Effect of Chromium Picolinate on Growth Performance, Carcass Characteristics, Serum Metabolites and Metabolism of Lipid in Pigs

Gang Xi*, Zirong Xu[1], Si-hung Wu, Shijiang Chen[1]
Department of Animal Science, University of Minnesota, St. Paul 55108, USA

ABSTRACT : The study was conducted to evaluate the effects of chromium picolinate (CrP) on growth, carcass characteristics and serum metabolites in growing-finishing pigs. A total of 96 Landrace×Yorkshire×Duroc hybrid pigs, initial live weight about 38.12±00 kg, were randomly assigned to 2 groups (16 pigs per pen, 3 pens per group), each group had 48 pigs with an equal number of barrows and gilts. The pigs were fed the diet with or without 200 μg/kg Cr from CrP. The results indicated that the addition of 200 μg/kg CrP increased ADG by 3.58% and decreased feed conversion rate (FCR) by 3.00% compared to the control group. Pigs fed CrP had 7.58% ($p<0.05$) higher carcass lean percentage, 15.55% ($p<0.05$) larger longissimus muscle area (LMA) and 10.90% ($p<0.05$) lower back fat thickness, 15.17% ($p<0.05$) lower carcass fat percentage. In addition, the IGF-I level in serum was elevated by 79.20% ($p<0.05$), the Insulin and cortisol level decreased by 27.35% ($p<0.05$) and 34.58% ($p<0.05$) respectively with supplementation of CrP. Analysis of subcutaneous fat (10th rib) showed that the activity of hormone sensitive lipase (HSL) increased by 79.58% ($p<0.05$) and the activities of isocitrate dehydrogenase (ISD) and malate dehydrogenase (MDH) decreased significantly by 15.06% ($p<0.05$) and 54.53% ($p<0.05$) respectively in the 200 μg/kg CrP group. The concentration of RNA, RNA/DNA in LMA increased by 31.89% ($p<0.05$) and 5.41% ($p<0.05$) respectively with the addition of CrP. These results suggest that CrP reduced fat deposits by decreasing lipogenic enzyme activities and increasing HSL activity and may have promoted muscle anabolic metabolism through elevated IGF-I levels. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 2 : 258-262)*

Key Words : Chromium Picolinate, Growth Performance, Carcass Characteristics, Serum Metabolites, Growing Finishing Pigs

INTRODUCTION

Chromium (Cr) is known to be an essential mineral component of GTF (glucose tolerance factor) which regulates glucose metabolism. It has been shown that Cr plays an important role in carbohydrate, lipid, protein, and nucleic acid metabolism in animals (Amoikon et al., 1995). However, most grains and feedstuffs for animals are deficient in Cr (Giri, 1990; Mertz, 1969). The addition of Cr in feeds is a feasible way to meet the Cr requirement. In the past several years, some reports have shown that Chromium Picolinate (CrP) functions to increase the loin eye area and decrease backfat thickness, increase the rate of carcass lean and decrease the rate of fat deposition in pigs (Page et al., 1993; Boleman et al., 1995; Lindemann et al., 1995; Lindemann and Purser, 1997). In the same time, others reported that CrP had no effects (Mooney and Cromwell, 1995; Ward et al., 1995; Crow and Newcomb, 1997). No explanation for this inconsistency has been proposed. However, an obvious result drawn from these reports is that organically complexed Cr sources are seemly utilized more efficiently than inorganic Cr sources (Page et al., 1990; Page et al., 1993; Anderson and Kozlovsky, 1985). Thus, most research uses CrP as the Cr source.

The effects of CrP on the growth, carcass characteristics in pigs are not completely clear yet. More studies need to be done to further evaluate these effects. The objective of the present research was to investigate the effects of CrP on the growth performance, carcass characteristics, serum metabolites and fat metabolism in growing-finishing pigs. These studies could enable us to know more about the effects of CrP on carcass characteristics and fat metabolism in pigs. Furthermore, some of the mechanisms of CrP in pigs could be elucidated with these results.

MATERIALS AND METHODS

Experimental design

As shown in table 1, experimental diets were formulated to contain 0, 200 μg/kg of chromium from CrP (Prince Agri. Products, Quincy, IL). A total of 96 cross bred pigs (Landrace×Yorkshire×Duroc), 48 barrow and gilt respectively, with similar initial body weight (38.12±00 kg) were used in this study. The animals were randomly alloted to 6 pens. Each treatment had 3 pens (replication), and each pen had 8 barrows and 8 gilts. The pigs had free access to diets and water during the experiment. Growing feeds were fed 42 days and finishing feeds were fed 27 days. Body weight and feed intake were recorded biweekly to calculate daily weight gain and feed conversion.

* Corresponding Author: Gang Xi. Tel: +1-612-624-8752, Fax: +1-612-625-8171, E-mail: xixx0004@tc.umn.edu.
[1] College of Animal Science, Zhejiang University, Hangzhou 310029, P. R China.
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Laboratory analysis

The percentage of protein, calcium, phosphorus in feeds was determined by the methods of AOAC (1995). The level of lysine in feeds was analyzed by the method of acid hydrolysis (AOAC, 1995), and determined by amino acids auto-analyzer (KNAVER 320, Germany).

Upon termination of the feeding trial, 2 randomly selected pigs (1 barrow and 1 gilt) from each pen were slaughtered after a 24 hour fast and kept at freezing temperature for subsequent carcass evaluation. Carcass weight, dressing percentage, back fat thickness and loin eye area were measured for comparison by the method of Xiao et al. (1999).

Before the pigs were slaughtered, blood was drawn into glass tubes and kept in a 37℃ water bath for 2 hours, then the serum was collected and kept in a -30℃ freezer until analysis. Serum insulin, cortisol, and IGF-I concentration were measured with the RIA kits (Beijing North Immuological Institute, China; Incstar Co. Ltd, USA) in a beta-counter (Packard 8500, USA).

Longissimus muscle area (LMA) samples and subcutaneous adipose tissues were collected at 10th rib, and kept at -30℃. Before enzyme assays, the enzymes were extracted from tissues by the method of Lee and Kalffman (1974): a 0.5 g portion of the subcutaneous adipose tissue was homogenized in 5 ml of 0.15 M Kcl in 50 μM Tris-Hcl, pH 7.4 and centrifuged at 100,000×g for 1 hour. The supernatant was decanted and used for measuring isocitrate dehydrogenase (ISD) and malate dehydrogenase (MDH). The activity of ISD was measured by the method of Plaut (1962), and MDH activity by the method of Ochoa (1955). Hormone sensitive lipase (HSL) activity was measured by the method of Fredrikson et al. (1981). One unit of HSL activity is defined as 1 umol of fatty acid produced per minute at 37℃.

The total of DNA and RNA of the muscle samples were extracted by the TRIzol (Biotech., Co. Ltd. USA) method, and the concentrations were measured spectrophotometrically at 260, 320 nm.

Statistical analysis

A completely randomized design with two treatments was used. Data were analyzed by analysis of variance using the general linear model procedures of PC SAS (SAS, 1989). For all data, the model included treatment as main effect. Comparisons were considered significantly different if $p<0.05$.

Table 1. Ingredients and chemical composition of the basal diets

	Growing	Finishing
	%	
Ingredients:		
Corn, yellow	66.75	67.95
Soybean meal (44%)	20.00	15.00
Wheat bran	8.50	13.00
Fish meal	2.00	1.50
Limestone	1.00	1.20
Dicalcium phos.	1.10	0.90
Salt	0.30	0.25
Vit & Min-premix[1]	0.20	0.20
Antibiotics	0.15	-
Total	100.00	100.00
Composition[2] :		
ME (Kcal/kg)	3100	3140
Crude protein (%)	16.45	14.88
Ca (%)	0.76	0.72
P (%)	0.53	0.54
Lysine (%)	0.77	0.62

[1] Provided the following per kilogram of diets for growing and finishing pigs: vitamin A, 4,400, 3,300 IU; vitamin D_3 700, 525 IU; riboflavin, 3.5 mg, 2.6 mg; d-pantothenic acid, 14 mg, 10 mg; niacin, 18 mg, 14 mg; choline chloride, 440 mg, 330 mg; vitamin B_{12}, 18 μg, 14 μg; Zn, 100 mg, 100 mg; Fe, 50 mg, 50 mg; Cu, 5 mg, 5, mg; I, 0.8mg, 0.8 mg; and Se, 0.09 mg, 0.07 mg.

[2] Analytic values except ME.

RESULTS

The average daily gain (ADG) and average daily feed intake (ADFI) of the growing-finishing pigs were unaffected by the addition of 200 μg/kg CrP in the diet (table 2). Feed conversion rate (F/G) was decreased by 3.00% when 200 μg/kg CrP was added. The significant difference of F/G was detected at finishing phage (table 2). Dietary CrP supplementation increased the lean ratio of carcass and loin eye area of the pigs by 7.58% and 15.55%, respectively, and decreased carcass fat percentage, backfat thickness by 15.17% and 10.90%, respectively. Significant differences in dressing percentage were not detected between the two groups (table 3).

Table 4 shows that the RNA concentration in longissimus muscle increased by 31.89% with supplementation of CrP, but CrP had no affect on DNA concentration. As a result, the RNA/DNA ratio was increased by 5.41%. In the serum, the insulin and cortisol concentrations were decreased by 27.35% and 34.58% with addition of CrP, while IGF-I increased dramatically by 79.20% (table 5).

Analysis of enzyme activities indicated an effect of CrP on activities of MDH, ISD and HSL in subcutaneous adipose tissue. Figure 1 shows that the activities of MDH and ISD, which are the main enzymes of NADH synthesis pathway, decreased by

Table 2. Effects of CrP on growth performance, feed intake and feed conversion ratio in growing-finishing pigs (n=96)

	CrP (μ g/kg)		SE
	0	200	
	Growing phase (42 d)		
Initial weight (kg)	37.79	38.15	1.02
Final weight (kg)	65.97	67.07	0.62
ADG (kg)	0.671	0.689	0.021
ADFI (kg)	1.78	1.80	0.02
F/G	2.65	2.61	0.03
	Finishing phase (27 d)		
Initial weight (kg)	65.97	67.07	0.62
Final weight (kg)	87.98	90.09	2.51
ADG (kg)	0.815	0.853	0.045
ADFI (kg)	2.80	2.79	0.02
F/G	3.44[a]	3.27[b]	0.05
	Growing-finishing phase (69 d)		
Initial weight (kg)	37.79	38.15	1.02
Final weight (kg)	87.98	90.09	2.51
ADG (kg)	0.727	0.753	0.036
ADFI (kg)	2.18	2.19	0.06
F/G	3.00	2.91	0.04

[a,b] Means with different superscripts within rows differ ($p<0.05$).

Table 3. Effects of CrP on carcass characteristics in growing-finishing pigs (n=12)

	CrP (μ g/kg)		SE
	0	200	
Dressing percentage	75.85	76.76	1.15
Lean ratio (%)	65.70[a]	70.68[b]	1.36
Fat ratio (%)	15.03[a]	12.75[b]	0.91
Loin eye area (cm^2)	34.21[a]	39.53[b]	1.78
Backfat thickness (cm)	2.11[a]	1.88[b]	0.28

[a,b] Means with different superscripts within rows differ ($p<0.05$).

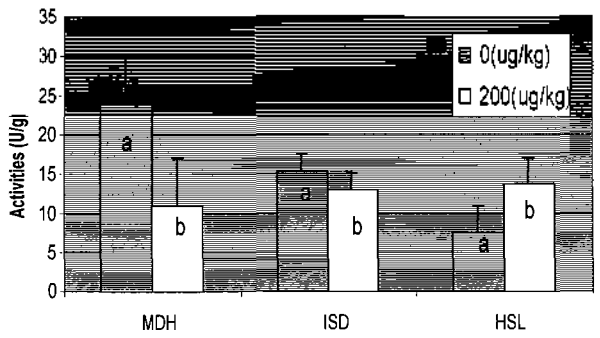

Figure 1. Effects of DrP on activities of MDH, ISD and HSL in subcutaneous fat (n=12)

Table 4. Effect of CrP on concentration of nucleic acid in longissimus muscle (n=12)

	CrP (μ g/kg)		SE
	0	200	
DNA (mg/g)	0.264	0.305	0.04
RNA (mg/g)	0.461[a]	0.608[b]	0.07
RNA/DNA	1.85[a]	1.95[b]	0.02

[a,b] Means with different superscripts within rows differ ($p<0.05$).

Table 5. Effect of CrP on hormone level in serum (n=12)

	CrP (μ g/kg)		SE
	0	200	
Insuline (μ l/ml)	5.96[a]	4.33[b]	0.57
IGF-I (nmol/L)	6.97[a]	12.49[b]	2.74
Cortisol (μ g/ml)	314.3[a]	205.6[b]	74.94

[a,b] Means with different superscripts within rows differ ($p<0.05$).

54.53% and 15.06% with the treatment of CrP. Meanwhile, the activity of HSL, which is responsible for the breakdown of stored lipids of adipose tissue, increased by 79.58%.

DISCUSSION

Previous experiments have demonstrated inconsistent results in the growth rate and feed:gain ratio in pigs fed diets supplemented with CrP. Page et al. (1993) first reported an increase in growth rate. However, an increase in growth rate was not observed in subsequent experiments, and no change in feed efficiency was detected either. Lindemann et al. (1995) observed no change in growth rates but found an improvement in the feed:gain ratio with the addition of Cr in the form of CrP. Harper et al. (1995), however, reported that supplementation of 200 μ g/kg of CrP increased body weight gain in the weanling pigs. Later, Amoikon et al. (1995) and Boleman et al. (1995) reported that CrP had no effect on either growth rate or feed efficiency in pigs. Two additional studies by Mooney and Crowell (1995, 1997) showed that 200 μ g/kg CrP increased ADG but did not change feed efficiency. In the present study, ADG increased by 3.58% ($p>0.05$) and feed:gain ratio decreased by 3.00% $p>0.05$) with the addition of 200 μ g/kg CrP. The significant difference of F/G was only detected at finishing phase. These results suggest that the effects of CrP on the growth performance of pigs vary greatly. Therefore, no definite conclusions can be drawn from these results at the moment.

In contrast, the effect of 200 μ g/kg of CrP on

LMA improvement appears to be more consistent. The increase of LMA in pigs fed a dietary supplementation of CrP was first reported by Page et al. (1993). In their experiment, LMA increased by 15.30%. Later, Mooney and Cromwell (1995, 1997), Lindemann et al. (1995) and Kornegay et al. (1997) obtained similar results. A few exceptions were reported, such as by Mooney and Cromwell (1999) who found that the supplementation of CrP in the diets of growing-finishing swine did not alter the carcass composition. Nevertheless, in our experiment, LMA was increased by 13.46% with the treatment of CrP, which supports most of the reported studies (Mooney and Cromwell, 1995, 1997; Lindemann et al., 1995; Kornegay et al., 1997).

In addition, we found the percentage of lean tissue in the carcass increased by 7.58%, which is consistent with the results of Boleman et al. (1995), Mooney and Cromwell (1997) and Min et al. (1997). The increase in protein accretion in CrP fed pigs may be attributed to several factors: one is the increase in glucose and amino acid uptake by muscle cells for protein synthesis mediated by the high sensitivity of insulin due to the presence of CrP (Mooney and Cromwell, 1995). Davis and Vincent (1997) suggested that Cr might activate insulin receptor tyrosine kinase activity in response to insulin. Another possibility is that Cr may affect the level of cortisol and IGF-I, resulting in an increase in protein accretion. The serum analysis in this study indicated that supplementation of CrP decreased the level of cortisol, the main hormone responsible for body catabolism, but it increased the level of IGF-I, which is a very effective anabolic growth factor. A study by Shageer and Mowat (1993) demonstrated that CrP decreased the cortisol level in serum, and the same result was obtained in growing steers by Chang and Mowat (1992). However, there have been no other reports of an increase in serum IGF-I levels when pigs fed supplemental CrP. The results of nucleic acid analysis of the longissimus muscle suggest a possible mechanism of action which would be consistent with a CrP-induced increase in the lean growth rate in the pig carcass. Okada et al. (1989) suggested that Cr could bind to nucleolar chromatin, resulting in significant stimulation of RNA synthesis, without any effects on DNA levels. The data obtained in this study support this postulate.

A decrease in backfat by CrP supplementation, as was observed by Page et al. (1993) and Lindemann et al. (1995), did not occur consistently in other studies. In studies by Mooney and Cromwell (1999) and Kornegay et al. (1997), a decrease in backfat was not detected. However, in this study, the 10th rib backfat decreased by 10.90% ($p<0.05$) and carcass fat percentage decreased by 15.17% ($p<0.05$). Thus, Kornegay et al. (1997) postulated that inconsistent effects of CrP on backfat thickness maybe explained by its effects on DM digestibility and N balance. In situations where N and energy intake are adequate and lean deposition is already maximized, improvements in digestibility will probably result in fatter carcass because the additional energy is not needed for lean deposition and then would be stored as fat. In other words, the effect of CrP on backfat thickness may be dependent on the relationship of nutrient adequacy of the diet and the response to Cr supplementation.

Up to now, few studies were reported about the effects of CrP on fat metabolism. An *in vitro* study, Choi et al. (1998) found that CrP supplementation increased the lipolytic activity in the adipose tissue of pigs, but had no effects on lipogenesis. In our study, HSL activity, which is a key enzyme responsible for lipolysis, increased by 80.29% in the subcutaneous adipose tissue of pigs fed CrP. However, we also found that the MDH and ISD activities, the key enzymes in the pathway of NADPH synthesis, were significant decreased by CrP in subcutaneous adipose tissue. The NADPH is an important coenzyme and proton donor in fatty acid biosynthesis. That is, it appears to have a strong positive relationship with lipogenesis in the carcass. Thus, CrP may decrease fat accretion through inhibiting lipogenesis, which is inconsistent with the result of Choi et al. (1998). More studies need to be done before the effects of CrP on fat metabolism in the animal body can be completely understood.

IMPLICATIONS

This research suggests that the dietary supplementation of 200 μg/kg chromium picolinate improves FCR at finishing phage and increases carcass lean percentage, LMA, decreases backfat thickness and carcass fat percentage in pigs. Meanwhile, IGF-I concentration in serum was increased but the insulin and cortisol levels were decreased by the addition of CrP. The change in RNA and RNA/DNA in longissimus muscle suggests that CrP may increase carcass lean percentage by enhancing protein synthesis. The enzyme activity analysis of 10th rib subcutaneous adipose tissue suggests that CrP decreases backfat and carcass fat percentage by the stimulation of lipolysis or the inhibition of lipogenesis in adipose tissue.

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