

EFFECT OF DIETARY EXCESSIVE CHROMIUM PICOLINATE ON GROWTH PERFORMANCE, NUTRIENT UTILIZABILITY AND SERUM TRAITS IN BROILER CHICKS

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Summary

An experiment was conducted to evaluate the effects of dietary excessive chromium picolinate on growth performance, nutrient utilizability and the content of serum cholesterol, HDL cholesterol, glucose, triglyceride and non-esterified fatty acid in broiler chicks. Experimental diets based on corn-soybean meal were supplemented at 0, 800, 1,600 and 2,400 ppb chromium in the form of chromium picolinate. Each treatment had six replicates of six female chicks each (average initial weight = 45.6 g). Experimental period lasted for six weeks.

Excessive supplementation of chromium as chromium picolinate had no effect on body weight gain, feed intake, feed conversion and nutrient utilizability of broiler chicks. Mortality was improved with a supplementation of chromium ($p < 0.05$). However, serum glucose decreased as chromium level increased ($p < 0.05$). Up to 2,400 ppb chromium as chromium picolinate, signs of toxicity were not noticed in this study.

(Key Words : Chromium Picolinate, Mortality, Serum Traits, Broiler Chicks, Growth Performance, Cholesterol)

Introduction

The nutritional status of chromium in poultry has been investigated by several researcher. Jensen et al. (1978) determined that chromium was biologically active in the laying hen, and Polansky et al. (1989) reported decreases in tissue chromium during turkey egg production. Hill and Matrone (1970) and Hafez and Kratzer (1976) reported that chromium reduced the toxicity of vanadium in growing chicks. While, Jensen and Maurice (1980), and Benabdeljelil and Jensen (1990) reported that chromium was not effective in reversing the adverse effects of vanadium on albumen by chromium (Steele and Rosebrough, 1979; Rosebrough and Steele, 1981). Chromium supplementation to turkeys (Anderson et al., 1989) showed that chromium concentrations of breast,

liver and kidney were linearly increased with increases in inorganic chromium dietary supplementation (25, 100 and 200 mg kg⁻¹, respectively).

However, chromium absorption is inversely related to dietary intake (Anderson and Kozlovsky, 1985); excessive chromium is not absorbed efficiently. Cr⁺³ or chromium in the trivalent form, is now recognized as an essential nutrient necessary for utilization of glucose in peripheral tissue, acting in conjunction with insulin. The biologically active form of chromium is called glucose tolerance factor (GTF). It is a small organic molecule that contains nicotinic acid, glycine, glutamic acid, cysteine and Ca, and chromium (Mertz, 1975). Its exact structure is not yet known. GTF form is approximately 50 times more active than inorganic Cr⁺³.

The long-term toxicity of Cr⁺⁴ is well known. It consist primarily of skin contact dermatitis and sores, irritation of the respiratory passages, ulceration and perforation of the nasal septum and lung cancer. Cr⁺³ had been reported to have no deleterious effects from its excessive intake. Cr⁺³ becomes toxic only at extremely high amounts acting as a gastric irritant rather than as a toxic element interfering with essential metabolism or biochemical pathway (Mertz, 1975).

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The purpose of this study was to evaluate the effects of feeding excessive chromium in the form of chromium picolinate on growth performance, nutrient utilizability and serum traits of broiler chicks.

Materials and Methods

1. Experimental design, animal and period

The experimental diets consisted of corn and soybean meal were supplemented at 0, 800, 1,600 and 2,400 ppb of chromium in the form of chromium picolinate. Each treatments had six replicates of six female chicks each.

Animal subjects were Arbor Acre broiler chicks produced by Han Il Breeding Farm. At one day of age, experimental animals with similar body weight were randomly allotted into pens and were fed experimental diets for six weeks. Chemical analysis of experimental diets and excreta samples were conducted at the Animal Nutrition Laboratory, Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University located in Suweon, Korea.

2. Experimental diets

Chicks were fed a commercial diet (CP: 23%, 3,200 kcal ME/kg) before feeding trial. For the starting period (1-3 weeks), birds were fed *ad libitum* a corn-soybean meal diets containing 23% crude protein, and supplemented at 0, 800, 1,600 and 2,400 ppb chromium, respectively. Experimental diets for the finishing period (4-6 weeks) were formulated to contain 20% crude protein, and supplemented at 0, 800, 1,600 and 2,400 ppb chromium, respectively. Chromium picolinate was produced by Prince Agri Products, Inc. (One Prince Plaza, Quincy, IL 62301, Lincensed under U.S. Patent No. 5,087,624). The formula and chemical composition of basal diets for the starting and finishing period are presented in table 1. All the nutrients were included to meet or exceed the requirement of National Research Council (NRC, 1984).

3. Methods of Experiment

1) Feeding trial

All the birds were raised in battery cages made of steel wire and housed in a room with 24 hours light and air ventilation. Experimental diets and drinking water were provided *ad libitum* during the entire experimental period of six weeks. Body weight and feed intake were recorded weekly. Body weight gain were calculated by the difference between the initial body weight and final body weight. Feed conversion was calculated by dividing the amount of feed consumed with the corresponding body

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE BASAL DIETS FOR TRIAL

Nutrient levels	Starter (1-3 weeks)	Finisher (4-6 weeks)
Ingredient (%)		
Corn, yellow	54.90	63.40
Soybean meal	27.30	22.80
Fish meal	5.00	3.50
Corn gluten meal	5.00	3.70
Tallow	5.00	3.90
Limestone	0.90	0.90
Salt	0.30	0.30
Vit.-min. mix. ¹	0.48	0.48
Tricalcium P.	1.00	0.95
Antibiotics	0.05 ²	0.05
Total	100.00	100.00
Chemical composition ²		
ME (kcal/kg)	3,200	3,200
Crude protein (%)	23.00	20.00
Lysine (%)	1.21	1.02
Methionine (%)	0.50	0.40
Calcium (%)	1.00	0.92
Avail. Phosphorus (%)	0.40	0.40

¹ Vit.-min. mixture contains followings in 1 kg: vitamin A, 10,000 IU; vitamin D₃, 1,500 IU; vitamin K₃, 5 mg; vitamin E, 15 mg; vitamin B₂, 8 mg; vitamin B₁₂, 0.008 mg; Ca-D-pantothenate, 8 mg; niacin, 25 mg; folic acid, 0.4 mg; biotin, 0.2 mg; choline, 500 mg; pyridoxine, 1 mg; B.H.T. 125 mg; Co, 0.85 mg; I, 1.29 mg; Zn, 100 mg; Mg, 110 mg; Cu, 8.75 mg; Se, 0.15 mg; Fe, 35 mg.

² Calculated values.

weight gain. During the feeding trial, deaths were counted to calculate mortality.

2) Metabolic trial

Three chicks were selected randomly for the metabolic trial and were caged in a cage individually. Experimental diets and water were fed *ad libitum*. After each bird was given four days of adaptation, excreta were collected four times a day for consecutive three days while avoiding contamination of foreign materials such as feed, feathers and scales. Excreta samples were pooled and dried in an air-forced drying oven at 60°C for 72 hours to gain constant dry weight. All the samples prepared in this way were ground with 1 mm mesh Wiley mill for chemical analysis.

3) Blood collection

Blood were collected into anticlotting agents treated

tubes from each bird selected from each pen by decapitation. Blood samples were centrifuged (Hanil, Korea) at 3,000 rpm for 20 minutes and their supernatants were collected and frozen at -20°C for the analysis of glucose, non-esterified fatty acid (NEFA), triglyceride (TG), total cholesterol and high density lipoprotein (HDL) cholesterol.

4) Chemical analysis

Approximate composition of experimental diets and excreta were analyzed according to the methods of AOAC (1990). Serum glucose, non-esterified fatty acid (NEFA), triglyceride (TG), total cholesterol, and high density lipoprotein (HDL) cholesterol were analyzed by kit (Asan Co., Korea). All samples were analyzed in a duplicate in a single assay to avoid inter-assay variation.

5) Statistical analysis

Statistical analysis for the present data was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model

(GLM) Procedure of SAS (1985) package program.

Results and Discussion

1. Growth performance

Table 2 summarized effects of dietary excessive chromium picolinate on body weight gain, feed intake and feed conversion during the entire experimental period (1-6 weeks). The highest body weight gain was observed in 1,600 ppb chromium supplemented group while the lowest body weight gain was noticed in 2,400 ppb chromium supplemented group. But there was no significant difference between treatments.

Feed intake was not affected by chromium supplementation. Chicks received the diet containing 1,600 ppb of chromium as chromium picolinate showed the highest feed intake. Feed conversion was not significantly different among treatments. Chicks fed a diet with 2,400 ppb of chromium showed the highest feed conversion.

TABLE 2. EFFECTS OF DIETARY EXCESSIVE CHROMIUM PICOLINATE ON THE PERFORMANCE OF BROILER CHICKS (1-6 WEEKS)

Treatment Cr ¹ (ppb)	Initial body weight (g/bird)	Final body weight (g/bird)	Body weight gain (g/bird)	Feed intake (g/bird)	Feed conversion	Mortality ³ (%)
0	45.6 ± 0.36 ²	1,969.7 ± 32.5	1,924.1 ± 32.4	3,657.1 ± 81.7	1.90 ± 0.02	8.3
800	45.8 ± 0.29	1,940.5 ± 28.4	1,894.6 ± 28.3	3,595.7 ± 72.0	1.90 ± 0.03	5.5
1600	45.5 ± 0.39	1,975.8 ± 27.5	1,930.3 ± 27.3	3,679.7 ± 74.5	1.91 ± 0.02	0.0
2400	45.5 ± 0.37	1,900.8 ± 10.5	1,855.3 ± 10.2	3,629.8 ± 51.1	1.96 ± 0.02	0.0

¹ Chromium was added at 0, 800, 1,600 and 2,400 ppb as chromium picolinate to each treatment.

² Values are mean ± SE; n = 6.

³ Calculated based on treatment unit.

Rats fed chromium, in the form of chromium nicotinic acid, up to 276 mg, exhibited no abnormalities after 20 weeks (Mertz and Roginiski, 1975; Mertz, 1975). No adverse effects were also observed in either mice or rats given an inorganic salts supplying 5 ppm chromium (III) in drinking water throughout their life (Schroeder et al., 1964; Schroeder et al., 1965).

Again, the results of this study indicated that excessive supply of chromium in the form of chromium picolinate would not adversely influence body weight gain, feed intake, or feed conversion of broiler chicks.

2. Mortality

Mortality over whole experimental period were shown in table 2. Mortality was reduced with increasing chromium level in the diet. The highest mortality was observed in groups fed the basal diet (8.3%), and the lowest mortality was noticed in groups fed 1,600 and 2,400 ppb of chromium.

Moonsie-Shageer and Mowat (1993) reported that supplemental chromium reduced morbidity of calves fed corn-silage diets, suggesting that chromium may be a limiting mineral in corn silage. Burton et al. (1993), using a periparturiant-lactation model, reported that both humoral and cell-mediated immunity of cattle was enhanced by Cr⁺³ (Cr⁺³-trinicotinate). Such studies should

be pertain to practical production problems as Cr^{+3} may act as an apparent immunomodulator.

3. Nutrient utilizability

TABLE 3. EFFECT OF DIETARY EXCESSIVE CHROMIUM PICOLINATE ON THE NUTRIENT UTILIZATION OF BROILER CHICKS (% 1-6 WEEKS)

Treatment Cr^1 (ppb)	Dry matter	Crude protein	Crude fat	Crude ash
Starting period (1-3 weeks)				
0	72.6 ± 0.78 ²	59.3 ± 1.24 ^{ab}	88.8 ± 0.39 ^c	26.3 ± 1.38 ^{bc}
800	72.9 ± 0.60	61.4 ± 0.99 ^a	89.7 ± 0.22 ^{bc}	23.1 ± 2.81 ^c
1600	73.5 ± 0.70	56.8 ± 1.61 ^{bc}	90.1 ± 1.61 ^b	30.6 ± 1.81 ^b
2400	73.0 ± 0.32	55.1 ± 1.26 ^c	91.8 ± 0.13 ^a	44.5 ± 2.33 ^a
Finishing period (4-6 weeks)				
0	78.4 ± 0.81 ^b	58.2 ± 2.67 ^{ab}	92.7 ± 1.08	41.6 ± 2.30 ^a
800	76.9 ± 0.34 ^b	53.9 ± 0.98 ^c	91.7 ± 0.31	36.5 ± 1.66 ^{ab}
1600	77.8 ± 0.91 ^b	59.9 ± 1.98 ^{ab}	91.3 ± 0.29	33.0 ± 2.77 ^{bc}
2400	84.0 ± 2.89 ^a	63.6 ± 2.05 ^a	92.8 ± 0.57	27.4 ± 2.22 ^c

¹ Chromium was added at 0, 800, 1,600 and 2,400 ppb as chromium picolinate to each treatment.

² Values are means ± SE; n=6.

^{ab,c} Means with different superscripts within the same column are significantly different ($p < 0.05$).

In starting period (1-3 weeks), the utilizability of dry matter showed no significance among treatments. Crude protein, crude fat and crude ash utilizability were affected by treatments ($p < 0.05$). Crude protein utilizability was significantly higher in 800 ppb chromium supplemented group than in other treatments. The highest crude fat utilizability was noticed in 2,400 ppb chromium supplemented group and the lowest was found in groups fed basal diet ($p < 0.05$). Crude ash utilizability was higher in groups fed either 1,600 or 2,400 ppb of chromium compared with those fed basal diet.

In finishing period (4-6 weeks), the utilizability of dry matter and crude protein were significantly different among treatments ($p < 0.05$). Dry matter and crude protein utilizability was significantly higher in groups fed 2,400 ppb chromium than in groups fed basal diet or other chromium levels. Crude fat utilizability was not affected by treatments. Utilizability of crude ash was decreased as chromium level increased ($p < 0.05$).

4. Total cholesterol and high density lipoprotein (HDL) cholesterol in serum

As shown in the figure 1, total cholesterol content in serum was significantly different among treatments ($p < 0.05$). Total cholesterol content in serum was the highest

The effects of dietary excessive chromium picolinate on the utilizability of the dry matter, crude protein, crude fat and crude ash are summarized in table 3.

in chicks fed basal diet and was the lowest in 800 ppb of chromium supplemented groups ($p < 0.05$).

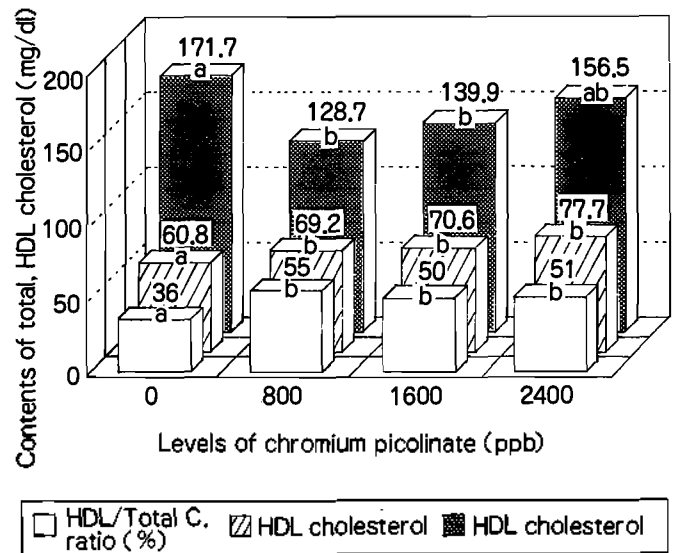


Figure 1. Effects of dietary excessive chromium picolinate levels on serum total cholesterol and HDL-cholesterol concentrations in broiler chicks.

HDL cholesterol content in serum was significantly higher in groups fed chromium supplemented diets than those fed control ($p < 0.05$). Serum HDL cholesterol concentrations tended to increase with increasing chromium level in the diet.

The HDL cholesterol/total cholesterol ratio was different among treatments ($p < 0.05$). The highest HDL cholesterol/total cholesterol ratio was found in groups fed 800 ppb chromium and was the lowest in groups fed basal diets.

The ability of chromium to reduce cholesterol was evident in our study, which agreed with other previous animal studies (Schroeder and Balassa, 1965; Riales and Albrink, 1981; Abraham et al., 1982; Mossop, 1983; Page et al., 1991).

In the study by Page et al. (1993), serum total cholesterol of pig was decreased by 6% when administered with 200 ppb chromium as chromium picolinate. Likewise, in case of human patients with slightly elevated serum cholesterol concentration, chromium picolinate administration led to a modest 6% reduction in total cholesterol and a significant increase in HDL cholesterol (Evans, 1989).

5. Glucose, triglyceride (TG) and non-esterified fatty acid (NEFA) in serum

As shown in table 4, glucose content in serum was significantly different among treatments ($p < 0.05$). Glucose content in serum was the lowest in groups fed 2,400 ppb of chromium ($p < 0.05$). Serum glucose concentration was reduced with increasing chromium picolinate in the diet.

TABLE 4. EFFECT OF DIETARY EXCESSIVE CHROMIUM PICOLINATE ON SERUM GLUCOSE, TRIGLYCERIDE, NEFA CONCENTRATIONS IN BROILER CHICKS

Treatment Cr ¹ (ppb)	glucose (mg/dl)	Triglyceride (mg/dl)	NFEA ² (μ Eq/l)
0	223.5 \pm 17.05 ^a	77.8 \pm 5.99 ³	762.6 \pm 11.6
800	211.1 \pm 3.98 ^a	71.4 \pm 10.41	819.2 \pm 33.2
1600	193.9 \pm 20.22 ^b	67.1 \pm 3.42	800.1 \pm 64.0
2400	175.9 \pm 2.52 ^c	65.2 \pm 11.47	767.7 \pm 24.0

¹ Chromium was added at 0, 800, 1,600 and 2,400 ppb in chromium picolinate to each treatment.

² Non-esterified fatty acid.

³ Values are means \pm Se; n=6.

^{a,b,c} Means with different superscripts within the same column are significantly different ($p < 0.05$).

Serum triglyceride and non-esterified fatty acid concentrations were not significantly different among treatments. However, several studies have shown that chromium supplementation resulted in decreasing serum triglyceride concentration (Riales and Albrink, 1981; Mossop, 1983). Page et al. (1991) reported, in their study with pigs, that serum triglyceride and glucose were not affected by chromium.

Further studies are required to further establish the relationship of blood lipid components and chromium although the responses to chromium differ from species to species.

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