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Effects of chromium-loaded chitosan nanoparticles on growth, carcass characteristics, pork quality, and lipid metabolism in finishing pigs

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ABSTRACT

The study was conducted to evaluate the effects of chromium-loaded chitosan nanoparticles (Cr-CNP) on growth, carcass characteristics, pork quality, and lipid metabolism in finishing pigs. A total of 160 crossbred barrows with an average initial BW of 66.10 ± 1.01 kg were randomly allotted to 4 dietary treatments, with 4 pens per treatments and 10 pigs per pen. Pigs were fed the basal diet supplemented with 0, 100, 200, or 400 μg/kg of Cr from Cr-CNP. All pigs were given free access to feed and water for 35 d. Two pigs from each pen were selected to collect serum samples and slaughtered to measure carcass characteristics and pork quality and collect adipose tissue samples. The results showed that gain to feed ratio of pigs fed supplemental Cr from Cr-CNP increased ($P < 0.05$) compared with those fed the control diet. Dietary Cr-CNP increased the carcass lean ratio ($P < 0.01$) and longissimus muscle area ($P < 0.05$), decreased carcass fat ratio ($P < 0.001$), and backfat thickness ($P < 0.01$) linearly and quadratically. The 24 h drip loss was decreased ($P < 0.01$) linearly and quadratically, while 45 min pH value and Hunter *L*, *a*, *b* values in longissimus muscle were unaffected with the dietary supplementation of Cr-CNP. Supplemental Cr from Cr-CNP increased serum free fatty acids (linear and quadratic, $P < 0.001$), lipase activity (linear and quadratic, $P < 0.01$), and serum insulin-like growth factor I (quadratic, $P < 0.01$), while decreased serum insulin (linear, $P < 0.001$). Dietary supplementation of Cr-CNP decreased activities of fatty acid synthase (linear and quadratic, $P < 0.01$) and malate dehydrogenase (linear, $P < 0.01$), while increased the activity of hormone-sensitive lipase (linear and quadratic, $P < 0.05$) in subcutaneous adipose tissue. The present results indicated that dietary supplementation of Cr as Cr-CNP had beneficial effects on growth, carcass characteristics, and pork quality, and positively affected lipid catabolism in finishing pigs.

1. Introduction

Chromium has been considered an essential trace element for over 50 years, and it is considered to be associated with various enzymes and hormones in human and animals, which plays an important role in carbohydrate, fat, and protein metabolism (Anderson, 1987; Mertz, 1993). A number of experiments have been conducted to study the effects of Cr from different chemical forms, such as chromium chloride (Mooney and Cromwell, 1997; Uyanik et al., 2002), chromium picolinate (CrPic; Kim et al., 2009, 2010; Lindemann et al., 1995; Page et al., 1993), chromium nicotinate (CrNic; Kegley et al., 1996),

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chromium propionate (CrProp; Jackson et al., 2009; Shelton et al., 2003), and chromium nanocomposite (CrNano; Wang and Xu, 2004; Zha et al., 2007a, 2007b) on growth performance, carcass characteristics, pork quality, reproduction, and tissue deposition in domestic animals. Page et al. (1993) first reported that supplementation of Cr could increase carcass leanness and decrease fat deposition in pigs, which was supported by Lindemann et al. (1995, 1997), Boleman et al. (1995), Mooney and Cromwell (1995, 1997), Wang et al. (2004, 2007), Jackson et al. (2009), and Sales and Jancik (2011). However, Matthews et al. (2001) reported no responses in carcass leanness to supplemental Cr. The inconsistent response of the experiments may result from different dietary levels, pigs′ Cr status, or absorption rate of different Cr sources (Dunshea et al., 2011; White et al., 1993).

The factors controlling absorption of Cr may include levels, source, and status in the gastrointestinal tract. It is well known that organic sources of Cr have a greater bioavailability than inorganic sources (NRC, 1997). Previous research indicated that Cr from nanocomposite of $CrCl_3$ (Wang and Xu, 2004; Wang et al., 2007) was shown to produce beneficial effects on carcass characteristics, pork quality, and individual skeletal muscle weight, with an approximate 2 to 3 fold greater tissue Cr deposition in selected muscle and organs compared to the control group, which implicated greater absorption rate and bioavailability in finishing pigs. And, a substantially greater absorption and uptake of Cr from CrNano was confirmed in Caco-2 cell lines (Zha et al., 2008). Chitosan, one of the nontoxic and biodegradable carbohydrate polymers, is prepared from chitin by treatment with alkali. It is applied in various fields, including biotechnology (Hirano, 1999), pharmaceuticals (Kathryn et al., 1999), waste water treatment (Jha et al., 1988), and food science (Wang et al., 2007). Chitosan nanoparticles have been synthesized and mainly used as drug carrier as reported in previous studies (De Campos et al., 2001; Xu and Du, 2003). A new form of Cr composite [chromium (III)-loaded chitosan nanoparticles, Cr-CNP] was developed, and was patented in China (Wang et al., 2012). The objective of the present study was to evaluate the effects of Cr-CNP supplementation on growth, carcass characteristics, pork quality, and lipid metabolism in finishing pigs.

2. Materials and methods

2.1. Materials

The chitosan used in the study was provided by a commercial company (Zhejiang Golden-Shell Biochemical Co. Ltd.; Zhejiang, China). The degree of deacetylation and molecular mass were about 90% and 150 kDa, respectively, as determined by elemental analysis and the viscometric method. The Cr-CNP (average size, approximate 90 nm) was constructed according to the method described by Wang et al. (2012). Briefly, chitosan was dissolved into 0.5% (v/v) acetic acid to obtain a 1% (w/v) chitosan solution and modulate its pH to 3.5 with 0.5% (v/v) acetic acid. The chitosan solution was stirred at room temperature for 1 h. Under stirring, the precipitate was added into 200 mg/L $CrCl_3$ solution to obtain a suspension that the ratio of chitosan to $CrCl_3$ was 47:3. The pH of the mixture was modulated to 6.5 and stirred for 5 h. Subsequently, the precipitate, centrifuged 12,000 × g for 15 min at room temperature, was purified with water to obtain Cr-CNP.

2.2. Animals and experimental design

The protocol of this study was approved by the Institution Animal Care and Use Committee at Zhejiang University. And, the animal trial was conducted in accordance with the National Institutes of Health guidelines for the care and use of experimental animals.

A total of 160 crossbred barrows (Duroc × Landrace × Yorkshire) with an average body weight of 66.10 ± 1.01 kg were selected (Anji Zhengxin Breeding Farm, Zhejiang,China). The pigs were blocked by initial BW and assigned to pens with 10 pigs per pen. Pens were randomly assigned within block to 4 dietary treatments with 4 replicates per treatment. The pigs were housed in 3.25 × 5.25 m pens with concrete floors. Feed was provided ad libitum and water was provided by nipple waterers. The duration of the feeding trial was 35 d. The ADG, ADFI, and G:F were determined throughout the experimental period. Pigs received the basal diet (Table 1) supplemented with 0, 100, 200, or 400 μg/kg of Cr from CNP-Cr. The basal diet, which consisted primarily of corn, soybean meal, and wheat bran, was supplemented with minerals and vitamins to meet or exceed NRC (1998) requirement estimates. To minimize potential variation that can occur with multiple diet mixings, a single batch of basal diet was prepared. Approximately the first 5 and

Table 1
Ingredient inclusion and chemical composition of basal diet.

Item	Content
Ingredient (g/kg)	
Corn	610.0
Soybean meal	210.0
Wheat bran	70.0
Alfalfa meal	50.0
Rapeseed meal	20.0
Limestone	14.0
Monocalcium phosphate	13.0
Salt	3.0
Mineral and vitamin premix[a]	10.0
Chemical composition[b]	
DE (MJ/kg)	13.2
CP (g/kg)	179.8
Crude fat (g/kg)	27.9
Ca (g/kg)	7.8
P (g/kg)	6.0
Lys (g/kg)	10.5
Met (g/kg)	4.5

[a] Provided per kilogram of diet: Cu, 15 mg (as $CuSO_4 \cdot 5H_2O$); Zn, 105 mg (as $ZnSO_4.7H_2O$); Fe, 135 mg (as $FeSO_4 \cdot H_2O$); Mn, 40 mg (as $MnSO_4 \cdot 5H_2O$); Se, 0.15 mg (as $Na_2SeO_3 \cdot 5H_2O$); I, 0.3 mg (as KI); vitamin A, 6200 IU; vitamin D_3, 700 IU; vitamin E, 88 IU; vitamin K (as menadione sodium bisulfite complex), 4.4 mg; vitamin B_2, 8.8 mg; D-pantothenic acid, 24.2 mg; niacin, 33 mg; and choline chloride, 330 mg (as 50% choline chloride premix).

[b] Analyzed values, except for DE, which was computed from data of the ingredient energy values provided by Feed Database in China (2010).