Effects of dietary supplementation with turmeric rhizome extract on growth performance, carcass characteristics, antioxidant capability, and meat quality of Wenchang broiler chickens

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Abstract

Our study aimed to determine the effect of increasing dietary levels of turmeric rhizome extract (TRE) on performance, carcass characteristics, antioxidant capability and meat quality of Wenchang broiler chickens. Three hundred, 1-day-old Wenchang broiler chickens were brooded together for 2 weeks, then randomly allocated into four treatments with five replicates of 15 chicks each. Birds were fed a corn-soybean basal diet supplemented with TRE at 0, 100, 200 and 300 mg/kg for 12 weeks. The results revealed that a TRE-supplemented diet had no significant effect (P>0.05) on the body weight, although birds fed a diet with TRE at 100 and 200 mg/kg had higher average daily weight gains and average daily feed as compared to controls from 9 to 12 week (P<0.05). Also, the addition of TRE at 100 to 300 mg/kg had a better feed conversion ratio compared to controls from week 9 to 12 (P<0.05). Dietary supplementation with TRE at 300 mg/kg increased the breast muscle weight ratio (P<0.05). Meanwhile, dietary supplementation with TRE at 100 to 300 mg/kg reduced the abdominal fat ratio (P<0.05), compared to that of the control group. TRE increased enzymatic activities of superoxide dismutase and glutathione peroxidase, and reduced malondialdehyde concentrations, compared to the control group. Dietary TRE supplementation at 300 mg/kg decreased the drip loss in both breast muscle and thigh muscles, compared with the control group (P<0.05). In conclusion, dietary TRE supplementation enhanced antioxidant capability, growth performance, breast muscle weight ratio, and reduced the abdominal fat ratio of Wenchang broiler chickens.

Introduction

Wenchang chicken, a well-known local breed in southern China, ranking the first of the four most popular in Hainan province because of its thin skin and fragrant meat, is characterized by a small body size and slow growth rate (Tang et al., 2009). Wenchang chickens reach marketing age at minimum of 12 weeks in China. Antibiotic supplementation in the diets promotes growth, and plays a key role in poultry production. In the presence of low antibiotic levels, resistant cells survive and multiply, thereby producing antibiotic resistance in bacteria in the final products (Schwarz et al., 2001; Lee et al., 2004). Therefore, the application of antibiotics as growth promoters in animal feed has been banned in many countries, particularly the European Union. Presently, there is an increasing interest to find alternative substances and strategies to improve the health status of farmed animals for human consumption. Among those, phyto-genic and herbal products have received increased attention since they are more widely accepted as natural additives.

Turmeric (Curcuma longa) is a tropical plant native to southern and southeastern tropical Asia. Curcumin, isolated from the rhizomes of turmeric is the main bioactive ingredient of C. longa, which was found to convey antioxidant (Karami et al., 2011), antiviral (Liu et al., 2013a), and antibacterial activities (Liu et al., 2013b). The significant biological properties of curcumin render it a potential substitute for antibiotics in livestock feed. A number of studies have been conducted to evaluate the effects of curcumin on the performance of broiler chickens (Suriya et al., 2012; Nayaka et al., 2013; Abou-Elkhair et al., 2014; Olovoski and Dono, 2014); however, the results of these studies have been inconsistent. Keeping in view of the medicinal attributes of C. longa, the purpose of the present study was to evaluate the effects of increasing levels of turmeric rhizome extract (TRE) on performance, carcass characteristics, antioxidant capability, and meat quality of Wenchang broiler chickens.

Materials and methods

Birds and housing management

Three hundred, 1-day-old Wenchang broiler chickens were procured from a commercial hatchery (Hainan (Tanniu) Wenchang Chicken Co., Ltd., Haikou, China). All chickens were brooded together for 2 weeks, weighted, and then randomly assigned to one of four treatment groups (T0, T100, T200 and T300) with five replicates of 15 chicks each. Chickens were raised for 12 weeks in floor pens (ten birds/m²) littered with sawdust under a 12-h light-dark cycle at an ambient temperature of about 35°C during the first week, which was then gradually reduced 2°C per week to about 25°C. Relative humidity was maintained at 55%-65%. All animal experiments were conducted in accordance with the Laboratory Animal Requirements of Environment and Housing Facilities (Protocol No. GB 14925-2010). The study protocol was approved by the Institutional Animal Care and Use Committee of the Chinese Academy of Tropical Agricultural Sciences (Haikou, China).

Feed and treatment

The birds were fed a starter diet from week 1 to 5, followed by a finisher diet from week 6 to 12. The basal diet was formulated according
to the standards of the commercial hatchery (Table 1). TRE was obtained from the Guangxi Subtropical Crops Research Institute (Nanning, China) and extracted by the supercritical carbon dioxide extraction method from turmeric rhizomes. The purity of curcumin was 86%. Relatively small amount of TRE were first added to the basal diet and then small batches were mixed with a larger amount of feed until the total amount of feed was well mixed. The birds in the T100, T200 and T300 treatment groups were fed a basal diet supplemented with TRE at 100, 200 and 300 mg/kg of feed, respectively while birds in control group (T0) were fed a basal diet without TRE supplementation. Feed and water were provided ad libitum throughout the experimental period.

Performance and carcass characteristics
Chickens were weighed per pen at 2, 5, 8, and 12 weeks of age after feed deprivation for 12 h. Feed intake was measured per floor pen throughout the experimental period and the feed conversion ratio (FCR, feed intake/weight gain) was calculated at the same intervals. At 12 weeks of age, one bird per replicate was randomly chosen and weighed after feed deprivation for 12 h. After blood collection, the birds were humanly slaughtered by exsanguination, de-feathered, and eviscerated. Live body weight (BW), carcass weight, abdominal fat weight, and weights of the bilateral breast and thigh muscles were weighed. Carcass weight was defined as the weight of the feather-scalded, eviscerated carcass after removal of the head, neck, blood, and hocks (Dilger et al., 2006). After measuring the carcass weight, the bilateral breast and thigh muscles were skinned and deboned for the measurements of pH, intermuscular fat (IMF) content and drip loss.

Blood collection and assay of antioxidant indices in serum
Blood was collected during the morning of weeks 5, 8 and 12 before water and feed were offered. One bird per replicate was randomly chosen and approximately 10 mL of blood were collected through the jugular vein. To obtain serum, the test tubes containing the blood samples were kept in a slanted position for 45 min and then centrifuged at 700 g for 15 min. Serum samples were stored in 2 mL plastic vials at -20°C. Then, serum levels of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and malondialdehyde (MDA) were measured using colorimetric methods with a spectrophotometer (UV-2600: Shimadzu Corporation, Tokyo, Japan). The assays were conducted according to the procedure described by Rajput et al. (2013) using reagent kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China).

Meat quality
Muscle pH was measured at 45 min and 24 h after slaughter using a penetrating electrode (Mettler-Toledo International, Inc., Columbus, OH, USA) attached to a portable pH-meter (FG2; Mettler-Toledo Instruments (Shanghai) Co., Ltd., Shanghai, China) (Zhang et al., 2014). The muscle was weighed, placed in a Whirl-pak bag (eNasco, Stamford, CT, USA) suspended in a 4°C cooler for 24 h, and then reweighed for the final pH measurement. Muscle drip loss was calculated based on the weight loss and expressed as percentage.

Statistical analysis
Analysis of variance was performed on the premise of the homogeneity of variance using SAS software ver. 9.0 (SAS Institute Inc., Cary, NC, USA). All data are expressed as means ± standard deviations. Significant differences among means were evaluated using the Tukey’s multiple-range comparison test. P<0.05 was considered statistically significant.

Table 1. Feed ingredients and nutrient composition of basal diets for experimental broiler chicks.

| Ingredients          | Starter, weeks 1-5 | Finisher, weeks 6-12 |
|----------------------|--------------------|----------------------|
| Corn, %              | 61.20              | 66.00                |
| Soybean meal, CP 44% | 28.50              | 25.20                |
| Fish meal, CP 62%    | 3.00               | 2.00                 |
| Palm oil, %          | 2.00               | 1.50                 |
| Shell powder, %      | 0.80               | 0.80                 |
| Sodium chloride, %   | 0.35               | 0.35                 |
| DL-methionine, %     | 0.15               | 0.15                 |
| Premix, %            | 4.00               | 4.00                 |
| Analysed chemical composition | | |
| ME, Mcal/kg          | 2.88               | 3.00                 |
| Crude protein, %     | 19.80              | 19.10                |
| Ether extract, %     | 4.40               | 4.82                 |
| Dry matter, %        | 82.60              | 82.47                |
| Methionine + cysteine, % | 0.78           | 0.70                 |
| Available phosphorus, % | 0.33           | 0.30                 |

| Analytical composition | | |
|------------------------| | |
| CP, crude protein; ME, metabolisable energy; "vitamin and mineral premix supplied the following per kilogram of diet: vitamin A, 3350 IU; cholecalciferol, 750 IU; vitamin E, 5 IU; vitamin K3, 0.5 mg; folic acid, 0.2 mg; biotin, 0.10 mg; Fe, 20 mg; Cu, 2 mg; Zn, 15 mg; Mn, 25 mg; I, 0.1 mg; Se, 0.1 mg; choline chloride, 80 mg." calculated. |

Results

Growth performance
The results of growth performance are presented in Table 2. Dietary TRE supplementation had no significant effect (P>0.05) on the BW of birds throughout the trial period. From week 9 to 12, the average daily gain (ADG) was significantly (P<0.05) improved in the T100 and T200 groups, as compared to controls. Dietary TRE supplementation had a significant effect (P<0.05) on the average daily feed intake (ADFI) of birds throughout the trial period. From week 3 to 8, birds in the control group had greater ADFI values. However, the ADFI of birds in the T100 and T200 groups increased and were greater than in controls from week 9 to 12. Dietary TRE supplementation had no significant effect (P>0.05) on the FCR of birds from week 3 to 8 week, while that of birds fed a TRE-supplemented diet was obviously improved (P<0.05) from week 9 to 12 week.

Carcass characteristics
The effects of dietary TRE supplementation on carcass traits are presented in Table 3. Dietary TRE supplementation had no significant effect (P>0.05) on the live weight, slaughter weight, dressing percentage, eviscerated weight, and thigh muscle weight. However, dietary TRE supplementation increased the breast muscle weight and breast muscle weight and ratio (P<0.05), but reduced abdominal fat weight and ratio (P<0.05), as compared to the control group.

| Table 1. Feed ingredients and nutrient composition of basal diets for experimental broiler chicks. | |
|----------------------------------------------------------|-------|
| Ingredients                                              |       |
| Corn, %                                                  | 61.20 |
| Soybean meal, CP 44%                                     | 28.50 |
| Fish meal, CP 62%                                        | 3.00  |
| Palm oil, %                                              | 2.00  |
| Shell powder, %                                          | 0.80  |
| Sodium chloride, %                                       | 0.35  |
| DL-methionine, %                                         | 0.15  |
| Premix, %                                                | 4.00  |
| Analysed chemical composition                            |       |
| ME, Mcal/kg                                              | 2.88  |
| Crude protein, %                                         | 19.80 |
| Ether extract, %                                         | 4.40  |
| Dry matter, %                                            | 82.60 |
| Methionine + cysteine, %                                 | 0.78  |
| Available phosphorus, %                                  | 0.33  |

| Analytical composition                                   |       |
|----------------------------------------------------------|-------|
| CP, crude protein; ME, metabolisable energy; "vitamin and mineral premix supplied the following per kilogram of diet: vitamin A, 3350 IU; cholecalciferol, 750 IU; vitamin E, 5 IU; vitamin K3, 0.5 mg; folic acid, 0.2 mg; biotin, 0.10 mg; Fe, 20 mg; Cu, 2 mg; Zn, 15 mg; Mn, 25 mg; I, 0.1 mg; Se, 0.1 mg; choline chloride, 80 mg." calculated. |
Antioxidant capability

Serum antioxidant enzymatic activities and lipid peroxidation levels are presented in Table 4. Dietary TRE supplementation increased (P<0.05) the enzymatic activities of SOD and GSH-Px at 5 and 8 weeks of age, respectively. Meanwhile, the serum MDA concentration was markedly reduced by dietary TRE supplementation, as compared to controls at 5, 8 and 12 weeks of age, respectively (P<0.05).

Meat quality

Dietary TRE supplementation had no significant effect (P>0.05) on pH at 45 min and 24 h, and the IMF of breast and thigh muscles, as compared with the control group (P<0.05).

Discussion

Growth performance

The results of the present study showed that dietary supplementation of 100-300 mg/kg of TRE had no effect on the BW of broilers. This result was similar to that of Emadi and Kermanshashi (2006) who reported that dietary supplementation of 2.5, 5 and 7.5 g/kg of turmeric had no effect on weight gain of Wenchang broiler chickens (Table 5). However, dietary TRE supplementation at 300 mg/kg decreased the drip loss in both breast and thigh muscles, as compared with the control group (P<0.05).

| Table 2. Effect of turmeric rhizome extract supplementation on body weight, average daily gain, feed intake, and feed conversion ratio of Wenchang broiler chickens |
|---------------------------------------------------------------|
| Diet treatments°                                           |
| T0 (control) | T100 | T200 | T300 |
|---------------------------------------------------------------|
| Body weight, g                                               |
| 5 w             | 357.30±1.58 | 347.35±8.16 | 342.25±16.46 | 340.55±16.18 |
| 8 w             | 680.54±18.78 | 675.48±29.65 | 659.03±34.79 | 638.37±40.20 |
| 12 w            | 1028.13±6.09 | 1142.48±56.05 | 1107.28±64.92 | 1037.56±42.84 |
| Average daily gain, g                                       |
| 2-5 w           | 12.07±0.08 | 11.66±0.36 | 11.41±1.64 | 11.30±2.09 |
| 6-8 w           | 16.16±1.00 | 16.41±1.32 | 15.64±3.35 | 14.69±4.31 |
| 9-12 w          | 11.99±0.62 | 16.10±0.94 | 15.46±1.26 | 13.77±0.84 |
| 2-12 w          | 13.19±0.09 | 14.81±0.80 | 14.31±0.91 | 13.32±0.90 |
| Average daily feed intake, g                                |
| 2-5 w           | 28.86±0.62 | 28.45±1.14 | 28.11±1.34 | 27.65±1.37 |
| 6-8 w           | 50.88±0.80 | 48.30±2.64 | 47.01±3.11 | 40.49±2.07 |
| 9-12 w          | 61.14±0.94 | 65.57±1.27 | 60.16±2.71 | 60.25±1.60 |
| 2-12 w          | 46.81±0.24 | 47.21±1.11 | 48.29±1.90 | 42.80±1.40 |
| Feed conversion ratio, g/g                                   |
| 2-5 w           | 2.47±0.06 | 2.44±0.07 | 2.49±0.29 | 2.50±0.43 |
| 6-8 w           | 3.16±0.24 | 2.95±0.25 | 2.97±0.19 | 2.87±0.80 |
| 9-12 w          | 5.11±0.22 | 4.08±0.17 | 4.49±0.25 | 4.38±0.16 |
| 2-12 w          | 3.55±0.03 | 3.19±0.13 | 3.38±0.14 | 3.22±0.14 |

°T0=0 mg/kg of turmeric rhizome extract (TRE) in the diet, T100=100 mg/kg of TRE in the diet, T200=200 mg/kg of TRE in the diet, T300=300 mg/kg of TRE in the diet. a,b,cDifferent letters in the same row denote significant differences (P<0.05).
Table 3. Effect of turmeric rhizome extract supplementation on carcass characteristics of Wenchang broiler chickens.

| Diet treatments | T0 (control) | T100 | T200 | T300 |
|-----------------|--------------|------|------|------|
| Live weight, kg | 0.97±0.13    | 1.19±0.06 | 1.13±0.12 | 1.09±0.02 |
| Slaughter weight, kg | 0.88±0.11   | 1.08±0.05 | 0.97±0.15 | 1.00±0.03 |
| Dressing percentage, % | 90.56±1.74 | 90.70±0.30 | 85.72±4.70 | 91.25±1.01 |
| Eviscerated weight, kg | 0.65±0.08   | 0.79±0.03 | 0.77±0.09 | 0.75±0.02 |
| Eviscerated percentage, % | 66.75±1.36 | 66.46±0.96 | 68.06±2.13 | 68.80±1.04 |
| Breast muscle weight, g | 103.63±11.95 | 140.25±7.32 | 139.66±16.54 | 135.48±3.21 |
| Breast muscle weight ratio, % | 16.08±0.22 | 17.81±0.35 | 16.92±0.17 | 18.00±0.58 |
| Thigh muscle weight, g | 122.95±17.66 | 156.72±5.72 | 151.56±20.82 | 156.91±3.06 |
| Thigh muscle weight ratio, % | 19.05±0.97 | 19.90±0.44 | 19.65±1.05 | 20.85±1.00 |
| Abdominal fat ratio, % | 3.41±0.36 | 2.06±0.26 | 1.63±0.44 | 1.56±0.36 |

Table 4. Effect of turmeric rhizome extract supplementation on activities of superoxide dismutase and glutathione peroxidase, and levels of malondiadehyde in the serum of Wenchang broiler chickens.

| Diet treatments | T0 (control) | T100 | T200 | T300 |
|-----------------|--------------|------|------|------|
| SOD, U/mL       | 115.85±8.86a | 134.47±9.19b | 133.36±9.14ab | 143.23±6.68a |
| GSH-Px, U/mL    | 653.68±26.46a | 761.71±58.36a | 789.49±35.91a | 840.12±30.84a |
| MDA, mmol/mL    | 5.34±0.76a   | 3.91±0.13ab  | 3.05±0.24bc  | 2.30±0.35ab  |
| SOD, U/mL       | 130.71±5.82a | 146.61±4.53b | 149.73±3.64ab | 147.19±3.30ab |
| GSH-Px, U/mL    | 449.13±23.96a | 630.31±37.91a | 654.51±36.13a | 678.99±13.73a |
| MDA, mmol/mL    | 6.15±0.20a   | 4.47±0.11ab  | 4.02±0.18bc  | 4.12±0.07bc  |
| SOD, U/mL       | 142.02±4.94ab | 153.05±5.91ab | 156.60±8.17ab | 162.58±8.46ab |
| GSH-Px, U/mL    | 728.22±76.21ab | 806.73±21.79ab | 837.38±54.82ab | 840.12±30.84ab |
| MDA, mmol/mL    | 15.06±4.08ab | 12.42±1.49ab | 10.82±0.62ab | 7.53±0.69ab |

Table 5. Effect of turmeric rhizome extract supplementation on meat quality of Wenchang broiler chickens.

| Diet treatments | T0 (control) | T100 | T200 | T300 |
|-----------------|--------------|------|------|------|
| pH 45min        | 6.18±0.22    | 6.16±0.22 | 5.99±0.17 | 6.00±0.15 |
| Drip loss, %    | 2.41±0.07a   | 2.33±0.10ab | 2.22±0.07a | 1.77±0.08ab |
| IMF, %          | 2.27±0.73    | 2.21±0.27 | 2.47±0.57 | 2.24±0.72 |
| pH 24h          | 5.86±0.13    | 5.78±0.11 | 5.74±0.09 | 5.62±0.04 |
| Drip loss, %    | 2.29±0.10a   | 2.19±0.04ab | 2.16±0.08ab | 1.92±0.06ab |
| IMF, %          | 2.57±0.23    | 2.22±0.17 | 2.54±0.38 | 2.42±0.36 |

**Note:** T0=0 mg/kg of turmeric rhizome extract (TRE) in the diet, T100=100 mg/kg of TRE in the diet, T200=200 mg/kg of TRE in the diet, T300=300 mg/kg of TRE in the diet. a,b,c Different letters in the same row denote significant differences (P<0.05).
age than standard industrial broiler breeds.

Fat deposition in the abdominal area of broilers is regarded as waste in the poultry industry, since it represents a loss in the market and reduced consumer acceptability. The results of the current study indicated that TRE supplementation of broiler diets has the potential to reduce this type of waste by reducing abdominal fat content. In accordance with our results, Nourozian et al. (2011) reported that the addition of turmeric powder (3.3, 6.6 and 10 g/kg of diet) markedly reduced abdominal fat weight of broilers, as compared with the control group. Similarly, Rajput et al. (2013) reported that the addition of curcumin (150-200 mg/kg of feed) markedly reduced the abdominal fat ratio, as compared with the control group.

This decrease in abdominal fat might be due to the influence of curcumin on adipocyte apoptosis or glucose withdrawn from blood as reported by Sugiharto et al. (2011). Gandhi et al. (2011) and Kumari et al. (2007) reported that curcumin significantly decreased total cholesterol, which might be due to inhibition of hepatic 3-hydroxyl-3-methylglutaryl CoA-reductase, which is responsible for cholesterol synthesis in the liver (Al-Kassie et al., 2011).

**Antioxidant capability**

Curcuminoids, such as curcumin, demethoxycurcumin and bisdemethoxycurcumin, have antioxidative, anti-inflammatory, anticarcinogenic and antihepatotoxic activities. These curcuminoids are major antioxidative compounds of turmeric (Cousins et al., 2007). Curcumin is a potent quencher of singlet oxygen (1O2) and hydroxyl radicals (Motterlini et al., 2000). In vitro, curcumin was reported to inhibit the generation of reactive oxygen species, such as superoxide anions, H2O2 and nitrite radical generation by activated macrophages. Curcumin was also shown to decrease lipid peroxidation in rat liver microsomes, erythrocyte membranes and brain homogenates (Chattopadhyay et al., 2004). The findings of the present study also demonstrated that dietary TRE supplementation could improve the antioxidative capacity of broilers by increasing SOD and GSH-Px activities and decreasing serum MDA concentrations in broilers. These results are in accordance with those of several reports of standard broilers (Daneshyar, 2012; Daneshyar et al., 2012).

**Meat quality**

Generally, muscle pH values are reduced during the immediate post-mortem period; the rate of pH decline has usually remarkable effects on meat quality. In the present study, the muscle pH values were not influenced by dietary TRE supplementation. Similar to our findings, Daneshyar et al. (2011) reported that dietary supplementation of turmeric rhizome powder had no significant effect on the pH of thigh muscle. Drip loss is a parameter to evaluate the water holding capacity of meat. A low water holding capacity in muscles can increase the liquid outflow and lead to loss of soluble nutrients and flavour (Otto et al., 2004). The results of the present study showed that dietary TRE supplementation decreased the drip loss of broiler muscle in a dose-dependent manner. The results of the current study indicated that dietary TRE addition could improve the antioxidative capacity of broilers, thereby subsequently maintaining the integrity of the cell membrane and increasing the water holding capacity.

The results of the current study indicated that TRE addition to the diet of broilers did not affect the IMF content, as compared with the control group, which is in accordance with the finding of Daneshyar et al. (2011), who reported that dietary supplementation of turmeric rhizome powder at 0.25%-0.75% had no significant effect on ether extract of the muscle.

**Conclusions**

In conclusion, the results of the present study indicated that dietary TRE supplementation enhanced antioxidant capability, overall growth performance, and breast muscle weight, and reduced the abdominal fat ratio of Wenchang broiler chickens. Meanwhile, the addition of TRE improved the meat quality of Wenchang broiler chickens by increasing the water holding capacity.

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