Effects of Various Sources and Levels of Chromium on Performance of Broilers

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ABSTRACT : Three hundred and twenty four one day old mixed sex broiler chicks were assigned at random into 9 treatment groups. The experimental design was a 3×3 factorial arrangement. During the starter period (week 1-3), chicks were fed *ad libitum*. A corn-soybean meal based diet contained 23% crude protein, 3,200 kcal/kg metabolizable energy (NRC, 1994), and supplemented with organic or inorganic forms of chromium. Two organic chromium products, chromium yeast (Cr-Yeast from Alltech Biotechnology Corporation Limited) and chromium picolinate (Cr-Pic) were supplemented at the rate of 200, 400 and 800 ppb. One inorganic product, chromium chloride, was supplemented at the rate of 200, 400 and 800 ppb. During the finishing period (week 4-7), the corn-soybean meal based diet contained 20% crude protein, 3,200 kcal/kg metabolizable energy (NRC, 1994), and the same levels of chromium as in the starter period were added. No significant difference was observed among treatment groups in average daily gain, feed intake, body weight gain, feed conversion ratio and mortality. The carcass percentage of broilers receiving 200 and 400 ppb organic chromium (Cr-Yeast or Cr-Pic) was significantly increased ($p<0.01$). In addition, the supplementation of organic chromium reduced ($p<0.05$) breast meat fat content but increased breast meat protein content. The addition of chromium in the diet had no effect on boneless breast, skinless boneless breast, boneless leg, skinless boneless leg but reduced percentage of sirloin muscle. Total cholesterol and triglycerides were reduced by organic Cr supplementation. Supplementation with 200 and 400 ppb of both Cr-Yeast and Cr-Pic showed the lowest total cholesterol. The effects of type of Cr on HDL and LDL were variable, however, LDL increased with increasing level of Cr supplementation. This trial indicates that organic chromium tended to improve growth performances and carcass composition, reduced total cholesterol and triglycerides. The optimum level of organic chromium supplementation was at 200 ppb. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 11 : 1628-1633)***

Key Words : Organic Chromium, Chromium Yeast, Chromium Picolinate, Broiler

INTRODUCTION

As the requirement to produce poultry more efficiently increases, new methods of improvement need to be sought outside of genetic and nutritional requirements. The use of natural additives has been considered for poultry feeds, such as the use of probiotics, enzymes, acidifiers, yeast culture and organic trace mineral. Chromium supplementation brings about a new interest in trace mineral nutrition, because it improves nutritional quality of poultry meat.

In recent years there has been considerable research interest in the utilization of organic chromium in animal feed. Beneficial effects of chromium in human health are well documented which include a role in maintenance of normal blood sugar and in cholesterol levels. Chromium (Cr) is an essential mineral due to its role as a cofactor in glucose tolerance factor, which potentiates insulin (Mertz, 1993). The hormone insulin regulates energy metabolism, muscle tissue deposition, fat metabolism and cholesterol utilization. Published research related to Cr supplementation of poultry diets is very limited, however, most of the studies prior to 1991 evaluated inorganic Cr effects on poultry. Steele and Rosenbrough (1979) conducted an experiment to determine if Cr^{+3} and/or nicotinic acid affected growth rate and feed efficiency of young turkey poults. The addition of 20 ppm trivalent Cr or 250 ppm nicotinic acid significantly improved weight gain compared to the unsupplemented corn soy bean meal basal diet over 14 day feeding trial. Ward et al. (1993) reported a tendency for 200 ppb Cr from Cr picolinate to increase protein percentage and decrease fat percentage in carcasses of 3-week-old broiler chicks. Ward and Southern (1995), using 0, 400 and 1,600 ppb organic Cr in broiler diets between 1 and 49 days found a linear effect of Cr on feed conversion during the first 21 days and a quadratic effect on feed conversion and gain during the last 7 days. They concluded that dietary Cr from Cr picolinate affected growth and carcass composition of broilers. Hossain (1995) reported a reduction in breast meat fat content and mortality when broilers were supplemented with 400 ppb of Cr from Cr yeast. Hossain et al. (1997) also observed that the body weight of broilers at 3 and 6 weeks was significantly increased by the level of Cr in the diet. The highest body weight gain was observed with 300 ppb Cr from Cr yeast in the diet. Feed conversion was unaffected by dietary Cr throughout the trial. Kim et al. (1996) fed broilers with 6

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Table 1. Ingredient and calculated nutrient composition of basal diets (as-fed basis)

	Diet (%)	
	Grower (0-3 wk)	Finisher (4-7 wk)
Ingredient and composition		
Ground corn	42.20	46.30
Rice bran	3.50	5.00
Soybean oil	7.00	7.00
Soybean meal	33.60	33.40
Fish meal	10.00	5.00
Dicalcium phosphate	1.80	1.20
Ground oystershell	1.20	1.30
DL-methionine	0.20	0.10
Premix[1]	0.50	0.70
Composition by calculation		
Metabolizable energy (kcal/kg)	3,200	3,227
Crude protein (%)	23.39	21.00
Calcium (%)	1.12	0.95
Phosphorus (%)	0.45	0.35
Lysine (%)	1.36	1.21
Methionine+cystine (%)	0.96	0.80
Tryptophan (%)	0.32	0.30
Threonine (%)	0.85	0.80

[1] Premix (/100 kilogram diet): vitamin A, 40,000 IU; vitamin D_3, 25,000 IU; vitamin E, 3 g; vitamin C, 3.04 g; vitamin K_3 1.32 g; vitamin B_1 1.02 g; vitamin B_2 1.64 g; vitamin B_6 1.22 g; vitamin B_{12} 0.01 g; Ca pantothenate 6.02 g; folic acid 0.02 g; nicotinic acid 8.29 g; choline 10.46 g; Co 0.04 g; Cu 0.37 g; I 0.05 g; Mn 8.62 g; Mg 10.8 g; Zn 6.24 g; Fe 4.22 g; Ca 1.10 g; Na 38.95 g; Cl 67.10 g; K 7.8 g; Met 4.5 g.

different levels of Cr picolinate (0, 100, 200, 400, 600 and 800 ppb) for 6 weeks. They found that dietary addition of Cr did not affect growth performance and nutrient utilization. However, mortality appeared to be reduced with addition of Cr to the diet. Moreover, Cr supplementation significantly decreased serum cholesterol and increased serum HDL cholesterol. They also concluded that chicks fed diets containing 200 or 400 ppb Cr showed the highest protein content and the lowest fat content in their carcass. Recent findings on the positive effects of chromium supplementation for pig on carcass leanness and on reproductive parameters have been impressive (Lindemann et al., 1995). Similar results were also reported in pigs (Page et al., 1993; Harper et al., 1995; Mooney and Cromwell, 1995; Savoini et al., 1996). The NRC (1994) did not specify any recommendation for Cr in poultry diets, which are basically composed of ingredients of plant origin containing small amounts of Cr (Giri et al., 1990). Broilers reared in high environmental temperatures on corn-soybean meal diets probably have a moderate Cr deficiency. For better performance and carcass quality, broiler diets should be supplemented with bioavailable forms of Cr. The purpose of this study is to determine the effect of various sources of chromium supplementation on broiler performance, carcass quality and dry matter, protein and fat retention.

MATERIALS AND METHODS

Experimental design

A total of 324 one day-old mixed sex Arbor Acre broiler chicks were randomly assigned into 9 treatment groups, (6 replicates/treatment and 6 chicks/replicate). The experiment was a 3×3 factorial design, with the first factor as the types of chromium ($CrCl_3$, Cr-yeast and Cr-picolinate) and the second factor as the levels of chromium addition in the feed (200, 400 and 800 ppb). Broiler chicks were housed in wire cages during 7 weeks of feeding trial.

Experimental diets

During the starter period (week 1-3), chicks were fed *ad libitum* a corn-soybean meal based diet containing 23% crude protein, 3,200 kcal/kg metabolizable energy (NRC, 1994), and supplemented with organic or inorganic forms of chromium. Two organic chromium products, chromium Yeast (Cr-Yeast from Alltech Biotechnology Corporation Limited) and chromium picolinate (Cr-Pic) were supplemented at the rate of 200, 400, 800 ppb. One inorganic product, chromium chloride, was supplemented at the rate of 200, 400, 800 ppb. During the finishing period (week 4-7), the corn-soybean meal based diets containing 20% crude protein, 3,200 kcal/kg metabolizable energy (NRC, 1994), and the same levels of chromium as in the starter period were added. The formula and chemical composition of basal diets of starting and finishing diets are presented in Table 1. The calculated nutrient composition is based on NRC recommendation (NRC, 1994).

Feeding trial

All the chicks were raised in cages made of steel wire and housed in a room with 24 h light and air ventilation. Broiler chicks were fed diets and water *ad libitum* during the entire experimental period. Body weight and feed intake were recorded weekly on group basis to calculate body weight gain and feed conversion ratio. During the feeding trial, dead chicks were counted to calculate the mortality rate.

Carcass analysis

Six chicks from each treatment were sacrificed and analyzed for carcass composition by AOAC (1990) methods.

Blood analysis

At 4 and 7 week of age, blood samples of 6 chicks from each treatment were drawn into tubes after decapitation and were centrifuged at 3,000 rpm for 20 minutes. Supernatants (serum) were poured into other sterile tubes for analysis of triglycerides, total cholesterol, high density lipoprotein (HDL), and low density lipoprotein (LDL).

Table 2. Effect of various sources and levels of chromium supplementation on average daily gain, average daily feed intake, body weight gain, feed conversion ratio, mortality during day 0 - day 21

Sources	Levels	ADG (g)	ADFI (g)	FCR	Mortality (%)
$CrCl_3$	200 ppb	24.2	39.4	1.63	2.78
	400 ppb	24.0	39.8	1.66	5.56
	800 ppb	25.2	40.1	1.59	0.00
Cr-yeast	200 ppb	25.3	39.7	1.57	5.56
	400 ppb	23.6	39.4	1.67	8.33
	800 ppb	25.2	40.3	1.60	5.56
Cr-picolinate	200 ppb	25.2	41.1	1.63	2.78
	400 ppb	22.3	40.6	1.82	5.56
	800 ppb	23.5	39.0	1.66	5.56
Cr-type		0.3695	0.7571	0.3811	0.3699
Cr-level		0.1425	0.9367	0.1863	0.4723
Type×level		0.7091	0.4379	0.9354	0.9056
SEM		1.82	5.66	0.12	4.50

ADG = Average daily gain; ADFI = Average daily feed intake; FCR = Feed conversion ratio; SEM = Standard error of the mean.

Table 3. Effect of various sources and levels of chromium supplementation on average daily gain, average daily feed intake, feed conversion ratio, mortality rate during day 0 - day 49

Sources	Levels	ADG (g)	ADFI (g)	FCR	Mortality (%)
$CrCl_3$	200 ppb	35.8	87.1	2.43	5.56
	400 ppb	37.3	87.8	2.35	8.33
	800 ppb	36.4	89.4	2.45	5.56
Cr-yeast	200 ppb	34.3	88.2	2.58	5.56
	400 ppb	34.5	87.7	2.54	8.33
	800 ppb	38.3	90.6	2.37	8.33
Cr-picolinate	200 ppb	36.0	90.4	2.51	2.78
	400 ppb	36.0	88.5	2.46	8.33
	800 ppb	36.0	90.1	2.50	5.56
Cr-type		0.7281	0.6425	0.7839	0.8150
Cr-level		0.3456	0.4524	0.4170	0.4461
Type×level		0.3712	0.9426	0.3459	0.9810
SEM		1.86	19.87	0.12	5.00

ADG = Average daily gain; ADFI = Average daily feed intake; BWG = Body weight gain; FCR = Feed conversion ratio.
SEM = Standard error of the mean.

Chemical analysis

A proximate composition of experimental diets and excreta were analyzed according to the methods by AOAC (1990). Moisture, fat and crude protein contents of breast meat were analyzed by proximate analysis (AOAC, 1997). Serum triglycerides, total cholesterol, HDL and LDL were analyzed by Reflectance method (Reflotron reflectance photometer) according to Boehringer Mannheim Diagnostics (1985).

Statistical analysis

All obtained data were subjected to analysis of variance (Steel and Torrie, 1986) using Statistical Analysis System (SAS, 1985).

RESULTS AND DISCUSSION

Growth performance

No significant difference was observed among treatments in terms of average daily gain (ADG), average daily feed intake (ADFI), feed conversion ratio (FCR) and mortality during the entire experimental periods (Tables 2 and 3). Ward et al. (1993) reported that dietary inclusion of chromium (0, 200, or 400 ppb as chromium picolinate; Cr-Pic) did not affect ADFI and FCR of growing broiler chicks. These reports are consistent with the present results. Comparable results were also reported by Kim et al. (1996) and Hossain et al. (1997). Kim et al. (1996) found that chromium supplementation from Cr-Pic (0, 200, 400, 800 ppb) did not affect body weight gain (BWG) and FCR but increased ADFI in broiler chicks. Hossain et al. (1997) reported an increase in BWG but no effect on FCR in broilers when 150 or 300 ppb Cr from Cr-Yeast was supplemented. In an earlier study, Rosebrough and Steele (1981) found that chromium from $CrCl_3 6H_2O$ supplementation of 3-week-old chicks increased BWG and ADFI.

Page et al. (1993b) reported either decreased growth performance or no effect of chromium supplementation in separate experiments. Lindemann et al. (1995) reported that

Table 4. Effect of various sources and levels of chromium supplementation on carcass composition

Sources	Levels	% MC	% Fat	% CP	% CC	BB	SBB	BL	SBL	SM
		------------- Breast meat ----------				------------------------ % of carcass weight ---------------				
$CrCl_3$	200 ppb	73.5	3.43	21.6	71.2	18.8	16.8	26.5	23.0	4.15
	400 ppb	72.6	3.44	22.0	71.5	18.8	16.3	26.4	23.1	4.00
	800 ppb	73.6	3.40	22.2	71.7	18.9	16.8	26.7	23.5	4.24
Cr-yeast	200 ppb	73.1	2.85	22.8	73.7	19.2	16.8	26.9	23.7	4.16
	400 ppb	73.1	2.98	22.6	72.9	18.6	16.5	26.2	22.5	4.14
	800 ppb	73.0	2.85	22.7	72.3	18.1	16.5	26.8	23.7	4.22
Cr-picolinate	200 ppb	73.3	2.82	22.3	73.4	19.4	16.9	27.0	23.7	4.09
	400 ppb	72.7	2.83	23.0	72.5	18.6	16.4	26.7	23.8	4.08
	800 ppb	73.1	3.03	22.7	71.7	18.7	16.5	25.8	22.6	3.84
Cr-type		0.8162	0.0001	0.0160	0.0132	0.4917	0.9656	0.6840	0.7315	0.0008
Cr-level		0.2119	0.0061	0.4382	0.2089	0.0387	0.2130	0.0857	0.2312	0.3920
Type×level		0.7007	0.0001	0.6919	0.4525	0.2858	0.9193	0.0172	0.0001	0.0005
SEM		0.58	0.03	0.49	0.87	0.13	0.38	0.34	0.35	0.08

MC = Moisture content; C = Crude protein; CC = Carcass composition; BB = Boneless breast; SBB = Skinless boneless breast.
BL = Boneless leg; SBL = Skinless boneless leg; SM = Sirloin muscle. SEM = Standard error of the mean.

250 and 500 ppb chromium as Cr-Pic tended to reduce ADFI without affecting ADG resulting in an increase in gain/feed ratio in pig. However, Evock-Clover et al. (1993) demonstrated no effect of Cr-Pic on ADG, ADFI, or gain/feed in growing pigs. Mooney and Cromwell (1995) observed that Cr-Pic increased ADG but did not affect ADFI or gain/feed in pigs.

Hossain et al. (1997) found that supplementation of 300, 400 ppb Cr from Cr-Yeast reduced mortality rate. Kim et al. (1996) also reported a reduction in mortality rate when Cr-Pic (0, 200, 400, 800 ppb) were supplemented.

Moisture content of breast meat was similar in all treatments. The carcass percentage of broilers receiving 200 and 400 ppb organic chromium, either as Cr-Yeast or Cr-Pic, was significantly increased ($p<0.01$; Table 4). The supplementation of organic chromium (both Cr-Yeast and Cr-Pic) reduced ($p<0.05$) breast meat fat content but increased breast meat protein content in the present study. Level of Cr supplementation had variable effect on fat content of breast meat. The addition of chromium in the diet had no effect on boneless breast, skinless boneless breast, boneless leg, skinless boneless leg but reduced percentage of sirloin muscle. However, organic chromium supplementation particularly at 400 and 800 ppb tended to reduce percentage of boneless breast. There were interactions between type and level of Cr supplementation on percentage of SBL and SM.

Other studies also found a reduction in carcass fat content and an increase in carcass protein content (Ward et al., 1993; Hossain et al., 1995; Kim et al., 1996). Ward et al. (1993) reported a tendency for 200 ppb Cr-Pic to increase carcass crude protein percentage and to decrease carcass fat percentage in 3 wk-old broiler chicks. Similarly, Hossain et al. (1995) found a reduction in breast meat fat content when 400 ppb Cr-Yeast was supplemented in the broiler diets. Kim et al. (1996) found higher carcass protein content and lower carcass fat content in 100, 200 and 400 ppb Cr-Pic supplemented groups than in the control group.

Two hundred ppb of organic chromium was regarded to be the optimum level in the diet to have favorable effects on muscling and fat of growing finishing pigs (Page et al., 1993). The results from the present study also showed an overall beneficial improvement at 200 ppb of organic chromium. However, the financial return when Cr needs to be added to the diet, should be taken into account.

It should be recognized that body composition can be altered by a proportional increase in net protein synthesis and/or by a reduction in lipogenesis. Kim et al. (1996) demonstrated a reduction in non-esterified fatty acid uptake by adipose tissues cultured with Cr-Pic, which means that lipogenesis was blocked while lipolysis was stimulated, compared with control, whereas glucose incorporation into adipose tissues cultured with Cr-Pic was increased, which means that protein synthesis was stimulated. The reduction in carcass fat may, therefore, result from fat synthesis inhibition, fat mobilization or a combination of the two.

Total cholesterol and triglycerides in blood were reduced by organic Cr supplementation at both day 21 and day 49. Supplementation with 200 and 400 ppb of both Cr-Yeast and Cr-Pic showed the lowest total cholesterol at both day 21 and day 49 (Tables 5 and 6). The effects of Cr sources on HDL and LDL were variable, however, LDL increased with increasing level of Cr supplementation.

Several studies have shown that chromium supplementation decreased total cholesterol and triglycerides, and increased HDL (Riales and Albrink, 1981; Mossop, 1983; Page et al., 1993; Lien et al., 1994; Kim et al., 1996). In monogastric animals, reduced serum cholesterol concentration by chromium supplementation was one of the most frequently reported responses in lipid metabolism (Mertz, 1993). Kim et al. (1996) reported that the total cholesterol content in serum was reduced and HDL

Table 5. Effect of various sources and levels of chromium supplementation on total cholesterol, high density lipoprotein, triglycerides, low density lipoprotein at day 21

Sources	Levels	TC	HDL	TG	LDL
$CrCl_3$	200 ppb	116.0	43.8	79.8	56.2
	400 ppb	118.8	50.5	88.5	50.7
	800 ppb	129.2	49.0	75.8	65.0
Cr-yeast	200 ppb	102.3	55.9	78.8	30.7
	400 ppb	104.8	46.0	79.1	43.0
	800 ppb	121.3	59.8	74.6	46.6
Cr-picolinate	200 ppb	103.8	52.8	76.5	35.8
	400 ppb	107.5	46.8	79.1	44.9
	800 ppb	115.8	48.1	73.0	53.2
Cr-type		0.0001	0.0001	0.0022	0.0001
Cr-level		0.0001	0.0011	0.0001	0.0001
Type×level		0.5459	0.0001	0.1092	0.0002
SEM		3.75	2.02	2.48	2.56

TC = Total cholesterol; HDL = High density lipoprotein; TG = Triglycerides; LDL = Low density lipoprotein; SEM = Standard error of the mean.

Table 6. Effect of various sources and levels of chromium supplementation on total cholesterol, high density lipoprotein, triglycerides, low density lipoprotein at day 49

Sources	Levels	TC	HDL	TG	LDL
$CrCl_3$	200 ppb	121.5	58.9	73.3	47.9
	400 ppb	124.8	62.4	76.6	47.1
	800 ppb	126.7	56.7	80.3	54.0
Cr-yeast	200 ppb	115.5	65.5	71.3	35.7
	400 ppb	117.2	48.5	72.9	54.1
	800 ppb	136.2	43.7	73.8	77.7
Cr-picolinate	200 ppb	112.2	57.2	71.4	40.7
	400 ppb	113.3	47.8	72.8	51.0
	800 ppb	127.3	59.9	77.5	51.9
Cr-type		0.0030	0.0001	0.0231	0.0001
Cr-level		0.0001	0.0001	0.0032	0.0001
Type×level		0.0062	0.0001	0.6874	0.0001
SEM		3.37	1.72	2.52	1.82

TC = Total cholesterol; HDL = High density lipoprotein; TG = Triglycerides; LDL = Low density lipoprotein; SEM = Standard error of the mean.

was increased in chicks fed diets with Cr-Pic. Page et al., (1993) found a reduction in total cholesterol and triglycerides by supplementing Cr-Pic.

The function of chromium is not yet clear. It has been postulated that chromium may facilitate the binding of insulin to membrane receptors and thereby increase the biological activity of insulin (Anderson et al., 1985; Anderson, 1986; Anderson et al., 1987; McCarty, 1991). Anderson et al. (1985) have proposed that chromium acts as a cofactor in initiating insulin action. Several investigations have shown that chromium interacts with glucose and/or lipid metabolism in pigs, poultry, turkeys, calves and humans (Anderson, 1986).

Glucose tolerance factor (GTF), of which chromium is an essential component, is indispensable for normal sugar, protein and metabolism. Furthermore, chromium favors the interactions between insulin and its specific receptors located in target organs such as muscles and fat tissue (Moorandian and Morley, 1987). This explains the enhanced trophic effect of GTF on insulin.

IMPLICATION

This research indicates that the supplementation of organic chromium tends to improve growth performance and carcass composition, decreases total cholesterol, triglycerides, low density lipoprotein and increases high-density lipoprotein. Organic chromium forms have the advantage over inorganic chromium. This study demonstrated that 200 ppb chromium was the optimum level when organic source was provided.

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