Indian J. Fish., 61(2) : 73-81, 2014

Effect of dietary supplementation of chromium on growth and biochemical parameters of *Labeo rohita* (Hamilton) fingerlings

ABHAY KUMAR GIRI, NAROTTAM PRASAD SAHU, NEELAM SAHARAN AND GYANARANJAN DASH*

Aquaculture Division, Central Institute of Fisheries Education, Versova, Mumbai – 400 061, Maharashtra India

**Veraval Regional Centre of Central Marine Fisheries Research iInstitute, Veraval – 362 269, Gujarat, India*

e-mail: abhayaq.maa @gmail.com

ABSTRACT

A 60-day feeding experiment was conducted to evaluate the effect of dietary chromium on growth, feed efficiency and biochemical parameters of *Labeo rohita* fingerlings. Four isonitogenous (crude protein 35%) and isocaloric (415 k cal 100 g^{-1}) experimental feeds were prepared by supplementing different levels of dietary chromium picolinate *viz*., control (0.0 mg kg^{-1}), T1 (0.4 mg kg^{-1}), T2 (0.8 mg kg^{-1}) and T3 (1.2 mg kg^{-1}). Weight gain WG (%), specific growth rate (SGR), feed efficiency ratio (FER) and protein efficiency ratio (PER) and apparent net protein utilisation (ANPU %) were significantly improved ($p<0.05$) when chromium was supplemented at 0.8 mg kg^{-1} feed. The protein retention (PR %) value increased with the dose of chromium, showing the highest value in T2 group. Chromium supplementation significantly increased ($p<0.05$) liver glycogen in T1 and T2 groups but decrease was observed at high level of chromium supplementation in T3 group. Chromium supplementation significantly reduced ($p<0.05$) serum cholesterol and triglycerides in all the experimental groups compared to control showing the highest reduction in T2 group. The serum high density lipoproteins-cholesterol (HDL-C) was increased ($p<0.05$)in all experimental groups due to chromium supplementation and the highest blood HDL-C was observed in T2 group. However, no difference ($p<0.05$) in the serum low density lipoproteins-cholesterol (LDL-C) and phospholipid was observed in any of the experimental groups. Similarly, highest muscle protein as well as lowest liver AST and ALT were observed in T2 group. The results of the present study indicates that growth, feed utilisation and biochemical parameters in *Labeo rohita* can be significantly improved by feeding the fingerlings with chromium picolinate supplemented diet (0.8 mg kg^{-1}feed).

Keywords: Cholesterol, Chromium, Glycogen, Growth, *Labeo rohita*

Introduction

Chromium (Cr) is an important trace element which plays a vital role in animal physiology (Mertz, 1993). It regulates carbohydrate metabolism as a structural component of glucose tolerance factor (GTF) by potentiating the action of insulin (Rosebrough and Steele, 1981; Mertz, 1993) which increases the absorption of glucose from circulation into peripheral tissues (Anderson, 1987). This essential trace element is also involved in the metabolism of lipid, protein, and nucleic acid (Rosebrough and Steele, 1981; Okada *et al.* 1983; Ohba *et al.* 1986; Press *et al.* 1990; McCarty, 1991). Cr supplementation increases animal growth performance by enhancing energy metabolism (Jacques and Stewart, 1993). Organic forms of chromium have a higher bioavailability than the inorganic forms (NRC, 1997). Research on animal models confirmed that organic form of dietary chromium such as chromium picolinate (CrPic), chromium nicotinate (CrNic), and chromium-enriched yeast, is absorbed more efficiently, about 25-30 % more than inorganic forms like chromic chloride ($CrCl_3$) or chromic oxide (Cr_2O_3), which are poorly absorbed (1-3%) regardless of dose or dietary chromium status (Underwood, 1977; Mowat 1994; Olim *et al.,* 1994). Chromium picolinate, an organic and low-toxic form of trivalent chromium (Cr^{3+}), is an essential element for optimum carbohydrate, lipid, protein and nucleic acid metabolisms (McCarty, 1991; Mertz, 1993), as well as for activating certain enzymes and stabilsing proteins and nucleic acids (Anderson, 1987; Mertz, 1993).

The effect of chromium supplementation on growth performance of targeted animal is equivocal. Chromium has been reported to enhance carbohydrate metabolism in both turkeys (Rosebrough and Steele, 1981) and humans (Levine *et al.*, 1968). It has been reported that organic chromium supplementation to diets of rats (Gray and Bowman, 1992), mice (Morris *et al.,* 1995), chicken (Lien *et al,.* 1999) and feeder calves (Kegley *et al.,* 1997) had positive effects on glucose metabolism and insulin activity. It has been reported that dietary inorganic Cr supplements as Cr_2O_3 (Shiau and Liang, 1995; Shiau and Shy, 1998) and $CrCl_3$ (Shiau and Lin, 1993) can significantly improve growth and feed utilisation parameters in hybrid tilapia fed diets containing high levels of glucose. Similar results have also been obtained on the same species when organic Cr (*i.e.,* Cr-Nic or Cr-Pic) was supplemented to the diet rich in glucose content (Pan *et al.*, 2002a). The growth enhancement by chromium supplementation at certain dosages has also been reported by Tacon and Beveridge (1982) in trout and by Jain *et al.* (1994) in Indian major carp. In contrary, it has also been reported that Cr supplementation has no significant effect on weight gain in hybrid tilapia when fed as Cr-Pic (Pan *et al.*, 2003) or Cr-Nic (Pan *et al.*, 2002b). Similarly, no significant improvement was observed in growth performance of gilthead seabream (Gatta *et al.*, 2001) and rainbow trout (Bureau *et al.*, 1995; Selcuk *et al.*, 2010) when fed diet supplemented with Cr-yeast or Cr-Pic. Moreover, no significant effect on growth performance of Nile tilapia was observed by feeding Cr-Pic supplemented feed (El-Sayed *et al.*, 2010; Mehrim, 2012). The results of the previous experiments suggest chromium plays an important role in fatty acid metabolism and can alter the serum fatty acid profile (Evock-Clover *et al.,* 1993, Kitchalong *et al.*, 1995; Min *et al.,* 1997; Wang *et al.,* 2007, Zha *et al.,* 2007, Wang *et al.,* 2009). Kroliczewska *et al.* (2004) as well as Patil *et al.,* (2008) reported decrease in serum total cholesterol, LDL-C, triglycerides and increased serum HDL-C when broiler chickens were fed with diet supplemented with chromium picolinate. A similar decrease in the serum lipid profile has been reported in grass carp when fed diet supplemented with chromium picolinate (Liu *et al.*, 2010). The present study was conducted to assess the effect of dietary chromium on growth performance and other biochemical parameters to elucidate its role in lipid and protein metabolism in the Indian major carp, rohu (*Labeo rohita*).

Materials and methods

Experimental animals

Two hundred and seventy *Labeo* rohita fingerlings (13.59 ± 0.02 g) were procured from Hans Aquaculture, Raigad, Maharastra. The animals were acclimatised for 45 days prior to the experiment in a 3000 l capacity rectangular tank and fed on an isocaloric basal diet containing 35% crude protein to satiation. Continuous aeration was provided along with 50% replacement of water with fresh borewell water.

Preparation of experimental diets

Chromium piconilate was procured from Oceanic Laboratories (P) Ltd., Tarapur, Mumbai, India, and four isonitogenous (crude protein 35%) and isocaloric (415 k cal 100 g^{-1}) experimental feeds were prepared by supplementing different levels of dietary chromium picolinate *viz*., control (0.0 mg kg^{-1}), T1 (0.4 mg kg^{-1}), T2 (0.8 mg kg^{-1}) and T3 (1.2 mg kg^{-1}) (Table 1).

Table 1. Formulation and composition of the experimental diet

Ingredients (g 100 g^{-1})	Control	T2	T3	T4
Casein	31.0	31.0	31.0	31.0
Gelatin	12.0	12.0	12.0	12.0
Dextrin white	11.0	11.0	11.0	11.0
Starch soluble	27.0	27.0	27.0	27.0
Cellulose powder	8.50	8.50	8.50	8.50
Carboxy methyl cellulose	1.0	1.0	1.0	1.0
[1]Sunflower oil	4.0	4.0	4.0	4.0
[2]Cod liver oil	3.50	3.50	3.50	3.50
[3]Vitamin-mineral mix	1.92	1.92	1.92	1.92
Vitamin C	0.03	0.03	0.03	0.03
Betaine hydrochloride	0.03	0.03	0.03	0.03
Butylatedhydroxy toluene	0.02	0.02	0.02	0.02
Chromium piconilate (supplemented)	0.00	0.00004	0.00008	0.00012
Proximate composition (g 100 g^{-1})				
Moisture	8.02	7.99	7.87	7.93
Carbohydrate (%)	52.64	51.81	52.53	52.61
Crude protein (%)	34.77	35.47	35.23	34.77
Crude fat (%)	7.22	7.07	7.22	7.00
Ash (%)	5.37	5.65	5.02	5.62

[1]Sunflower oil, Nature Fresh, Cargill India Pvt. Ltd.: Saturated fatty acids - 10.1; MUFA - 45.4; PUFA - 40.1; Trans fatty acids -<0.5)

[2]Cod liver oil (Type B) BP, Universal medicare Pvt. Ltd., Mumbai

[3]vitamin mineral mix (EMIX PLUS) (quantity/2.5kg): Vitamin A: 55,00,000 IU; Vitamin D3: 11,00,000 IU; Vitamin B2:2,000 mg; Vitamin E: 750 mg; Vitamin K: 1,000 mg; Vitamin B6: 1,000 mg; Vitamin B12 : 6 mcg; Calcium pantothenate: 2,500 mg; Nicotinamide: 10 g; Choline chloride: 150 g; Mn: 27,000 mg; I: 1,000 mg; Fe: 7,500 mg; Zn: 5,000 mg; Cu: 2,000 mg; Co: 450 mg; Ca: 500 g; P: 300 g; L- lysine: 10 g; DLMethionine:10 g; Selenium: 50 ppm.

Experimental design

The experiment was conducted for a period of 60 days in the wet laboratory facility of Central Institute of Fisheireis Education (CIFE) Mumbai. One hundred and eighty advanced fingerlings of *L. rohita* (13.59 ± 0.02 g) were randomly distributed in four distinct experimental groups with three replicates following a completely randomised design (CRD). Twelve rectangular plastic tubs of uniform size (300 l capacity) were used as experimental units for all the experimental trials where each tub contained fifteen fishes. Feeding was done to satiation twice a day and continuous aeration was provided along with 25% replacement of water at every 24 h. The water quality parameters in all the experimental tanks were within the normal range throughout the experimental period (temperature - 26 - 28 ºC; dissolved oxygen - 6.5 to 7.0 mg l^{-1} and pH - 7.0 -7.5) .

Growth and feed efficiency parameters

The growth parameters of the experimental fishes were assessed by taking their body weight at 15 days interval. The animals were kept starved overnight before body weight measurement. The growth performance was assessed using the following formulae:

Weight gain (WG %)	=	[(Final weight gain-Initial weight gain)/ Initial weight gain] ×100
Specific growth rate (SGR %)	=	[(ln final weight - ln initial weight)/ Experimental period in days] × 100
Feed efficiency ratio (FER)	=	Net weight gain (wet weight)/ Feed given (dry weight)
Protein efficiency (PER)	=	Net weight gain (Wet weight)/Crude ratio protein fed
Apparent net protein utilization (ANPU)	=	[(Total final carcass protein-Total initial carcass protein)/ Protein fed] × 100
Protein retention (PR %)	=	(Gram protein gain/Gram protein fed) × 100

Biochemical analysis

After 60 days experimental period, fishes were collected from each tub and anaesthetised with clove oil (50 µl l^{-1}). Blood was withdrawn from the caudal vein using a syringe. For collection of serum, blood was withdrawn without the use of anticoagulant and allowed to clot for 2 h in slanting position till the serum separated out. This clotted blood sample was then centrifuged at 3500 rpm at 4 ºC and the serum was collected as supernatant and stored at -18 ºC until use. Serum protein was estimated by biuret method using commercial kit (Qualigen Diagnostics, India). Serum biochemical parameters such as cholesterol, triglycerides, high density lipoproteins-cholesterol (HDL-C), low density lipoproteins-cholesterol (LDL-C), and phospholipids, were quantified using respective colorimetric assay kits procured from Merck, Germany and the analysis was done in the Auto blood analyser, Spectra Junior (Merck, Germany).

Statistical analysis

Data on growth, feed utilisation and biochemical parameters among treatment groups were tested by one way analysis of variance (ANOVA) and the comparison of mean values were made by Tukey's HSD test. At significance level p<0.05. Statistical analysis was performed using the software program SAS version (2007).

Results

Growth and feed efficiency parameters

Significantly higher (p<0.05) body weight gain (WG %) and specific growth rate (SGR) were observed in T2 group (0.8 mg kg^{-1}) (Table 2). Similarly, FER, PER and ANPU % significantly improved (p<0.05) in T2 group, whereas no significant difference was observed among other treatment groups and control (Table 2). The PR % value increased with the dose of chromium, showing the highest value in T2 group which decreased as the chromium level increased above 0.8 mg kg^{-1} feed (T3).

Biochemical parameters

Chromium supplementation significantly increased (p<0.05) liver glycogen in T1, and T2 groups but significant decrease (p<0.05) was observed in T3 group when chromium supplementation increased above 0.8 mg kg^{-1} feed (Table 3). In the present study, chromium supplementation significantly reduced (p<0.05) serum cholesterol and triglycerides in all the experimental groups compared to control showing the lowest value in T2 group (Table 3). The serum HDL-C increased (p<0.05) in all experimental groups due to chromium supplementation and the highest blood HDL-C was observed in T2 group. No significant difference in the serum LDL-C and phospholipid was observed in any of the experimental group. Similarly, highest muscle protein as well as lowest liver AST and ALT were observed in T2 group.

Discussion

In the present study, dietary supplementation of chromium piconilate (0.8 mg kg^{-1} feed) significantly improved the WG, SGR, FER, PER, ANPU and PR of rohu fingerlings. The present results are in agreement with the previous observations obtained by supplementing diet with chromium picolinate (Liu *et al.,* 2010) in grass carp, chromic oxides (Shiau and Chen, 1993; Shiau and Liang, 1995; Shiau and Shy, 1998) and chromium chloride (Shiau and Lin 1993) in hybrid tilapia diets. However,

Table 2. Growth parameters (% weight gain, SGR, FCR, PER, PR and ANPU of different experimental groups fed with different experimental diets (Mean ± SE)

Parameters	Control	T1	T2	T3
WG (%)	$114.76^a \pm 2.86$	$115.59^a \pm 12.49$	$175.15^b \pm 6.21$	$109.77^a \pm 5.61$
SGR	$1.27^a \pm 0.02$	$1.27^a \pm 0.10$	$1.69^b \pm 0.04$	$1.23^a \pm 0.05$
FER	$0.478^a \pm 0.01$	$0.482^a \pm 0.05$	$0.729^b \pm 0.03$	$0.457^a \pm 0.02$
PER	$1.36^a \pm 0.03$	$1.38^a \pm 0.15$	$2.08^b \pm 0.07$	$1.31^a \pm 0.06$
PR (%)	$27.24^a \pm 0.04$	$28.93^c \pm 0.07$	$32.03^d \pm 0.04$	$28.22^b \pm 0.16$
ANPU (%)	$18.68^a \pm 0.67$	$18.73^a \pm 0.50$	$21.76^b \pm 0.47$	$18.69^a \pm 0.49$

Values in the same row having same superscript are not significantly different ($p > 0.05$)

WG : Weight gain, SGR : Specific growth rate, FER: Feed efficiency ratio, PER : Protein efficiency ratio, PR: Protein retention, ANPU : Apparent net protein utilisation

Table 3. Biochemical parameters (Cholesterol, Triglycerides, HDL-C, LDL-C, Phospholipids, Insulin, GOT and GPT) of different experimental groups fed with different experimental diets (Mean ± SE)

Parameters	Control	T1	T2	T3
Liver glycogen (mg g^{-1})	$32.17^b \pm 0.14$	$35.57^c \pm 0.08$	$35.81^c \pm 0.07$	$30.26^a \pm 0.17$
Serum cholesterol (mg dl^{-1})	$91.33^c \pm 0.25$	$88.51^b \pm 0.28$	$81.06^a \pm 0.60$	$88.57^b \pm 0.17$
Serum triglycerides (mg dl^{-1})	$76.21^b \pm 0.34$	$70.33^a \pm 0.72$	$70.91^a \pm 0.48$	$70.98^a \pm 0.45$
Serum HDL-C (mg dl^{-1})	$42.25^a \pm 0.21$	$43.89^c \pm 0.11$	$46.90^d \pm 0.08$	$43.99^c \pm 0.10$
Serum LDL-C (mg dl^{-1})	$37.25^a \pm 4.69$	$36.92^a \pm 2.19$	$36.40^a \pm 5.89$	$43.27^a \pm 6.37$
Serum phospholipids (mg dl^{-1})	$162.55^a \pm 2.56$	$164.73^a \pm 4.76$	$164.27^a \pm 1.28$	$162.89^a \pm 5.71$
Muscle protein (mg g^{-1})	$20.45^a \pm 0.45$	$21.39^a \pm 0.82$	$28.95^b \pm 0.10$	$21.43^a \pm 1.38$
Liver AST (nM mg^{-1}protein min^{-1})	$26.26^b \pm 1.11$	$25.98^b \pm 2.21$	$18.99^a \pm 2.77$	$26.95^c \pm 1.12$
Liver ALT (nM mg^{-1}protein min^{-1})	$18.60^b \pm 2.46$	$18.19^b \pm 0.61$	$10.90^a \pm 0.49$	$29.32^c \pm 1.97$

Values in the same row having same superscript are not significantly different ($p>0.05$)

HDL-C : High density lipoprotein-cholesterol, LDL-C: Low density lipoprotein–cholesterol, AST : Glutamate oxaloacetate transaminase
ALT : Alanine amino transferase

the present results are not found to be in congruence with the earlier studies conducted with hybrid tilapia (Pan *et al.*, 2003, Pan *et al.*, 2002b), gilthead seabream (Gatta *et al.*, 2001), rainbow trout (Bureau *et al.*, 1995; Selcuk *et al.*, 2010), Nile tilapia (El-Sayed *et al.*, 2010; Mehrim, 2012), where no significant improvement in growth performance was noticed by Cr supplementation. The variation among the results obtained from different studies could be attributed to several factors such as the form of chromium used, carbohydrate source and level of diet, dose and duration of treatment as well as feeding behaviour of the target species used for the experiment. It has been proven that adequate levels of non-protein energy sources (carbohydrate and lipid) in the diet can minimise the catabolism of protein by their protein sparing property (Cho and Kaushik, 1990). Wilson (1994) reported that an adequate level of carbohydrates in fish diet reduces catabolism of protein and lipid for energy purposes and provides metabolic intermediates for the synthesis of other biologically important compounds. In the present study, the increase in growth performance may be due to the protein sparing action of carbohydrate resulted by the increased carbohydrate utilisation due to chromium piconilate supplementation. However, all the growth and feed efficiency parameters declined when the chromium piconilate supplementation were higher than 0.8 mg kg^{-1} feed, which indicated that high-chromium supplementation was intolerable to *L. rohita* leading to reduced growth rate.

Glycogen level in liver was found to be significantly higher in rohu fed with the diet containing low level of chromium (0.8 mg kg^{-1}). This is in agreement with the finding of Liu *et al.* (2010) where higher liver glycogen level was reported in grass carp fed with the diet containing low level of chromium. It has been reported that chromium supplementation increases liver glycogen levels as a result of increasing activity of the enzyme glycogen synthetase (Rosebrough and Steele, 1981). Chromium piconilate supplementation also increases the carbohydrate utilisation and the excess glucose is stored in the form of glycogen in liver and muscle. However, liver glycogen was significantly reduced when chromium level in the diet exceeded 0.8 mg kg^{-1}. This concurs with the observation in the freshwater field crab, *Barytelphusa guerini* (Sridevi *et al.,* 2000) and in *Anabas scandens* (Venugopal and Reddy, 1992) where liver and kidney glycogen contents were depleted by the higher level of chromium. Chromium at higher level induces release of adrenal catecholamines causing glycogenolysis (Sridevi *et al.,* 2000).

In the present study, chromium supplementation significantly reduced serum total cholesterol, triglycerides and increased serum HDL-C. This is in congruence with the findings of Kroliczewska *et al.* (2004) and Patil *et al.* (2008), who reported decrease in serum total cholesterol, LDL-C, triglycerides and increased serum HDL-C when broiler chickens were fed diet supplemented with chromium. The results of the previous experiments suggest that chromium plays an important role in fatty acid metabolism and can alter the serum fatty acid profile (Evock-Clover *et al.,*1993; Kitchalong *et al.*, 1995; Min *et al.,* 1997; Wang *et al.,* 2007; Zha *et al.,* 2007; Wang *et al.,* 2009). Cholesterol is an important biomolecule which is essential for the synthesis of cell membrane, bile salts and steroid hormones. It is synthesised predominantly in liver and transported by blood. However, excess cholesterol in blood has a negative impact as it can lead to arterial congestion and heart disease (Cabin *et al.,* 1982; Castelli *et al.,* 1988). The positive effect of chromium supplementation on lowering the serum cholesterol has been well documented (Page *et al.,* 1993; Kucukbay *et al.,* 2006; Jain *et al.*, 2007; Wang *et al.,* 2007; Liu *et al.,* 2010). Similarly, triglycerides are important form of storage fat which are stored mainly in the adipocytes and used during starvation. Like cholesterol, excess triglycerides in serum increase the chance of arterial congestion and heart disease (Menotti *et al.,* 1994, Miller *et al.,* 1999, Onat *et al.,* 2006). Chromium supplementation increases the biological activity of Insulin which decreases adipocyte lipolysis by reducing the activities of adenylate cylase and hormone-sensitive lipase (Lambert and Jacqumin, 1979). Insulin can also decrease triglycerides rich lipoprotein by increasing the lipoprotein lipase activity (Garfinkel *et al.*, 1976; Howard *et al.*, 1993) which in turn increases serum triglyceride clearance (lien *et al.,* 1999). The beneficial effect of chromium on lowering the serum triglycerides has been supported by previous studies (Jain *et al.,* 2007; Wang *et al.,* 2007). The HDL-C which is also known as good cholesterol plays a beneficial role in clearing and transporting the excess cholesterol back to the liver for its disposal and thus prevents arterial congestions and heart disease (Gordon *et al.,* 1977; Goldbourt *et al.,* 1979; Jacobs *et al.,* 1990). Insulin decreases the liver LDL receptor and thus decreases the serum LDL-C content with a concurrent increase in HDL-C (Brindley and Salter, 1991). Similar increase in serum HDL-C due to chromium supplementation has also been reported in previous studies (McCarty, 1991; Lien *et al.,* 1999; Zha *et al.,* 2007; Liu *et al.,* 2010)

Increase in muscle protein can be used as an indicator of enhanced protein synthesis. Chromium supplementation stimulates insulin activity, increases glucose utilisation and thus may indirectly plays a vital role in the protein-sparing mechanism. Insulin plays an important role in protein metabolism rather than carbohydrate metabolism in fish (Jobling, 1994). Insulin increases protein synthesis in muscle tissues (Jefferson *et al.*, 1980, Duguay and Mommsen, 1994; Davis *et al.,* 2002; Craig *et al.,* 2003). Insulin facilitates amino acid transport into the muscle cell (Tovar *et al.,* 1991, Bonadonna *et al.,* 1993), increases the ribosomal content of cell as well as their translation efficiency (Proud and Denton, 1997; Proud, 2006) and thus enhances protein anabolism in muscle cells. Moreover, insulin reduces proteolysis by downregulating cellular lysozyme activity (Jefferson *et al.,* 1974, Fulks *et al.,* 1975). This can be further correlated with reduced ALT and AST level in the liver tissue. ALT and AST are important transaminase in fish which plays important role in amino acid catabolism (Asadi *et al.,* 2006; Melo *et al.,* 2006). Fish fed with high protein diet usually show higher aminotransferase activity in liver which catabolise excess amino acid for energy purpose (Sa *et al.,* 2006) More over ALT and AST level also increases during stress to supply amino acid for gluconeogenesis (Chatterjee *et al.,* 2006; Tejpal *et al.,* 2008; Hoseini *et al.,* 2011). In the present study, lowest ALT and AST levels observed in T2 group is an indicator of reduced amino acid catabolism for energy purpose resulting in better somatic growth.

The results of the present study have clearly shown that the growth and feed utilisation parameters of *L. rohita* improved significantly ($p<0.05$) when the animals were fed with experimental diet supplemented with Cr-Pic at a level of 0.8 mg kg^{-1} feed. Chromium supplementation increased liver glycogen, muscle protein and reduced serum cholesterol, HDL-C, triglycerides as well as liver AST and ALT which shows its regulatory effect on biochemical parameters of fish. However, the present findings are based on the study at laboratory scale and further studies should be conducted at field level to test practical applicability at culture scale.

Acknowledgements

Authors are grateful to the Indian Council of Agricultural Research, New Delhi, India for the financial support and to the Central Institute of Fisheries Education, Mumbai, India for providing all the facilities required for the present study.

References

Anderson, R. 1987. Chromium. In: Mertz, M. (Ed.), *Trace elements in human and animal nutrition*, 5th edn., Academic Press Inc., San Diego, CA, p. 225-244.

Asadi, F., Masoudifard, M., Vajhi, A., Lee K., Pourkabir, M. and Khazraeini, P. 2006. Serum biochemical parameters of *Acipenser persicus*. *Fish*. *Physiol*. *Biochem*., 32: 43-47.

Bonadonna, R. C., Saccomani, M. P., Cobelli, C. and DeFronzo, R. A. 1993. Effect of insulin on system amino acid transport in human skeletal muscle. *J. Clin*. *Invest.,* 91(2): 514-521.

Brindley, D. N. and Salter, A. M. 1991. Hormonal regulation of the hepatic low density lipoprotein: relationship with the secretion of very low density lipoprotein. *J. Lipid Res*., 30: 349-360.

Bureau, D. P., Kirkland, J. B. and Cho, C. Y. 1995. The effects of dietary chromium supplementation on performance, carcass yield and blood glucose of rainbow trout *Oncorhynchus mykiss* fed two practical diets. *J. Anim. Sci*., 73: 194-194.

Cabin, H. S. and Roberts, W. C. 1982. Relation of serum total cholesterol and triglyceride levels to the amount and extent of coronary arterial narrowing by atherosclerotic plaque in coronary heart disease: quantitative analysis of 2,037 five mm segments of 160 major epicardial coronary arteries in 40 necropsy patients. *Am. J. Med*., 73: 227-234.

Castelli, W. P. 1988. Cholesterol and lipids in the risk of coronary artery disease: the Framingham heart study. *Can. J. Cardiol*., (*suppl A*): 5A-10A.

Chatterjee, N., Pal, A. K., Das, T., Manush, S. M., Sarma, K., Venkateshwarlu, G. and Mukherjee, S. C. 2006. Secondary stress response in Indian major carps *Labeo rohita* (Ham), *Catla catla* (Ham) and *Cirrhinus mrigala* (Ham) fry to increasing packing densities. *Aquacult*. *Res*., 37: 472-476.

Cho, C. Y. and Kaushik, S. J. 1990. Nutritional energetics in fish: energy and protein utilisation in rainbow trout (*Salmo gairdneri*). In: Bourne, G. H. (Ed.), *Aspects of food production, Consumption and energy values. World Rev. Nutr. Diet Karger Basel*, 61: 132-172.

Craig, S. S, Kevin, R. S, Maureen, L. B., Jill, M. S., and Nair, K. S. 2003. Effect of insulin on human skeletal muscle mitochondrial ATP production, protein synthesis, and mRNA transcripts. *PNAS,* 100 (13): 7996-8001

Davis, T. A., Fiorotto, M. L., Burrin, D. G., Reeds, P. J., Nguyen, H. V., Beckett, P. R., Vann, R. C. and O' Connor, P. M. 2002. Stimulation of protein synthesis by both insulin and amino acids is unique to skeletal muscle in neonatal pigs. *Am. J. Physiol. Endocrinol. Metab*., 282(4): E880-890.

Duguay, S. J. and Mommsen, T. P. 1994. Molecular aspects of pancreatic peptides. In: Hoar, W. S. and Randall, D. J. (Eds.). *Fish physiology*, vol. 13 San Diego: Academic Press, p. 225-271.

El-Sayed, E. H., Hassanein, E. I., Soliman, M. H. and El-Khatib, N. R. 2010. The effect of dietary chromium picolinate on growth performance, blood parameters and immune status in nile tilapia (*Oreochromis niloticus*). *Proceedings of the 3rd Global Fisheries and Aquaculture Research Conference*, November 29 - December 1, 2010, Foreign Agricultural Relations (FAR), Egypt, p: 51-63.

Evock-Clover, C. M., Polansky, M. M., Anderson, R. A. and Steele, N. C. 1993. Dietary chromium supplementation with or without somatotropin treatment alters serum hormones and metabolites in growing pigs without affecting growth performance. *J . Nutr*., 123: 1504.

Fulks, R. M., Li, J. B. and Goldberg, A. L. 1975. Effects of insulin, glucose, and amino acids on protein turnover in rat diaphragm. *J. Biol. Chem*., 250(1): 290-298.

Garfinkel,, A. S., Nilsson Ehle, P. and Schotz, M. C. 1976. Regulation of lipoprotein lipase induction by insulin. *Biochem*. *Biophys*. *Acta*, 424: 264-269.

Gatta, P. P., Piva, A., Paolini, M., Testi, S., Bonaldo, A., Antelli, A. and Mordenti, A. 2001. Effects of dietary organic chromium on gilthead seabream (*Sparus aurata* L.) performances and liver microsomal metabolism. *Aquacult. Res*., 32: 60-69.

Goldbourt, U. R. I. and Medalie, J. H. 1979. High density lipoprotein cholesterol and incidence of coronary heart disease: the israeli ischemic heart disease study. *Am. J. Epidemiol*., 109 (3): 296-308.

Gordon, T., Castelli, W. P., Hjortland, M. C., Kannel, W. B. and Dawber, T. R. 1977. High density lipoprotein as a protective factor against coronary heart disease - The Framingham study. *Am J. Med.,* 62(5): 707-714.

Gray, W. E. and Bowman, T. D. 1992. Chromium picolinate increase membrane fluidity and rate of insulin internalization. *J. Inorg. Biochem.,* 46: 243-250.

Hoseini, S. M., Hosseini, S. A., Nodeh, A .J. 2011. Serum biochemical characteristics of beluga, *Huso huso* (L.), in response to blood sampling after clove powder solution exposure. *Fish Physiol. Biochem.*, 37: 567-572.

Howard, B. V., Schneiderman, N., Falkner, B., Haffner, S. M. and Laws, A. 1993. Insulin, health behaviors, and lipid metabolism. *Metabol*., 42: 25-35.

Jacobs, D. R. Jr., Mebane, I. L., Bangdiwala, S. I., Criqui, M. H. and Tyroler, H. A. 1990. High density lipoprotein cholesterol as a predictor of cardiovascular disease mortality in men and women: the follow-up study of the Lipid Research Clinics prevalence study. *Am. J. Epidemiol*., 131(1): 32-47.

Jacques, K. and Stewart, S. 1993. Does chromium have a future in feed? *J. Feed Tech. Market*, Vol. 44 (2).

Jain, K. K., Sinha, A., Srivastava, P. P. and Berendra, D. K. 1994. Chromium: an efficient growth enhancer in Indian major carp (*Labeo rohita*). *J. Aquacult. Trop*., 9: 49-54.

Jain, S. K., Rains, J. L. and Croad, J. L. 2007. Effect of chromium niacinate and chromium picolinate supplementation on lipid peroxidation, TNF-alpha, IL-6, CRP, glycated hemoglobin, triglycerides, and cholesterol levels in blood of streptosotocin-treated diabetic rats, *Free Radic. Biol. Med*., 43(8): 1124-1131

Jefferson, L. S. 1980. The role of insulin in the regulation of protein synthesis. *Diabetes*, 29: 487-496.

Jefferson, L. S., Rannels, D. E., Munger, B. L. and Morgan, H. E. 1974. Insulin in the regulation of protein turnover in heart and skeletal muscle. *Fed. Proc.,* 33: 1098-1104.

Jobling, M. 1994. Biotic factors and growth performance In: Jobling, M. (Ed.), *Fish bioenergetics*, Chapman Hall, London, p. 169-206.

Kegley, E. B., Spears, J. W. and Brown, T. T. Jr. 1997. Effect of shipping and chromium supplementation on performance, immune response, and disease resistance of steers. *J. Anim. Sci*., 75: 1956-1964.

Kitchalong, L., Fernandez, J. M., Bunting, L. D., Southern, L. L. and Bidner, T. D. 1995. Influence of chromium tripicolinate on glucose metabolism and nutrient partitioning in growing lambs. *J. Anim. Sci*., 73: 2694-2705.

Kroliczewska, B., Zawadzki, W., Dobrzanski, Z. and Kaczmarek-Oliwa, A. 2004. Changes in selected serum parameters of broiler chicken fed supplemental chromium. *J. Anim. Physiol. Anim. Nutr.* (Berl.), 88(11-12): 393-400.

Kucukbay, F. Z., Yazlak, H., Sahin, N. and Cakmak, M. N. 2006. Effect of dietary chromium picolinate supplementation on serum glucose, cholesterol and minerals of rainbow trout (*Oncorhynchus mykiss*) *Aquacult.Iint.*, 14: 259-266

Lambert, B. and Jacquemin, C. 1979. Inhibition of epinephrine induced lipolysis in isolated white adipocytes of aging rabbits by increased alpha-adrenergic responsiveness. *J. Lipid Res*., 20: 208-216.

Levine, R. A., Streeten, D. H. and Doisy, R. J. 1968. Effects of oral chromium supplementation on the glucose tolerance of elderly human subjects. *Metabol.,* 17: 114-125.

Li, X., Jiang, Y., Liu, W. and Ge, X. 2011. Protein-sparing effect of dietary lipid in practical diets for blunt snout bream (*Megalobrama amblycephala*) fingerlings: effects on digestive and metabolic responses. *Fish. Physiol. Biochem.,* DOI 10.1007/s10695-011-9533-9

Lien, T. F., Horng, Y. M. and Yang, K. H. 1999. Performance, serum characteristics, carcasss traits and lipid metabolism of broilers as affected by supplement of chromium picolinate. *Brit. Poul. Sci*., 40: 357-363.

Liu, T., Wen, H., Jiang, M., Yuan, D., Gao, P., Zhao, Y., Wu, F. and Liu, W. 2010. Effect of dietary chromium picolinate on growth performance and blood parameters in grass carp fingerling, *Ctenopharyngodon idella*. *Fish physiol. Biochem*., 36: 565-572.

McCarty, M. F. 1991. The case for supplemental chromium and a survey of clinical studies with chromium picolinate. *J. Appl. Nutr.,* 43: 58-66.

Mehrim, A. I. 2012. Effect of dietary chromium picolinate supplementation on growth performance, carcass composition and organs indices of Nile tilapia (*Oreochromis niloticus* L.) Fingerlings. *J. Fish. Aqua. Sci.* 7: 224-232.

Melo, J. F. B., Lundstedt, L. M., Meton, I., Baanante, I. V. and Moraes, G. 2006. Effects of dietary levels of protein on nitrogenous metabolism of *Rhamdia quelen* (Teleostei: Pimelodidae). *Comp. Biochem. Physiol.*, 145A: 181-187.

Menotti, A., Scanga, M. and Morisi,, G. 1994. Serum triglycerides in the prediction of coronary artery disease (an Italian experience). *Am. J. Cardiol.*, 73: 29-32.

Mertz, W. 1993. Chromium in human nutrition: a review. *J. Nutr.*, 123: 626-633.

Miller, M. 1999. The epidemiology of triglyceride as a coronary artery disease risk factor. *Clin. Cardiol.*, 22 (suppl II): 1-6.

Min, J. K., Kim, W. Y., Chae, B. J., Chung, I. B., Shin, I. S., Choi, Y. J. and Han, I. K. 1997. Effects of chromium picolinate (CrP) on growth performance, carcass characteristics and serum traits in growing–finishing pigs. *J. Anim Sci.*, 10: 8-14.

Morris, G. S., Guidry, K. A., Hegsted, M. and Hasten, D. L. 1995. Effects of dietary chromium supplementation on cardiac mass, metabolic enzymes and contractile proteins. *Nutr. Res.*, 15: 1045-1052.

Mowat, D. N. 1994. Organic chromium, a new supplemental nutrient for stressed animals. In: Lyons, T. P., Jacques, K. A. (Eds.), *Biotechnology in the feed industry*. Nottingham University Press, Nottingham, UK, p. 275-282.

NRC 1997. *The role of chromium in animal nutrition*. National Academy Press, Washington, D. C.

Ohba, H., Suketa, Y. and Okada, S. 1986. Enhancement of *in vitro* ribonucleic acid synthesis on chromium (III)-bound chromatin. *J. Inorg. Biochem.*, 27: 179.

Okada, S., Suzuki, M. and Ohba, H. 1983. Enhancement of ribonucleic acid synthesis on chromium (III) in mouse liver. *J. Inorg. Biochem.*, 19: 95-100.

Olin, K. L., Starnes, D. M., Amstrong, W. H. and Kearn, C. L. 1994. Comparative retention/absorption of ^{51}Cr from ^{51}Cr chloride, ^{51}Cr nicotinate and ^{51}Cr picolinate in a rat model. *Trace Elem. Electrol.*, 11: 182.

Onat, A., Sari, I., Yazici, M., Can, G., Hergenc, G. and Avci, G. S. 2006. Plasma triglycerides, an independent predictor of cardiovascular disease in men: a prospective study based on a population with prevalent metabolic syndrome. *Int. J. Cardiol.*, 108: 89-95.

Page, T. G., Southern, L. L., Ward, T. L. and Thompson, D. L. Jr. 1993. Effect of chromium picolinate on growth and serum and carcass traits of growing-finishing pigs. *J. Anim. Sci.,* 71: 656-662.

Pan, Q., Bi, Y. Z., Yan, X. L., Pu, Y. Y. and Zheng, C. 2002a. Effect of organic chromium on carbohydrate utilization in hybrid tilapia (*Oreochromis niloticus* x *O. aureus*). *Acta Hydrobiol. Sin.*, 26: 393-399.

Pan, Q. S., Liu, C. Zheng and Bi, Y. Z. 2002b. The effect of chromium nicotinic acid on growth, feed efficiency and tissue composition in hybrid tilapia (*Oreochromis niloticus* X *O. aureus*). *Acta Hydrobiol. Sin.*, 26: 197-200.

Pan, Q. S., Liu, Y. Tan and Bi, Y. 2003. The effect of chromium picolinate on growth and carbohydrate utilization in tilapia, *Oreochromis niloticus* and *Oreochromis aureus*. *Aquaculture*, 225: 421-429.

Patil, A., Palod, J., Singh, V. S. and Kumar, A. 2008. Effect of graded levels of chromium supplementation on certain serum biochemical parameters in broilers. *Indian J. Anim. Sci.*, 78(10): 1149-1152.

Press, R. I., Geller, J. and Evans, G. W. 1990. The effect of chromium picolinate on serum cholesterol and apolipoprotein fractions in human subjects. *West. J. Med.*, 152(1): 41-45.

Proud C. G. and Denton R. M. 1997. Molecular mechanisms for the control of translation by insulin. *Biochem. J.*, 328 (2): 329-341.

Proud, C. G. 2006. Regulation of protein synthesis by insulin. *Biochem. Soc. Trans.,* 34(2): 213-216.

Rosebrough, W. and Steele, N. C. 1981. Effect of supplemental dietary chromium or nicotic acid on carbohydrate metabolism during basal, starvation and refeeding periods in poultry. *Poult. Sci.*, 60: 407-411.

Sa, R., Pousao-Ferreira, P., Oliva-Teles, A. 2006. Effect of dietary protein and lipid levels on growth and feed utilization of white seabream (*Diplodus sargus*) juveniles. *Aquacult. Nutr.*, 12: 310-321.

Selcuk, Z., Tiril, S. U., Alagil, F. Belen, V., Salman, M., Cenesiz, S., Muglali, O. H. and Yagci, F. B. 2010. Effects of dietary L-carnitine and chromium picolinate supplementations on performance and some serum parameters in rainbow trout (*Oncorhynchus mykiss*). *Aquacult. Int.*, 18: 213-221.

Shiau, S. Y. and Chen, M. J. 1993. Carbohydrate utilisation by tilapia (*Oreochromis niloticus* x *Oreochromis aureus*) as influenced by different chromium sources. *J. Nutr*., 123: 1747-1753.

Shiau, S. Y. and Liang, H. S. 1995. Carbohydrate utilisation and digestibility by tilapia (*Oreochromis niloticus* x *O. aureus*) are affected by chromium oxide inclusion in the diet. *J. Nutr.*, 125: 976-982.

Shiau, S. Y. and Lin, S. F. 1993. Effects of supplementation of dietary chromium and vanadium on the utilisation of different carbohydrates in tilapia, (*Oreochromis niloticus* x *O. aureus*). *Aquaculture*, 110: 321-330.

Shiau, S. Y. and Shy, S. M. 1998. Dietary chromic oxide inclusion level required to maximize glucose utilization in hybrid tilapia (*Oreochromis niloticus* x *O. aureus*). *Aquaculture*, 161: 357-364.

Sridevi, B. and Reddy, L. N. 2000. Effect of trivalent and hexavalent chromium on carbohydrate metabolism of a freshwater field crab, *Barytelphusa guerini*. *Environ. Monit. Assess*., 61: 291-300.

Tacon, A. G .J. and Beveridge, M. M. 1982. Effects of dietary trivalent chromium on rainbow trout. *Nutr. Rep. Int*., 25: 49-56.

Tejpal, C. S., Pal, A. K., Sahu, N. P., Kumar, J. A., Muthappa, N. A., Sagar, V. and Rajan, M. G. 2008. Dietary supplementation of L-tryptophan mitigates crowding stress and augments the growth in *Cirrhinus mrigala* fingerlings. *Aquaculture*, 293: 272-277.

Tovar, A. R., Tews, J. K., Torres, N. and Harper, A. E. 1991. Neutral amino acid transport into rat skeletal muscle: competition, adaptive regulation, and effects of insulin. *Metabol*., 40(4): 410-419.

Underwood, E. J. 1977. Chromium. In: Underwood, E. J. (Ed), *Trace elements in human and animal nutrition,* 4th edn. Academic Press, New York, p. 258-270.

Venugopal, N. B. R. K. and Reddy, S. L. N. 1992. Nephrotoxic and hepatotoxic effects of hexavalent and trivalent chromium in a freshwater teleost *Anabas scandens*, biochemical and environmental changes. *Ecotoxicol. Environ. Safety*, 24: 287-293.

Wang, M. Q., He, Y. D. Lindeman, M. D. and Jiang, Z. G. 2009. Efficacy of Cr (III) supplementation on growth, carcass composition, blood metabolites and endocrine parameters in finishing pigs. *Asian-Aust. J. Anim. Sci*., 22(10): 1414-1419.

Wang, M .Q., Xu, Z. R., Zha, L. Y. and Lindemann, M. D. 2007. Effects of chromium nanocomposite supplementation on blood metabolites, endocrine parameters and immune traits in finishing pigs. *Anim. Feed. Sci. Technol*., 139(1-2): 69-80.

Wilson, R. P. 1994. Utilization of dietary carbohydrate by fish. *Aquaculture*, 124: 67-80.

Zha, L. Y., Wang, M. Q., Xu, Z. R. and Gu, L. Y. 2007. Efficacy of chromium (III) supplementation on growth, body composition, serum parameters, and tissue chromium in rats. *Biol. Trace. Elem. Res*., 119: 42-50.

Date of Receipt : 09-12-2013

Date of Acceptance : 21-11-2013