of nickel (Ni^{2+}) concentration of 70.40, 71.99 and 79.9 mg L^{-1} during 60 days of growth trial. This experiment was related with the work of [8] who studied the effect of nickel stress at 10, 20, 30 and 40 mg L^{-1} concentrations on the fish (*Channa punctatus*) during 30 days of trial.

The properties on the fish growth were worked out by the wet weight gains measurement during sub-lethal effect of nickel exposure time. This exposure resulted in an increase in the average wet weight, fork and total lengths in *C. catla* than *L. rohita* and *C. mrigala*. The results were related to the findings of [6] as well as [1] studied on the growth response of fish species under the chronic exposure of Ni^{2+} and Mn^{2+}. During the stress of both Ni^{2+} and Mn^{2+}, *Labeo rohita* and *Cirrhina mrigala* exhibited a decrease in their weights. Similarly [23], worked on the growth of *Catla catla* under metal exposure (Fe^{+}) and resulted in an increase in body weight of fish [17]. worked on the four fish species (*Puntius sophore, Rasbora daniconius neilgerensis, Channa punctatus* and *Lebistes reticulates*) under the exposure of Ni^{2+} and Zn^{2+} concentrations from 29.88 to 54.95 and 13.57 to 48.83, respectively. The results showed that *Puntius sophore* was more sensitive to nickel than other species. Nickel metal changes the behavior of all fish species. Worked on yellow perch under metals environment exposure and found that metals showed a negative effect on growth performance of yellow perch. Among the control fish species, *Cirrhina mrigala* exhibited maximum average wet weights, fork and total lengths than other fish species. The growth of dietary exposed fish was significantly lower than the control fish. The results are in line with the findings of [15] who reported that control (without stress) *Cirrhina mrigala* had significantly higher weight increments than the fish exposed to waterborne metals [20]. reported that Cr^{3+}, Ni^{2+}, Mg^{2+} and Pb^{2+} exposures exerted adverse effects on the growth performance (reduction in weight) of fish, *Labeo umbratus*. The increased accumulation of metals in fish organs have resulted in the decreases of fish length also.

The feed intake and feed conversion ratios exhibited a significant difference between treated and control fish. The control fish had significantly higher feed intakes and FCR than that of treated fish. Feed intake and feed conversion ratios, during growth trial, were substantially better in *Labeo rohita* than that of *Catla catla* and *Cirrhina mrigala*. These results are in line with the findings of [4], who exposed *Cirrhina mrigala* to the sludge. The results showed that feed intake and growth performance of fish were affected significantly. [13] studied the toxicity of Cu^{2+} on Thicklip grey mullet (*Chelon labrosus* Risso) for ten weeks. They concluded that growth rate and feed intake was reduced underexposure of copper to the fish. [18] studied the effect of metals' mixture (Cd+Cr+Cu+Pb) on three cyprinids (*Catla catla, Labeo rohita* and *Cirrhina mrigala*), and they described that *Cirrhina mrigala* was most susceptible to the metals as compared to other species. The results showed that under the exposure of Ni^{2+}, length and weight of fish decreased. While working on *Oreochromis niloticus*, [12] reported that different sub-lethal waterborne copper concentrations caused a significant effect on feed consumption, weight increment, specific growth rate and feed conversion ratio.

Conclusion

Form the present studies it is concluded that all the concentration of nickel have bad impact on the growth of fish and cause in the weight reduction so the fish diet should be free form nickel ingredients.

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