Effects of Turmeric Residue on Production Performance, Egg Quality, and Yolk Cholesterol and Malondialdehyde Content in Laying Hens (Postprint)

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Abstract

This study aimed to investigate the effects of dietary turmeric residue supplementation on production performance, egg quality, and the contents of fat, cholesterol, and malondialdehyde (MDA) in egg yolk of laying hens. A total of 384 healthy 46-week-old Lohmann Brown laying hens were randomly allocated into 4 groups with 6 replicates per group and 16 birds per replicate. The control group was fed a basal diet, while the experimental groups were fed experimental diets supplemented with 0.5%, 1.0%, and 1.5% turmeric residue to the basal diet, respectively. The preliminary period was 7 days, and the experimental period was 56 days. The results showed that compared with the control group, dietary turmeric residue supplementation had no significant effect on average daily feed intake, laying rate, average egg weight, feed-to-egg ratio, or mortality and culling rate of laying hens ($P > 0.05$). Dietary supplementation with 1.5% turmeric residue significantly increased the qualified egg rate ($P < 0.05$) and significantly decreased the soft-shell and broken egg rate and inferior egg rate ($P < 0.05$). Dietary turmeric residue supplementation had no significant effect on egg quality ($P > 0.05$). Dietary supplementation with 0.5%, 1.0%, and 1.5% turmeric residue significantly decreased the cholesterol and MDA contents in egg yolk ($P < 0.05$). Therefore, it can be concluded that dietary turmeric residue supplementation can increase the qualified egg rate, decrease the inferior egg rate and soft-shell and broken egg rate, and reduce the cholesterol and MDA contents in egg yolk.

Full Text

Effects of Turmeric Residue on Performance, Egg Quality and the Contents of Cholesterol and Malondialdehyde in Yolk of Laying Hens

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Abstract

This experiment was conducted to investigate the effects of dietary turmeric residue on production performance, egg quality, and the contents of ether extract, cholesterol, and malondialdehyde (MDA) in egg yolk of laying hens. A total of 384 healthy 46-week-old Roman Brown laying hens were randomly allocated to four groups with six replicates per group and sixteen hens per replicate. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 0.5%, 1.0%, and 1.5% turmeric residue, respectively. The pre-test period lasted 7 days, followed by a 56-day experimental period. The results showed that compared with the control group, dietary turmeric residue supplementation had no significant effects on average daily feed intake, laying rate, average egg weight, feed-to-egg ratio, or mortality rate ($P > 0.05$). However, supplementation with 1.5% turmeric residue significantly increased the qualified egg rate ($P < 0.05$) and significantly decreased both the soft-broken egg rate and defective egg rate ($P < 0.05$). Although turmeric residue supplementation did not significantly affect egg quality parameters ($P > 0.05$), the addition of 0.5%, 1.0%, and 1.5% turmeric residue significantly reduced the contents of cholesterol and MDA in egg yolk ($P < 0.05$). These findings indicate that dietary turmeric residue can improve the qualified egg rate while reducing defective and soft-broken egg rates, and can decrease cholesterol and MDA contents in egg yolk.

Keywords: turmeric residue; laying hen; performance; egg quality; cholesterol; malondialdehyde

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Introduction

Turmeric (*Curcuma longa*), also known as yellow ginger, is a traditional Chinese medicinal herb with functions including promoting blood circulation, dis-

sipating blood stasis, soothing the liver, and reducing blood lipids. Its active components are flavonoid curcuminoids and various volatile oils [1]. Curcumin exhibits broad-spectrum antioxidant activity [2] and can scavenge free radicals in vivo, demonstrating hepatoprotective and anticancer effects [3]. Additionally, curcumin can reduce cholesterol and triglyceride levels, thereby protecting the cardiovascular system [4]. Both volatile oils and curcumin possess strong anti-inflammatory and antibacterial properties [5,6]. When used as a feed additive in broiler diets, curcumin can prevent diseases, improve health status, enhance production performance and feed utilization, improve meat quality, and regulate immune function [7-9]. Turmeric residue is a powdered substance produced by drying and crushing turmeric after organic solvent extraction of curcumin and turmeric oil. While turmeric contains 3%-6% curcumin [10], some residual curcumin remains in the residue after extraction [11]. Turmeric residue also contains starch, protein, fat, cellulose, trace elements, and alkaloids. Utilizing this byproduct as a feed additive in animal production not only represents rational use of waste resources but may also confer beneficial effects on animal performance and physiological status. Tropical regions of Asian countries such as India and China are the primary producers of turmeric. With increasing demand for curcumin in pharmaceutical and healthcare applications, China' s turmeric imports have grown substantially from 2 tons in 2009 to approximately 1,000 tons in 2014. Consequently, the production of turmeric residue as a byproduct of curcumin manufacturing has also increased annually. Applying turmeric residue in animal production could enhance the added value of turmeric products while improving animal performance and economic benefits. This study aimed to investigate the effects of turmeric residue on laying hen performance, egg quality, and the contents of ether extract, cholesterol, and MDA in egg yolk, thereby providing a scientific basis and guidance for its application in animal production.

1.1 Experimental Materials

Turmeric residue was purchased from Henan Laieryin Biological Technology Co., Ltd. Laboratory analysis determined its nutrient composition as follows: dry matter 91.71%, crude protein 5.16%, ether extract 1.21%, crude fiber 8.67%, gross energy 14.77 MJ/kg, and apparent metabolizable energy for chickens 5.89 MJ/kg. The amino acid composition was: aspartic acid 0.79%, glutamic acid 0.74%, histidine 0.20%, serine 0.12%, glycine 0.34%, threonine 0.25%, arginine 0.24%, alanine 0.25%, tyrosine 0.18%, methionine 0.05%, valine 0.40%, phenylalanine 0.32%, isoleucine 0.30%, leucine 0.54%, and lysine 0.15%.

Cholesterol standard (purity $\geq$ 99.7%) was obtained from the National Institute of Metrology, China. The micro-MDA assay kit was purchased from Nanjing Jiancheng Bioengineering Institute.

1.2 Experimental Animals and Management

The experiment utilized 384 healthy 46-week-old Roman Brown laying hens. A single-factor completely randomized design was employed, dividing the hens into four groups with six replicates per group and sixteen hens per replicate. The pre-test period lasted 7 days, followed by a 56-day formal experimental period.

Hens were housed in two-tiered step cages with one bird per cage, and replicates were evenly distributed throughout the poultry house. Birds had ad libitum access to feed and water. Lighting combined natural and artificial illumination, while ventilation employed both natural and negative-pressure systems. Manure removal and egg collection were performed twice daily, with routine immunization and disinfection conducted according to standard protocols.

1.3 Experimental Design and Diets

The basal diet was formulated according to the nutrient requirements for laying hens established by NRC (1994). The control group received the basal diet, while the experimental groups were fed the basal diet supplemented with 0.5%, 1.0%, and 1.5% turmeric residue, respectively. The composition and nutrient levels of the experimental diets are presented in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (air-dry basis), %

Note: The premix provided the following per kg of diet: Fe (as ferrous sulfate) 70 mg, Cu (as copper sulfate) 20 mg, Zn (as zinc sulfate) 70 mg, Se (as sodium selenite) 0.5 mg, VA 7,000 IU, VD_3 2,500 IU, VE 30 mg, VK_3 1 mg, VB_1 1.5 mg, VB_2 4 mg, VB_6 1.5 mg, nicotinic acid 30 mg, folic acid 0.55 mg, D-pantothenic acid 10 mg, VB_{12} 0.02 mg, biotin 0.16 mg, and choline 400 mg. Nutrient levels were all calculated values.

1.4 Measurements and Methods

1.4.1 Production Performance During the experimental period, daily records were maintained for each replicate, including total egg production, total egg weight, feed intake, numbers of soft-broken eggs (soft-shelled and broken eggs), defective eggs (misshapen, thin-shelled, and rough-shelled eggs), and mortality. Group-based statistics were calculated for laying rate, average egg weight, qualified egg rate, soft-broken egg rate, defective egg rate, mortality rate, average daily feed intake, and feed-to-egg ratio.

1.4.2 Egg Quality Every 7 days, one egg per replicate with weight close to the average was selected for quality analysis. Measurements included protein ratio, yolk ratio, eggshell thickness (using an eggshell thickness gauge), egg shape index (using vernier calipers), yolk color (using yolk color fan), and albumen height (using an albumen height gauge). Haugh units were calculated using the formula: Haugh unit = $100 \times \log(H - 1.7W^{0 \cdot 37} + 7.60)$, where H represents

albumen height (mm) and W represents egg weight (g). Data collected over the 56-day period were averaged by group for statistical analysis.

1.4.3 Ether Extract, Cholesterol, and MDA Contents in Egg Yolk
Every 7 days, one egg per replicate with weight close to the average was collected for analysis of ether extract (by Soxhlet extraction), cholesterol (by high-performance liquid chromatography), and MDA contents. The 56-day average values were subjected to group-based statistical analysis.

The cholesterol extraction method followed the direct extraction procedure described by Zhang et al. [12]. Briefly, 5 g of egg yolk was accurately weighed, dissolved, and diluted to 50 mL. Then 1.0 mL of the diluted yolk solution was transferred to a 10 mL centrifuge tube, mixed with 1.0 mL of 95% ethanol using a vortex mixer, followed by addition of 2.5 mL diethyl ether. After mixing, 2.5 mL petroleum ether was added, vortexed, and centrifuged at 3,000 r/min for 5 minutes. The upper extract was collected, dried under nitrogen at below 45 °C, redissolved in 2.0 mL anhydrous ethanol, filtered through a 0.45 μm organic microporous membrane, and injected for analysis. Chromatographic conditions were: column ZORBAX Eclipse XDB-C18 (4.6 mm × 150 mm, 5 μm); mobile phase acetonitrile-isopropanol (4:1, V/V); flow rate 0.8 mL/min; column temperature 35 °C; detection wavelength 210 nm; injection volume 10 μL. The cholesterol retention time was 12.571 minutes.

1.5 Statistical Analysis

Experimental data were initially processed using Excel 2010 and subsequently analyzed using SPSS 19.0 statistical software. One-way ANOVA was performed, followed by independent samples t-tests. Significance was declared at $P < 0.05$, and Duncan' s multiple comparison test was applied when significant differences were detected. Results are expressed as "mean ± standard deviation."

2.1 Effects of Turmeric Residue on Production Performance of Laying Hens

The effects of turmeric residue on production performance are presented in Table 2 . Compared with the control group, dietary turmeric residue supplementation had no significant effects on average daily feed intake, laying rate, average egg weight, feed-to-egg ratio, or mortality rate ($P > 0.05$). However, supplementation with 0.5%, 1.0%, and 1.5% turmeric residue increased the qualified egg rate by 2.33% ($P > 0.05$), 0.46% ($P > 0.05$), and 5.25% ($P < 0.05$), respectively, while decreasing the soft-broken egg rate by 39.90% ($P > 0.05$), 48.56% ($P > 0.05$), and 56.73% ($P < 0.05$), and reducing the defective egg rate by 15.40% ($P > 0.05$), 10.51% ($P > 0.05$), and 43.03% ($P < 0.05$), respectively.

Table 2 Effects of turmeric residue on performance of laying hens

Note: In the same row, values with different lowercase letter superscripts indicate significant differences ($P < 0.05$), while values with the same or no letter

superscripts indicate no significant difference ($P > 0.05$). This applies to all tables.

2.2 Effects of Turmeric Residue on Egg Quality of Laying Hens

The effects of turmeric residue on egg quality are shown in Table 3 . Compared with the control group, dietary turmeric residue supplementation increased eggshell thickness, egg shape index, yolk color, and Haugh unit, but these differences were not statistically significant ($P > 0.05$).

Table 3 Effects of turmeric residue on egg quality of laying hens

2.3 Effects of Turmeric Residue on Ether Extract, Cholesterol, and MDA Contents in Egg Yolk

The effects of turmeric residue on ether extract, cholesterol, and MDA contents in egg yolk are presented in Table 4 . Compared with the control group, dietary supplementation with 0.5%, 1.0%, and 1.5% turmeric residue decreased ether extract content by 1.79% ($P > 0.05$), 2.04% ($P > 0.05$), and 1.07% ($P > 0.05$), respectively. However, all three supplementation levels significantly reduced cholesterol content by 17.87% ($P < 0.05$), 21.82% ($P < 0.05$), and 18.52% ($P < 0.05$), respectively, and significantly decreased MDA content by 13.61% ($P < 0.05$), 20.39% ($P < 0.05$), and 22.71% ($P < 0.05$), respectively.

Table 4 Effects of turmeric residue on the contents of ether extract, cholesterol and malondialdehyde in yolk of laying hens

3.1 Effects of Turmeric Residue on Production Performance and Egg Quality

Previous studies have demonstrated that dietary turmeric powder or curcumin can significantly improve daily weight gain and reduce feed-to-gain ratio in broilers [7-9,13], but has shown no significant effects on production performance indices such as average egg weight, egg production, laying rate, or feed-to-egg ratio in laying hens [14-16]. As a byproduct of turmeric processing, turmeric residue may exert similar but not necessarily identical effects to curcumin, and research on this material remains scarce. The present study found that turmeric residue supplementation increased laying rate and average egg weight numerically, though not significantly. Notably, 1.5% turmeric residue significantly improved the qualified egg rate while reducing both soft-broken and defective egg rates. Soft-broken egg production is associated with eggshell quality and the nutritional status of calcium, phosphorus, and vitamins, and turmeric residue supplementation increased eggshell thickness while decreasing soft-broken egg rate [17]. However, whether turmeric residue can improve calcium and phosphorus utilization in laying hens requires further investigation. Defective egg production is often related to disease, stress, and nutritional factors [18]. Samarasinghe et al. [13] reported that turmeric powder enhanced dietary energy and

protein utilization in broilers, suggesting that turmeric residue may share similar benefits in improving nutritional status of laying hens.

Dietary curcumin has been shown to improve yolk color, eggshell thickness, and Haugh unit in laying hens [16], findings consistent with the present results, indicating that turmeric residue and curcumin have similar effects on egg quality. The Haugh unit reflects albumen condition and egg freshness, and curcumin' s antioxidant function in scavenging free radicals [2] helps maintain protein properties and functionality, thereby potentially increasing Haugh unit. However, due to the relatively low curcumin content in turmeric residue, supplementation at 0.5%, 1.0%, and 1.5% showed trends for improved yolk color and Haugh unit but without significant differences from the control group. The maximum inclusion level in this study was 1.5%, and whether higher supplementation levels would significantly affect egg quality parameters warrants further investigation.

3.2 Effects of Turmeric Residue on Ether Extract, Cholesterol, and MDA Contents in Egg Yolk

The current study demonstrated that dietary turmeric residue supplementation had no significant effect on ether extract content in egg yolk, a finding consistent with previous studies using curcumin in laying hen diets [15,16]. Research in mice, rats, and rabbits has shown that curcumin significantly reduces serum total cholesterol [19-22], while studies in broilers revealed that 250 and 350 mg/kg curcumin significantly decreased abdominal fat percentage, liver fat percentage, and subcutaneous fat thickness in Arbor Acres broilers and Wannan Jianghuang chickens [23], and significantly reduced serum total lipids and cholesterol in broiler chickens [24]. However, results in laying hens have been inconsistent, with some studies reporting no significant effects of curcumin on serum or yolk cholesterol [15,16]. In contrast, the present study found that turmeric residue significantly reduced yolk cholesterol content, a discrepancy that may be attributed to differences in dosage or the presence of other bioactive compounds in turmeric residue besides curcumin. In laying hens, the liver and ovary are the primary sites of cholesterol synthesis [25], with the liver having the fastest synthesis rate. Yolk cholesterol is mainly derived from very low-density lipoprotein (VLDL) and vitellogenin (VTG) synthesized in the liver [26]. The liver assembles cholesterol into VLDL-cholesterol (VLDL-C) for secretion into the bloodstream, which is then transported to oocytes to form yolk cholesterol [27]. Curcumin can increase the activities of heparinized plasma total lipolytic enzyme (PHTA), lipoprotein lipase (LPL), and hepatic lipase, thereby accelerating cholesterol lipoprotein metabolism and significantly reducing serum and liver cholesterol [21]. Turmeric residue may similarly regulate hepatic lipase activity in laying hens, accelerating cholesterol metabolism in the liver and reducing cholesterol entry into the bloodstream, consequently decreasing yolk cholesterol formation, though the detailed mechanism requires further validation.

Malondialdehyde is the primary product of lipid peroxidation, and its content reflects the degree of lipid oxidation. The phenolic hydroxyl groups in curcumin'

s molecular structure confer antioxidant properties and make it an effective free radical scavenger [28,29]. Studies have shown that curcumin reduces lipid peroxide content in rat serum and liver while increasing superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities [30,31]. The present study demonstrated that dietary turmeric residue significantly decreased MDA content in egg yolk, an effect likely attributable to the residual curcumin present in turmeric residue.

Conclusion

Dietary supplementation with 1.5% turmeric residue significantly improved the qualified egg rate while reducing soft-broken and defective egg rates. Supplementation with 0.5%, 1.0%, and 1.5% turmeric residue significantly decreased cholesterol and MDA contents in egg yolk.

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Note: Figure translations are in progress. See original paper for figures.