Effect of Chromium Nanoparticle on Growth Performance, Carcass Characteristics, Pork Quality and Tissue Chromium in Finishing Pigs

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ABSTRACT : The study was conducted to evaluate the effect of chromium nanoparticle (CrNano) on growth, carcass characteristics, pork quality, and tissue chromium in finishing pigs. A total of 100 Duroc×Landrace×Yorkshire barrows (average initial BW of 64.78±0.83 kg) were divided into 10 pens, 10 pigs per pen. 5 pens of pigs were fed with control diet (corn-soybean meal, 1.05% Lys) and others were fed with control diet addition with 200 μg/kg Chrome (Cr) from CrNano. During the trial, all pigs were given free access to feed and water. After 35 days trial, 10 pigs from each each treatment (weight similar to average group weight, 91.34±1.31 kg for control group, and 92.26±0.56 kg for CrNano treated group) were sacrificed to measure carcass characteristics, pork quality, and to collect the samples of longissimus muscle, liver, kidney and heart. The results indicated that the addition of 200 μg/kg CrNano decreased feed: gain ratio by 3.56% ($p<0.05$) compared to the control group. Pigs fed CrNano had 14.06% higher ($p<0.05$) carcass lean percentage, 19.96% ($p<0.05$) larger longissimus muscle area and 25.53% lower ($p<0.05$) carcass fat percentage, 18.22% lower ($p<0.05$) backfat thickness. Drip loss in chops from pigs fed CrNano was decreased by 21.48% ($p<0.05$) and weights of longissimus muscle and semimembranosus were increased by 16.33% ($p<0.05$) and 14.87% ($p<0.05$) respectively. In addition, supplemental CrNano resulted in 184.11% ($p<0.05$), 144.99% ($p<0.05$), 88.13% ($p<0.05$) and 52.60% ($p<0.05$) increment of Cr concentration in longissimus muscle, liver, kidney and heart, respectively. These results suggest that supplemental CrNano has beneficial effects on carcass characteristics, pork quality and individual skeletal muscle weight, increase tissue chromium concentration in selected muscle and organs. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 8 : 1118-1122)***

Key Words : Chromium, Nanoparticle, Pigs, Carcass Characteristics, Pork Quality

INTRODUCTION

Chromium (Cr) is a trace mineral that is widely distributed throughout the body. It is considered essential for maintenance of normal glucose tolerance (Schwartz and Mertz, 1959) by increasing insulin activity in animals and humans (Anderson, 1987). Steele et al. (1977) reported that a synthetic glucose tolerance factor containing Cr potentiated insulin activity in pigs and that this glucose tolerance factor was "biologically active" in pigs. Chromium also has been showed to be involved in protein synthesis and nucleic acid and lipid metabolism (Anderson, 1987).

There is no recommendation of Cr for swine (NRC, 1998), but most swine diets are primarily composed of ingredients from plant origin, which are usually low in Cr (Giri et al., 1990). A goal for meat producer is to increase lean meat and reduce fattening in food-producing animals. In pigs, Cr from chromium picolinate (CrPic) has been shown to increase longissimus muscle area and decrease fat thickness (Page et al., 1993; Lindemann et al., 1995; Gang Xi et al., 2001) and to increase the ratio of lean and decrease the ratio of fat deposition (Boleman et al., 1995). Mooney and Cromwell (1995), however, did not find 200 ppb Cr from CrPic to be effective in increasing absolute longissmus muscle area or decreasing backfat thickness. Mooney and Cromwell (1997) suggest that organically complexed chromium as CrPic or Cr nicotinic acid is more effective than inorganic chromium as chromium chloride in increasing the accretion of lean and protein and decreasing the accretion of fat tissue and lipid in growing-finishing pigs. The absorption and utilization of Cr may be dependent on its status in intestinal tract.

The factors controlling intestinal absorption of particles are now better known. Size, nature of the polymer, zeta potential and vehicle have been determined as critical factors influencing particle uptake (Florance, 1998). As a given nanomaterial, there is at least one dimension reduced to a nanometer size (1 nm=10^{-9} m). The associated new electrical, magnetic, mechanical and biological properties may then originate from three features, the reduced linear dimension, the high surface area and, eventually a reduced dimension in nanofilms, nanowires and nanoparticles, respectively. The new phenomena and properties of nanoparticle may bring unique potential application. Though there is few studies on mechanism of uptake of nanoparticles, Desai et al. (1997) reported that in some cell lines (e.g. Caco-2), nanoparticles showed relatively greater efficacy of uptake than microparticles. This objective of this

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Table 1. Composition and nutritive value of basal diets

Ingredients (%)	
Corn	64.0
Soybean meal	22.0
Rapeseed meal	4.0
Wheat bran	6.0
Limestone	1.2
Calcium phosphate	1.5
Salt	0.3
Mineral premix[1]	0.8
Vitamin premix[2]	0.2
Chemical composition (% as fed)[3]	
Digestible energy (kcal/kg)	3,145
Crude protein	17.20
Calcium	0.78
Phosphorus	0.60
Lysine	1.05
Methionine	0.45

[1] Contained per kg diet: Cu 10 mg; Zn 100 mg Fe 140 mg; Mn 40 mg; Se 0.1 mg; I 0.3 mg.
[2] Contained per kg diet: V-A 6,000 IU; V-D_3 700 IU; V-E 88 IU; V-K 4.4 mg; V-B_2 8.8 mg; D-pantothenic acid 24.2 mg; Niacin, 33 mg; Choline Chloride 330 mg.
[3] All of the data are analyzed values except digestive energy.

study was to assess the growth, carcass characteristics, pork quality and tissue chromium response of finishing pigs using chromium in nanometer scale.

MATERIALS AND METHODS

Experimental materials

Chromium Nanoparticle (CrNano, size 40-50 nanometer) was provided by Key Laboratory of Molecular Animal Nutrition, Ministry of Education, China. A total of 100 barrows (Duroc×Landrace×Yorkshire) with an average BW of 64.78±0.83 kg were selected from Haiyan Yixing breeding farm. The diet met or exceed NRC (1998) recommendations for nutrients except digestible energy and was analyzed to provide 17.20% CP, 0.78% calcium, 0.60% phosphorus, 1.05% lysine, 0.45% methionine and was calculated to provide digestible energy concentration of 3,145 kcal/kg. The composition of basal diets is shown in Table 1.

Experimental design

One hundred growing barrows were randomly assigned by weight to two dietary treatments and each treatment had five replicates with ten pigs per replicate. The pigs were penned in 3.25 m×5.25 m pens with floors that were concrete. Half of the pigs were fed with diets containing 200 μg/kg chromium from CrNano, the other half pigs were fed the diets without CrNano. Feed was provided *ad libitum* and water was provided by automatic waterers. The duration of the feeding trial was 35 days. ADG, average daily feed intake (ADFI) and feed: gain ratio were collected for all pigs throughout the experimented period.

Carcass measurement

Upon termination of the feeding trial, 10 pigs from each group were selected to determine the carcass composition. Pigs were stunned by electric shock and then killed by exsanguinations. At slaughter, the head, hair and viscera were removed from carcass and the right and left halves of the carcasses were separated. One half of the carcass was dissected by separating bone, muscle fat and skin. Each component was weighed respectively. Measurements of backfat depth and longissmus muscle area were made from carcass tracings taken at the 10th rib. The other half of the carcass was used to yield biceps femoris, quadriceps femoris, gluteus medius, semimembranosus, semitendinous and longissmus muscle, which were weighed separately. Carcass dressing percentage or yield was calculated by the following formula: hot carcass weight divided by final live weight×100.

Pork quality evaluation

Approximately 45 min after slaughter, pH were measured in the longissimus muscle between the 10th and 11th ribs. The pH of longissimus muscle was determined using a hand-held pH meter (Model 2000, VWR Scientific Products Co., USA) fitted with a spear-tipped electrode (Coleparmer Instrument Co., USA). Two 2.5 cm (thickness) chops were collected from the 9th and 10th ribs. Immediately after collection of the chops, Hunter L (light index), a (red index) and b (yellow index) value were obtained from three orientation on the 10th-rib chop using a Hunter Lab ColorFlex Spectrophotometer (Hunter Associates Laboratory, Inc., USA). Pork quality scores (color and marbling) also were determined on the 10th rib chop using the guidelines of the (NPPC, 2000). The drip loss was determined according to the method of Jiang et al. (2003). The 9th rib chop was used for determining 24 h drip loss using a suspension method. The chops were weighed and then suspended using a hook and line; while suspended chop was placed in a 10.8 ×21.6 cm Whirl-Pak sample bag and sealed. Chops were stored at 2°C for 24 h then reweighed to determine drip loss.

Samples collection and analysis

The longissimus muscle, liver, kidney, and heart samples were collected and stored at -30°C. Tissues were rinsed with deionized water after thawing. One-inch-square samples were cut from the center portion of the thawed tissues with care to stay away from excess fat and veins. Tissue chromium content was determined by the method of Anderson et al. (1996) with atomic absorption spectrometry (AA6510, SHIMADZU, Japan).

Table 2. Effects of CrNano on the growth performance of finishing pigs[1]

	CrNano (μg/kg)		SEM[2]
	0	200	
Initial weight (kg)	65.05	64.50	0.371
Final weight (kg)	91.38	92.30	0.460
ADG (kg/d)	0.752	0.794	0.016
ADFI (kg/pig/d)	2.53	2.58	0.015
Feed:gain	3.37[a]	3.25[b]	0.022

[1] Values are presented as means; n=5 per treatment. Means in a row with different letters differ significantly.
[2] Standard error of the mean.

Table 3. Effects of CrNano on carcass characteristics and pork quality in finishing pigs[1]

	CrNano (μg/kg)		SEM[2]
	0	200	
Dressing percentage	75.85	76.76	0.966
Lean ratio (%)	53.93[a]	61.51[b]	1.343
Fat ratio (%)	23.50[a]	17.50[b]	1.397
Longissmus muscle area (cm^2)	48.90[a]	58.66[b]	2.633
Backfat thickness (cm)	2.25[a]	1.84[b]	0.102
45 min pH value	6.18	6.21	0.041
24 h drip loss (%)	7.68[a]	6.03[b]	0.119
Marbling score	1.92	1.84	0.054
Color score	2.08	2.04	0.074
Hunter L	48.41	46.87	3.049
Hunter a	10.47	10.76	1.073
Hunter b	11.79	10.35	0.743

[1] Values are presented as means; n=5 per treatment. Means in a row with different letters differ significantly.
[2] Standard error of the mean.

Statistical analysis

A completely randomized design with two treatments was used. Data were analyzed by analysis of variance (ANOVA) using GLM procedures and SAS Version 8 (SAS, 1989). For all data, the model included treatment as main effect. A probability of $p<0.05$ was considered significant.

RESULTS

The average daily gain (ADG) and average daily feed intake (ADFI) of the pigs were unaffected by the addition of 200 μg/kg Cr from CrNano in the diet (Table 2). Feed:gain ratio was decreased by 3.56% ($p<0.05$) when 200 μg/kg Cr from CrNano was added.

Dietary CrNano supplementation increased the lean ratio of carcass and longissimus muscle area of pigs by 14.06% ($p<0.05$) and 19.96% ($p<0.05$), respectively, and decreased carcass fat percentage, and backfat thickness by 25.53% ($p<0.05$) and 18.22% ($p<0.05$) respectively. No significant difference in dressing percentage was detected between two groups.

Twenty-four-hour drip loss in the longissimus muscle was decreased by 21.48% ($p<0.05$) with the supplementation of 200 μg/kg CrNano. Other measure of pork quality (dressing percentage, pH, marbling score, color, and Hunter L, a, b) were not affected by CrNano addition.

Table 4. Effects of CrNano on weights of selected muscles[1]

	CrNano (μg/kg)		SEM[2]
	0	200	
Longissimus muscle (g)	2,229.91[a]	2,594.12[b]	100.114
Biceps femoris (g)	1,075.90	1,155.10	43.738
Quadriceps femoris (g)	943.60	983.80	30.822
Semimembranosus (g)	931.00[a]	1,069.40[b]	49.322
Semitendinosus (g)	406.00	413.50	16.596

[1] Weights of skeletal muscle corrected according to 90 kg body weight; Values are presented as means; n=5 per treatment. Means in a row with different letters differ significantly.
[2] Standard error of the mean.

Table 5. Chromium contents in pooled samples selected[1]

	CrNano (μg/kg)		SEM[2]
	0	200	
Longissimus muscle (ng/g)[3]	32.73[a]	92.99[b]	5.767
Heart (ng/g)	48.80[a]	74.47[b]	6.129
Liver (ng/g)	24.07[a]	58.97[b]	4.297
Kidney (ng/g)	47.85[a]	90.02[b]	6.512

[1] Values are presented as means; n=5 per treatment. Means in a row with different letters differ significantly.
[2] Standard error of the mean.
[3] Chromium value is per gram of wet weight samples.

Effects of CrNano on individual muscle weight is presented in Table 4. Weight of longissimus muscle and semimembranosus in pigs that received the diet containing CrNano was increased by 16.33% ($p<0.05$) and 14.87% ($p<0.05$) respectively. No significant differences were found in biceps femoris, quadriceps femoris and semitendinosus.

Analysis of chromium concentration in selected muscle and organs is presented in Table 5. It showed that supplemental CrNano insulted in 184.11% ($p<0.05$), 144.99% ($p<0.05$), 88.13% ($p<0.05$) and 52.60% ($p<0.05$) increment of Cr concentration in longissimus muscle, liver, kidney and heart respectively.

DISCUSSION

Previous experiments have demonstrated inconsistent results in the growth rate and feed gain ratio in pigs fed diets supplemented with Cr. Page et al. (1993) first reported an increase in growth rate, average daily gain was increased by the 50 and 200 μg/kg Cr addition. 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 CrPic. Amoikon et al. (1995) and Boleman et al. (1995) reported that CrPic had no effect on either growth rate or feed efficiency in pigs. Two additional studies by Mooney and Cromwell (1995; 1997) showed that 200 μg/kg Cr from CrPic increased ADG but did not change feed efficiency. Shelton et al. (2003) reported that overall growth performance was not affected by addition of Cr in the form of CrPic or chromium propionate (CrProp). In the present study, only significant difference of feed:gain ratio was detected with the supplementation of 200 μg/kg CrNano. These results suggest that the effects of Cr on the growth performance of pigs vary greatly. Therefore, no definite conclusion on the effect of Cr on growth performance can be drawn from these studies at the moment.

The addition of Cr to diets for growing-finishing pigs has been reported to increase carcass leanness and decrease carcass fatness (NRC, 1998). The research with Cr supplementation to swine diets has been primarily conducted with Cr picolinate, Cr nicotinate, Cr chloride or Cr propionate. No research was conducted with Cr nanoparticle. Page et al. (1993) and Lindemann et al. (1995) reported an increase in longissimus muscle area and a decrease in 10^{th} rib backfat thickness when CrPic was added to growing-finishing pig diets. However, Evock-Clover et al. (1993) and Mooney and Cromwell (1997) reported inconsistent or no effect on carcass traits with supplementation of CrPic or $CrCl_3$. In our study, carcass characteristics of pigs were greatly improved with the supplementation of CrNano. The increase in lean ratio and longissimus muscle area, and decrease in 10^{th} rib and backfat fat ratio were more significant than previous experiments conducted with other forms of Chromium as CrPic, Cr nicotinate, CrProp and $CrCl_3$. The current study results suggest that CrNano may be a more bioavailable source of Cr.

There is limited research on the effect of Cr supplementation on pork quality. Boleman et al. (1995) reported no effect on drip loss or shear force when CrPic was added to swine diets. O'Quinn et al. (1998) reported a decreased visual color score of chop from barrows and gilts and an increased Hunter a:b ratio in barrows when Cr nicotinate was increased in the diet. Furthermore, O'Quinn et al. (1998) reported decreased marbling and drip loss in gilts fed diets with supplemental CrPic. However, Matthews et al. (2003) reported an increase in marbling when pigs were fed CrProp. Our data are in agreement with Mattews et al. (2003), who indicated a decrease in drip loss in chops from pigs fed CrProp. The present study results suggest that Cr supplementation may have an effect on water holding capacity.

Little information has been reported on the effect of Cr on individual muscle weight. In our study, weights of longissimus muscle and semimembranosus were heavier ($p<0.05$) in pigs receiving 200 μg/kg CrNano. And weights of biceps femoris, quadriceps femors and semitendinosus were not influenced by the supplementation of CrNano. The increased longissimus muscle weight is in agreement with the enlarged 10^{th} longissimus muscle area in our study. The significant effect of CrNano on lean ratio may partly due to individual muscles weights increment.

Chromium concentrations in longissimus muscle and selected organs were greatly increased with the addition of 200 μg/kg CrNano in the diet. This result is partly consistent with the study of Anderson et al. (1996) in CrPic. They reported that there was an approximate doubling of kidney Cr concentration and liver Cr increased roughly 50% with the supplementation of 300 μg/kg CrPic in the diet. Their results from rats (Anderson et al., 1996) and turkeys (Anderson et al.1989) showed that increased in tissue Cr following Cr supplementation were greatest for the kidney, followed by the liver, with considerably smaller changes in the heart and skeletal muscle tissues. However Change et al. (1992) could not detect changes in muscle, liver, and kidney Cr concentrations of steers fed 200 μg of Cr/kg of diet as high-Cr yeast. In our study, increases in tissue Cr are greatest for the muscle, followed by the liver and kidney. Whether CrNano has higher bioavailability or due to problems associated with chromium analyses remains to be established. Especially, the approach to absorption and distribution of chromium nanoparticle should be further studied.

IMPLICATION

This research suggests that the dietary supplementation of 200 μg/kg chromium nanoparticle increases carcass lean percentage, longissimus muscle area, decreases backfat thickness and carcass fat percentage in pigs. Drip loss in chops from pigs fed chromium nanoparticle was decreased and weights of longissimus muscle, semimembranosus were significantly increased. Meanwhile, chromium concentrations in longissimus muscle and selected organs were greatly increased with the supplementation of chromium nanoparticle in the diet.

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