Effects of chromium picolinate on fat deposition, activity and genetic expression of lipid metabolism-related enzymes in 21 day old Ross broilers

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Objective: This experiment was conducted to investigate the effects of chromium picolinate (CrP) on fat deposition, genetic expression and enzymatic activity of lipid metabolism-related enzymes.

Methods: Two hundred forty one-day-old Ross broilers were randomly divided into 5 groups with 4 replicates per group and 12 Ross broiler chicks per replicate. The normal control group was fed a basal diet, and the other groups fed the same basal diet supplemented with 0.1, 0.2, 0.4, and 0.8 mg/kg CrP respectively. The experiment lasted for 21 days.

Results: Added CrP in the basal diet decreased the abdominal fat, had no effects on subcutaneous fat thickness and inter-muscular fat width; 0.2 mg/kg CrP significantly decreased the fatty acid synthase (FAS) enzymatic (p<0.05); acetyl-CoA carboxylase (ACC) enzymatic activity decreased in all CrP groups (p<0.05); hormone-sensitive lipase (HSL) enzymatic activity also decreased, but the change was not significant (p>0.05); 0.4 mg/kg CrP group significantly decreased the lipoprotein lipase (LPL) enzymatic activity. FAS mRNA expression increased in all experimental groups, and the LPL mRNA expression significantly increased in all experimental groups (p<0.05), but not 0.2 mg/kg CrP group.

Conclusion: The results indicated that adding CrP in basal diet decreased the abdominal fat percentage, had no effects on subcutaneous fat thickness and inter-muscular fat width, decreased the enzymatic activity of FAS, ACC, LPL and HSL and increased the genetic expression levels of FAS and LPL.

Keywords: Ross Broiler; Chromium Picolinate (CrP); Fatty Acid Synthase; Acetyl-CoA Carboxylase; Hormone-sensitive Lipase; Lipoprotein Lipase; Enzymatic Activity; mRNA Expression

INTRODUCTION

Chromium (Cr) exists in various oxidation states (−2 to +6) [1], +3 and +6 are the most naturally states in environment [2]. Hexavalent Cr is more toxic than trivalent [3-5] when measured for genotoxicity, cytotoxicity, and carcinogenicity [6-8]. Trivalent Cr is the most stable form, and have less toxicity. So the Hexavalent Cr is usually used for toxicologic study, and the trivalent Cr is usually used as a nutrient element. Chromium is an integral component of the glucose tolerance factor [9]. The low molecular weight chromium binding substance was known as chromodulin, is the most viable candidate for the biologically active form of Cr3+ which could stimulate the activity of the insulin receptor protein tyrosine kinase [10]. Chromodulin and its synthetic analogue increase the activity of tyrosine kinase 3 to 8 fold [11].

Previous studies indicated that organic Cr is absorbed more efficiently [12], and has a higher bioavailability than inorganic Cr [13]. Different organic forms of Cr would be ex-
expected to have different bioavailabilities [12,14]. Published studies describing the effects of organic Cr on broilers, including increasing immune response and alleviating the negative effects of heat stress [15,16], increasing the weight of pectoral muscles [17], decreasing body fat deposition in broilers [18]. In addition, supplement with Cr alter lipid and glucose metabolism [19-21], and growth performance in pigs [22]. Cr improved glucose tolerance [23,24], decreased total cholesterol and low-density lipoprotein levels [25,26]. The previous studies indicated that Cr alter lipid and glucose metabolism, but the underlying mechanism is unknown.

Therefore, this study was conducted to investigate the effects of chromium picolinate (CrP) on percentages of abdominal, subcutaneous and inter-muscular fat, enzyme activities and mRNA expression in Ross broilers, via adding CrP in dietary to reveal the mechanism underlying the effects of Cr on lipid metabolism.

**MATERIALS AND METHODS**

**Animals, diets, and treatments**

A total of 240 one-day-old Ross broilers were randomly divided into 5 groups, and each group containing 4 replicates of 12 Ross broilers. The normal control group was fed the basal diet, the other groups fed the same basal diet supplemented with 0.1, 0.2, 0.4, 0.8 mg/kg CrP. The experiment lasted for 21 days. CrP in this experiment was supplied by Shaanxi Pioneer Biotech Co., Ltd. The commodity’s CAS No.: 14639-25-9; Model No.: PW-S67; CrP content: 98%. The corn-soybean meal basal diet was used in this experiment, in accordance with the National Research Council (NRC [27]). Standard for broilers nutrient requirements and Chinese Feeding Standard for broilers. Table 1 lists the composition and nutrient levels of the basal diet. The Cr concentration in basal diets is 0.33 mg/kg, just same as report by Padmavathi [28].

**Feeding managements**

All experimental utensils and surroundings were disinfected before initiating the experiment. During the experiment, feed and water were given *ad libitum*. During days 1 to 3, the indoor temperature was maintained at 33°C to 35°C and decreased gradually reach to 24°C after 14 days. Natural ventilation and humidity was maintained at 55% to 60%. During days 1 to 3, the broilers were exposed to light for 24 hours, and after three days, the broilers were exposed to light for 20 to 23 hours.

**Sample collection**

On days 21, the experimental Ross broilers starved for 12 hours, then two Ross broilers were selected from each replicates and killed at the neck. The abdominal fat was subsequently separated and weighed, and the subcutaneous and inter-muscular fat width were measured. Liver and pectoralis were collected and placed into liquid nitrogen and then stored at −80°C to be measured (The study protocol conforms to the guideline for the use of laboratory animals, form the College of Agriculture, Guangdong Ocean University).

**Fat deposition, subcutaneous fat thickness, inter-muscular fat width measurement**

Abdominal fat percentage

= (Abdominal fat weight/body weight)×100%

*Subcutaneous fat thickness:* An incision was made at the former end of the caudal vertebra along the middle line of the back. The incised skin corner (including the skin) was measured at different positions with Vernier calipers to obtain three numbers. The averaged number is the subcutaneous fat thickness.

*Inter-muscular fat width:* The inter-muscular fat width was measured at three different position from the pectoral muscle major border to the sternum end, and the averaged number is the inter-muscular fat width.

**Enzymatic activity of FAS, ACC, LPL, and HSL**
RESULTS

Effects of CrP on fat deposition of Ross broilers
Compared to normal control group, 0.4 mg/kg CrP group significantly decreased the abdominal fat percentage (p<0.05), while the rest of the experimental groups only showed a slight reduction (p>0.05) (Figure 1A). There was no significant change between the experimental and normal control group on the subcutaneous fat width (p>0.05) (Figure 1B). The changes in the inter-muscular fat width consistent with the observed in abdominal fat percentage, 0.4 mg/kg CrP decreased the most, but there was no significant change (p>0.05) (Figure 1C).

Effects of CrP on the enzymatic activities of FAS, ACC, LPL, and HSL of Ross broilers
As shown in Figure 2, the FAS activity of all experimental groups decreased compared with the normal control group (p<0.05), and 0.2 mg/kg CrP significantly decreased the activity of FAS (p<0.05) (Figure 2A). The enzymatic activity of ACC was significantly decreased in all experimental groups (p<0.05) (Figure 2B). HSL activity was also decreased, but the differences were not significant (p>0.05) (Figure 2C). Supplementing with 0.4 mg/kg CrP significantly decreased the LPL activity compared to normal control group (p<0.05) (Figure 2D).

Effects of CrP on mRNA expression levels of FAS and LPL in Ross Broilers
Basal diets added with CrP influenced expression levels of FAS and LPL in Ross broilers of 1 to 21 days. Compared to the normal control group, expression levels of FAS increased in all the experimental groups (Figure 3A). LPL expression levels were significantly decreased (p<0.05) in 0.2 mg/kg CrP group, while it increased in the rest of the experimental groups (Figure 3B).
DISCUSSION

Studies have shown that Cr can improve glycometabolism and lipid metabolism in diabetes mellitus [29-31], due to its role in glucose/insulin metabolism [32]. Previous studies also indicated that Cr could affect lipid metabolism and reduce body fat deposition of broilers [18,28,33]. Abdominal fat tissue grows faster compared with other fat tissues in poultry [34]. And the abdominal fat is a reliable parameter for judging the total body fat content because it is linked directly to total body fat content in avian species [35,36]. Our results showed that abdominal fat percentage tended to be reduced in all experimental groups (p>0.05), and the experimental group with 0.4 mg/kg Cr had the most significant reduction (p<0.05). Basal

Figure 1. (A) The abdominal fat percentage of Ross broilers, abdominal fat weight/body weight (n = 8); (B) an incision was made at the former end of the caudal vertebra along the middle line of the back. The incised skin corner (including the skin) was measured at different positions with Vernier calipers to obtain three numbers. The averaged number is the subcutaneous fat thickness (n = 8); (C) the inter-muscular fat width was measured at three different position from the pectoral muscle major border to the sternum end, and the averaged number is the inter-muscular fat width (n = 8).

Figure 2. (A), (B), (C), (D) were the relative activity of FAS, ACC, HSL, and LPL enzyme respectively (100% of control). FAS, fatty acid synthase; ACC, acetyl-CoA carboxylase; HSL, hormone-sensitive lipase; LPL, lipoprotein lipase.
diets supplemented with Cr had no effects on the subcutaneous fat thickness and the inter-muscle fat width of Ross broilers.

FAS is the rate-limiting enzyme in the last step of de novo synthesis of the long-chain fatty acids in animals, catalyzes Acetyl-CoA and Maloney-CoA to synthesize the fatty acid [37]. The liver and fat tissue is enriched with FAS, but more than 90% fatty acid is synthesized in the liver of the broiler, and the fat tissue just has a storage function. Therefore, the experiment reported here used liver to study FAS activity. The results showed that Cr decreased FAS activity in all experimental groups, and this is consistent with the previous study that clenbuterol decrease lipogenesis in the liver by decreasing FAS activity, consequently affecting the abdominal fat pad weight [38]. The ACC is a biotin-dependent enzyme that catalyzes the carboxylation of acetyl-CoA to produce malonyl-CoA substrate for the biosynthesis of fatty acids [39]. Due to its unique position in lipid metabolism, inhibition of ACCs has been proposed to reduce lipogenesis and favor lipid oxidation [40]. Our results suggested that the liver ACC activity decreased in all experimental groups, and 0.4 mg/kg CrP reduced the most. HSL is controlled by many hormones, so it is also called hormone-sensitive lipase or fat-hormone sensitive enzyme. HSL hydrolyzes fat into non-esterified fatty acids and glycerin by joint function of double-glyceridase and single-glyceridase. However, the hydrolytic activity of HSL is much lower than the other enzymes, making it the rate-limiting enzyme in fat hydrolytic processes [41]. Our study found that HSL activity reduced in all experimental groups (p>0.05). LPL is a key enzyme of fat deposition in animal tissues. It is a rate-limiting enzyme for the catalysis of triglycerides into glycerin and non-esterified fatty acids [42]. The products of LPL catalysis provide raw material for fat synthesis and play an important role in fat metabolism and transportation. Our results suggested that CrP tended to decreased the LPL activity in experimental groups, especially for 0.4 mg/kg group which significantly decreased the LPL activity. All the results showed that supplemented with CrP in basal diets had certain effects on the enzymatic activity of fat deposition: including reduced FAS activity in the liver, significantly reduced ACC activity in the liver, reduced HSL activity in abdominal fat and reduced the LPL activity in pectorals. Therefore, we thought that CrP decreased fat deposition through decreasing the enzymatic activities of FAS, ACC, HSL, and LPL. Though HSL activity was also reduced, it was not significant compared to the former.

Supplemented with CrP in the basal diets significantly decreased the enzyme activity involved in lipid metabolism. Then, whether or not supplemented with CrP would influence the gene involved in lipid metabolism. Our results showed that the expression of FAS significantly increased in 0.2 mg/kg and 0.8 mg/kg groups, and the expression of LPL were significantly decreased in 0.2 mg/kg group (p<0.05), while it significantly increased in 0.1 mg/kg and 0.4 mg/kg group (p<0.05). Though we had not concluded the effects of Cr on the mRNA expression of FAS and LPL in Ross broilers were correlated with dosage, but we could conclude a series of conclusion when we linked the mRNA expression of FAS and LPL with the enzymatic activity. The regression analysis of FAS activity and FAS gene expression showed that the intercept is 53.80 and the variable is –0.38 (raw data analysis). The regression analysis indicated that the expression of FAS would increase along with the decrease of FAS activity. Therefore, we concluded that supplement Cr could decrease FAS activity, and the low enzymatic activity of FAS in turn stimulate the organism to produce more FAS to meet its needs, lead to the increase of the expression of FAS. However, there was no obvious regularity on the LPL enzyme activity and mRNA expression.

CONCLUSION
Basal diets with CrP reduced the abdominal fat percentage and subcutaneous fat thickness of Ross broilers of 1 to 21 days, decreased the enzymatic activities of FAS, ACC, LPL, and HSL activity, increased the expression of FAS gene in Ross broilers. And we thought that Cr could decrease FAS activity, and the low enzymatic activity of FAS in turn stimulate the organism to produce more FAS to meet its needs. However, these changes did not appear to be related to the Cr dosage.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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