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ANIMAL

Effects of dietary supplementation with curcumin-steviol glycoside on the growth performance and meat quality of white semi broilers

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Abstract

The aim of this study was to investigate the effect of adding curcumin-steviol glycoside complex (CSG) on the growth performance and meat quality of white semi broilers. A total of 60 one-day-old white semi broilers with an initial body weight (BW) 40.0 ± 0.2 g were used in a 5-week experiment. The three treatments were as follows: 1) CON; basal diet, 2) T1; CON + 0.5% CSG and 3) T2; CON + 1.0% CSG. Each treatment consisted of 5 replicate cages with 4 broilers per cage. In 0 - 2 weeks, the supplementation of 1.0% CSG in the diets significantly increased ($p < 0.05$) the BW and decreased the feed intake (FI), thereby improving the feed conversion ratio (FCR) compared to the CON group. For meat quality, the T2 group showed a higher water holding capacity (WHC) and lower drip loss (DL) and cooking loss (CL) compared to the CON group ($p < 0.05$). For meat color, the T2 group showed a significantly lower lightness (L*) and yellowness (b*) than that of the other treatment groups ($p < 0.05$). In the sensory evaluation, the meat color and texture in the T2 group were significantly improved ($p < 0.05$) compared with those of the other treatment groups. As a result, the acceptability of consumers was ameliorated. In conclusion, this study shows that the supplementation of CSG improved the growth performance and meat quality in white semi broilers. This study suggests that 1.0% CSG is the optimal level in the diet.

Keywords: curcumin-steviol glycoside, growth performance, meat quality, white semi broiler

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Introduction

Curcumin, the yellow compound in turmeric, is recognized as the main bioactive component of turmeric, which has neuroprotective activity *in vivo* (Prasad et al., 2014). The biological action of curcumin stimulates the secretion of bile acids and activates digestive enzymatic activity, thereby increasing the digestibility of nutrients (Platel and Srinivasan, 2000; AL-Sultan, 2003). In fact, it was reported that curcumin improved broiler's growth performance and liver function, and reduced

blood triglycerides and low-density lipoprotein (LDL)-cholesterol in broilers (Platel and Srinivasan, 2004; Durrani et al., 2006; Emadi and Kermanshahi, 2007; Kumari et al., 2007). In addition, curcumin improved meat quality and meat color by increasing antioxidant enzymatic activity in the breast meat of broilers (Zhang et al., 2015). Curcumin also demonstrated positive effects such as antibacterial (Gunes et al., 2013), anti-inflammatory (Gupta et al., 2010), and anti-proliferative (Sandur et al., 2007) activity, and has been used for the prevention and treatment of chronic pro-inflammatory diseases (Jurenka, 2009). However, despite the beneficial health effects of curcumin, its low water solubility, unstable chemical structure, and rapid metabolism make it difficult to absorb in the body, so its bioavailability is limited (Kharat and McClements, 2019). Steviol glycosides are substances extracted from stevia (*Stevia rebaudiana* Bertoni) leaves and have been used to increase solubility by dissolving poorly soluble substances (Ju, 2015). Previous studies have shown that steviol glycosides could improve the solubility of curcumin (Zhang et al., 2011). However, until now, there has been no research on curcumin as a feed additive for white semi-broilers, and most studies on curcumin supplementation have used broilers. Therefore, this study was conducted to investigate the effect of adding curcumin-steviol glycoside complex to white semi-broiler feed on growth performance and meat quality.

Materials and Methods

Prior to this study, the experimental protocol was revised and approved by the Institutional Animal Care and Use Committee of Chungbuk National University, Cheongju, Korea (CBNUA-1531-21-02).

Animals and experimental design

A total of 60 one-day-old white semi broilers with an initial body weight (BW) 40.0 ± 0.2 g were used in a 5-week experiment. White semi broiler was assigned to a completely randomized into three treatment groups based on the starting weight. curcumin-steviol glycosides complex (CSG) using this experiment was obtained by a commercial company (BIOTEN, Jeongeup, Korea). Dietary treatments were as follow: 1) CON (basal control), 2) T1 (CON + 0.5% complex of curcumin-steviol glycosides), 3) T2 (CON + 1.0% complex of curcumin-steviol glycosides). White semi broilers were fed with same diets that were formulated to meet or exceed the NRC (1994) requirement for poultry (Table 1). Table 1 was based on the basal diet composition table of Oh et al. (2020). All chickens allowed to consume diet and water *ad libitium*.

Sampling and measurements

Growth performance

Body weight gain (BWG) was calculated by measuring the BW for an individual at the beginning, middle (week 2) and final (week 5) of experimental period. Feed intake (FI) was calculated by subtracting the remaining amount from the diet supply amount when measuring weight, and feed conversion ratio (FCR) was calculated by dividing FI by BWG.

Table 1. Compositions of basal diets (as-fed-basis)[x].

Item	Content	
	Phase 1 (0 - 2 week)	Phase 2 (2 - 5 week)
Ingredients (%)		
Corn	46.16	57.75
Soybean meal (48% CP)	36.04	28.00
Wheat	10.00	10.00
Corn gluten meal (60% CP)	0.00	0.80
Wheat bran	4.50	0.00
L-lysine	0.00	0.14
DL-methionine	0.20	0.21
Choline chloride	0.20	0.20
Limestone	1.00	1.00
Dicalcium phosphate	1.50	1.50
Salt	0.20	0.20
Vitamin premix[y]	0.10	0.10
Mineral premix[z]	0.10	0.10
Calculated composition		
ME (Kcal·kg^{-1})	3,220	3,283
CP (%)	23.00	20.04
Lysine (%)	1.275	1.151
Methionine (%)	0.55	0.527
Ca (%)	0.80	0.80
P (%)	0.64	0.64

CP, crude protein; ME, metabolizable energy.

[x] Based on the basal diet composition table of Oh et al. (2020).

[y] Provided per kg of complete diet: 12,000 IU of vitamin A; 2,500 IU of vitamin D_3; 25 mg of vitamin E; 0.7 mg of vitamin K_3; 1 mg of thiamin, 12 mg of riboflavin; 2 mg of pyridoxine; 0.03 mg of vitamin B_{12}; 35 mg of niacin; 10 mg of Ca-pantothenate; 0.5 mg of folic acid and 0.085 mg of biotin; 1,700 mg of ethoxyquin.

[z] Provided per kg of complete diet: 35 mg, Fe; 60 mg, Zn; 85 mg, Mn; 70 mg, Cu; 1.6 mg, I; 0.1 mg, Se.

Meat quality

After the end of the experiment, 5 broilers per treatment (1/replicate pen) were selected at the time of slaughter, and then the breast meat was cut out and analyzed according to the item after freeze-drying. The pH of chicken breast was measured by adding 100 mL of distilled water to 10 g. All samples were homogenized at 7,000 rpm for 30 seconds using a homogenizer (Bihon seiki, Ace, Osaka, Japan), and then measured with a pH meter (Thermo Orion 535A, Thermo, IL, USA). The water holding capacity (WHC) was analyzed according to the Laakkonen et al. (1970) method. The drip loss (DL) was measured as the weight ratio (%) of the initial sample by measuring the loss generated by forming 2 cm thick breasts in a circular shape and vacuum packaging in a polypropylene bag and storing at 4℃ for 24 h. The cooking loss (CL) was measured by shaping a 3 cm-thick chicken breast into a circular shape, and immersed in a 70℃ water bath, allowing it to cool for 30 minutes, and measured by the weight ratio (%) of the initial sample. Shear force was carried out by a shear force cutting test using a Rheometer (Compac-100, Sun Scientific co., Tokyo, Japan), and the program used was R.D.S (Rheology Data System) Ver 2.01. The shearing force (SF) test condition was as follows: Table speed of 110 mm·min^{-1}, Graph Interval of 20 m·sec^{-1}, Load cell (max) of 10 kg. The meat color was measured with a spectro colorimeter (Model JX-777, Color Techno. System Co.,

Tokyo, Japan) standardized with a white plate (L*, lightness 94.04; a*, redness 0.13; b*, yellowness -0.51). At this time, a white fluorescent lamp (D65) was used as the light source.

Sensory evaluation

The sensory evaluation was conducted by subjective judgments of 20 people. The meat color, texture, taste/flavor, and acceptability were scored as 5 points-very high preference, 4 points-high preference, 3 points-moderate preference, 2 points-low preference, 1 point-very low preference.

Statistical analysis

All data were statistically processed using the GLM procedures of SAS (SAS Institute, Cary, NC, USA). Differences among all treatment means were determined using the Tukey's multiple range test with a $p < 0.05$ indicating statistical significance.

Results

Growth performance

Table 2 shows the effect on growth performance by adding CSG in white semi broilers diet. At 2 weeks, the BW was significantly higher ($p < 0.05$) in the T2 group which was the supplementation of 1.0% CSG in diets. There was no significant difference ($p > 0.05$) due to the large deviation within the treatment group in the end weight of the study. However, the average of BW was increased in the treatment group containing the CSG compared to the CON group. In 0 - 2 weeks, white semi broiler fed T2 treatment had higher ($p < 0.05$) BWG, and lower FI and FCR than CON group. In 2 - 5 weeks, T2

Table 2. Effect of supplemental complex of curcumin-steviol glycosides on growth performance in white semi broilers.

Item	CON	T1	T2	SE	p-value
BW					
Initial	40.3	40.0	39.7	0.2	-
week 2	186.7b	187.0b	203.0a	2.5	0.001
Final	629.3	651.7	655.0	20.3	0.626
0 - 2 weeks					
BWG	146.4b	147.0b	163.3a	2.5	0.001
FI	273.7a	257.3ab	241.7b	2.7	0.031
FCR	1.887a	1.751b	1.482c	0.029	0.014
2 - 5 weeks					
BWG	442.7	464.7	452.0	20.0	0.739
FI	934.7a	905.0a	841.0b	13.2	0.001
FCR	2.198	2.014	1.885	0.103	0.108
0 - 5 weeks					
BWG	589.0	611.7	615.3	20.3	0.615
FI	1208.4a	1162.3b	1082.7c	13.2	0.001
FCR	2.102a	1.936ab	1.771b	0.074	0.012

SE, standard error; BW, body weight; BWG, body weight gain; FI, feed intake; FCR, feed conversion ratio.
CON, basal diet; T1, basal diet + 0.5% complex of curcumin-steviol glycosides; T2, basal diet + 1.0% complex of curcumin-steviol glycosides.
a - c: Means with different letters are significantly different ($p < 0.05$).

group showed significantly lower FI ($p < 0.05$) than other treatment groups, but there was no difference in BWG. This means that the same efficiency and growth performance were showed even with a small amount of diet. During the overall period, T1 and T2 groups with supplementing CSG in diets had significantly lower FI ($p < 0.05$) than CON groups. In particular, the T2 group had lower FCR ($p < 0.05$) thereby improving growth performance ($p < 0.05$).

Meat quality

Table 3 shows the effect on meat quality when adding CSG in white semi broilers diet. The fat in the breast meat of white semi broiler was significantly increased ($p < 0.05$) in T1 and T2 groups compared to the CON group. Also, the pH in the breast meat was the lowest ($p < 0.05$) in T2 treatment. The WHC was significantly increased ($p < 0.05$) in the T2 group compared with other treatment groups.

Compared to the CON groups, the T2 group showed significantly lower values ($p < 0.05$) in DL and CL. For meat color, the T2 group showed significantly lower lightness (L*) and yellowness (b*) than the other treatment groups ($p < 0.05$).

Table 3. Effect of supplemental complex of curcumin-steviol glycosides on meat quality of chicken breast from white semi broilers.

Item	CON	T1	T2	SE	p-value
Water content (%)	81.1	79.8	79.9	0.50	0.167
Fat content (%)	3.52b	4.84a	4.60a	0.24	0.002
Ash content (%)	0.65	0.64	0.53	0.05	0.228
pH	6.29a	6.11b	6.00c	0.03	0.001
Water holding capacity (%)	55.8b	58.8ab	64.1a	2.50	0.085
Drip loss (%)	6.37a	5.73ab	3.59b	0.78	0.048
Cooking loss (%)	26.97a	24.74a	20.99b	1.14	0.007
Shearing force ($g \cdot g^{-1}$)	1735.0	1880.0	1960.0	90.2	0.210
Meat color					
L*	71.77a	71.27a	66.63b	1.46	0.038
a*	4.41	5.40	6.04	0.97	0.498
b*	14.49a	14.83a	12.79b	0.55	0.034

SE, standard error; L*, lightness; a*, redness; b*, yellowness.

CON, basal diet; T1, basal diet + 0.5% complex of curcumin-steviol glycosides; T2, basal diet + 1.0% complex of curcumin-steviol glycosides.

a, b: Means with different letters are significantly different ($p < 0.05$).

Sensory evaluation

Table 4 showed the effect of CSG on sensory evaluation of breast meat from white semi broilers. As a result of the sensory evaluation, the T2 group showed significantly higher results in meat color, texture, and acceptability than other treatment groups ($p < 0.05$).

Table 4. Effect of supplemental complex of curcumin-steviol glycosides on sensory evaluation of chicken breast from white semi broilers.

Sensory evaluation[z]	CON	T1	T2	SE	p-value
Meat color	1.80b	2.20b	3.53a	0.20	0.001
Texture	2.53b	2.80b	3.47a	0.20	0.007
Taste/flavor	2.40	2.80	2.93	0.19	0.133
Acceptability	1.87c	2.47b	3.53a	0.18	0.001

SE, standard error.

CON, basal diet; T1, basal diet + 0.5% complex of curcumin-steviol glycosides; T2, basal diet + 1.0% complex of curcumin-steviol glycosides.

[z] Sensory evaluation: Very high preference - 5, high - 4, moderate - 3, low - 2, very low - 1.

a - c: Means with different letters are significantly different ($p < 0.05$).

Discussion

White semi-broiler is a breed produced by crossing commercial laying hens and male broilers and is used as a raw material for Korean Samgyetang because of its low price and high growth performance (Cho et al., 2007; Oh et al., 2019). However, until now, there have been no studies on soluble curcumin supplements in white semi-broilers. So, in this study, we used soluble curcumin and white semi-broilers to compare growth performance and meat quality.

Growth performance

In this study, the addition of 1.0% CSG improved BWG and FCR compared to the control (CON) group at 0 - 2 and 0 - 5 weeks. According to a study by Johannah et al. (2018), the addition of 1.0% curcumin increased the BWG of broilers by 10% and decreased the FCR by 7.6%. Other studies have also demonstrated that the addition of curcumin improved the growth performance of broilers, consistent with the results of the present study (AL-Sultan, 2003; Mondal et al., 2015; Badran et al., 2020). This effect might be due to curcumin stimulating the secretion of digestive enzymes and bile acids, which increased the digestibility of nutrients (AL-Sultan and Gameel, 2004; Hernandez et al., 2004). However, in other studies, the addition of curcumin did not show a significant effect on growth performance (Rajput et al., 2013). The reason for this is that curcumin is fat-soluble and has a low absorption rate in the body due to its low solubility (Porn-anek and Promkot, 2017). Therefore, in this study, the absorption rate was increased through the solubility of curcumin, and it seems that the growth performance was increased.

Meat quality

In the present study, the fat content in the breast meat of white semi-broilers was significantly increased when CSG was added. In addition, the pH of the breast meat was lower than that of the CON group. In general, the pH of the muscle drops from pH 7.0 to pH 5.4 - 6.0 within 24 hours after slaughter (Penny, 1977). Therefore, it could be said that all the pH values in this study were within the normal range, and although there were significant differences between the treatment groups, the addition of CSG to the white semi-broiler diet was considered to have no dramatic effect on pH. Kim et al. (2010) reported that water-holding capacity, which is a property of maintaining moisture in meat, is inversely related to cooking loss and drip loss. In this study, the addition of the curcumin-steviol complex increased water-holding capacity and decreased cooking and drip

loss, which was similar to the results of previous studies (Partovi et al., 2019). The oxidation of myoglobin, which is mainly responsible for meat color post-mortem, could lead to the discoloration of meat (Faustman et al., 2010). According to Zhang et al. (2015), curcumin, which has antioxidant properties similar to those of vitamin E, significantly improved the antioxidant capacity of breast meat. In addition, other studies have shown that the increased activity of antioxidant enzymes improved meat quality, especially meat color (Brenes et al., 2008; Sahin et al., 2012). However, in this study, redness (a*) and yellowness (b*) significantly decreased when the additives were increased. This difference was thought to be due to the difference in the species of animals used in the experiments, the difference in the forms of curcumin, and the level of supplementation.

Sensory evaluation

Spice has traditionally been used for centuries to improve the sensory characteristics of foods (Botsoglou et al., 2002). Lipid oxidation is a major cause of quality deterioration and undesirable odors and flavors, which affect the sensory and nutritive values of meat products (Gray et al., 1996; Ruiz et al., 2001). However, curcumin has antioxidative activity (Nishiyama et al., 2005). Curcumin is a potent quencher of singlet oxygen species (Das and Das, 2002) and the major antioxidant component of turmeric. It was shown to inhibit lipid peroxidation and scavenge superoxide anion and hydroxyl radicals (Ruby et al., 1995; Motterlini et al., 2000). It is thought that meat color was improved in the sensory evaluation of this study due to this antioxidant activity. According to Kim et al. (2010), WHC affects the texture of meat. In this study, the addition of CSG increased the WHC and thus, improved the texture. In addition, CSG supplementation had a positive effect on texture and meat color, and for this reason, it is considered that the acceptability by consumers was the highest.

Conclusion

The results of this study indicated that supplementation of 1.0% CSG improved growth performance including increased BWG and reduced FI for 0 - 2 weeks. Also, the addition of 1.0% CSG did not affect the BWG but reduced FI, resulting in improving FCR within the overall period. For meat quality, the supplementation of 1.0% CSG resulted in improved meat quality with high WHC, low DL and CL. Moreover, in the sensory evaluation, it scored high in texture and meat color, increasing the consumer's acceptability. In conclusion, the addition of 1.0% CSG in white semi broiler diets improved on growth performance, meat quality and sensory evaluation.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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