Effects of Green Tea Powder on Laying Performance and Egg Quality in Laying Hens

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ABSTRACT : This experiment was carried out to evaluate the effects of feeding green tea powder on laying performance and egg quality in hens. A total 180 "Tetran Brown" laying hens aged 40 weeks were assigned to 6 treatments in a completely randomized design. Each treatment consisted of five replicates accommodating six layers per replication. The experimental diets were a negative control containing no green tea, a positive control diet containing antibiotics (0.05% chlortetracycline) and diets containing 0.5%, 1.0%, 1.5% and 2.0% green tea powder. Egg production rate of layers fed the diets containing green tea powder did not differ significantly from that of the negative and positive controls ($p>0.05$). Egg weight was decreased significantly in the group fed the diet containing 0.5% green tea powder ($p<0.05$). Feed intake of layers was significantly higher for the diet containing 1.5% green tea powder compared to that of negative and positive control diets ($p<0.05$). The eggshell thickness reduced significantly in the layer group fed the diets containing green tea powder regardless of dietary levels ($p<0.05$). Green tea powder tended to reduce egg yolk cholesterol in this experiment. Particularly, dietary 2% level of green tea powder significantly suppressed the cholesterol contents of the egg yolk ($p<0.05$). Thiobarbituric acid value (TBA) of egg yolk was significantly reduced by green tea diets ($p<0.05$). The yellowness of egg yolk was increased in the layers fed the 2.0% green tea diet compared with that of control diet ($p<0.005$). The Linoleic and α-linolenic acids tended to increase in the group fed diets containing 1.5% green tea powder even though there were no significant differences among treatments ($p>0.05$). The oleic and docosahexaenoic acid contents of the egg yolk were similar among treatments ($p>0.05$). Based on the results of the experiment, it is concluded that green tea powder inclusion in the diet for layers at 2.0% level can reduce the cholesterol content and TBA value of the egg yolk, implying its potential effect on egg quality parameters. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 12 : 1769-1774)***

Key Words : Green Tea, Antibiotics, Feed Intake, Albumin, Cholesterol, Laying Hens

INTRODUCTION

In recent days, consumers are interested in functional foods that can prevent or ameliorate adult diseases. These food products are specially labeled to be differentiated from other general products in the market. Chicken eggs are among such food groups. Consumers' interest in health as well as food safety and animal welfare issues began to increase demand for functional eggs from hens fed the animal fat-free, hormone-free diets (Cherian et al., 2002). There has been much information about the positive impacts of functional foods on human health in the past five years and special attention has been paid to the non-nutritive components of plant resources such as teas, spices and herbs (Dufresne and Farnworth, 2001).

Green tea (*Camellia sinensis)* is much more than just a refreshing beverage. It provides many health benefits as well. Recent studies demonstrated that about 2.5 million cubic tons of dried tea is manufactured annually, of this total, approximately 20% is consumed in Asian countries including China, Korea and Japan. Some studies have been performed with animal models, mostly with rodents, to get a better understanding of the effects of green tea components on living organisms (Yang and Wang, 1993; Dreosti et al., 1997). Current studies informed that green tea and catechins, the main components of green tea, have many physiological and biochemical functions including antioxidant and antimutagenic effects (Yen and Chen, 1995; Kuroda and Tomita, 1999). Grimble (1998) reported that green tea had effects to reduce the serum and liver cholesterol levels in the rat. Yamane et al. (1999) reported that green tea extracts included in the diet improved egg quality profiles in a short-term experiment. Also in a long-term feeding study of green tea powder for laying hens had favorable effects on egg quality traits such as thick albumen stability without adverse effect on laying performance (Biswas et al., 2000). Therefore, the objective of this study was to evaluate the effects of green tea powder on laying performance and egg composition of layers as a reference to recommend the optimum dietary level of green tea powder for egg-laying hens.

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Table 1. Formula and chemical composition of the experimental diets (%)

Ingredients (%)	Control	Anti-biotics	Green tea powder level (%)			
			0.5	1.0	1.5	2.0
Corn grain	65.59	65.59	65.59	65.59	65.59	65.69
Wheat bran	6.50	6.45	6.00	5.50	5.00	4.50
Soybean meal-44%	16.00	16.00	16.00	16.00	16.00	16.00
Corn gluten meal-60	2.60	3.60	2.60	2.60	2.60	2.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vit-min. mix[1]	0.30	0.30	0.30	0.30	0.30	0.30
Lysine-HCI	0.04	0.04	0.04	0.04	0.04	0.04
Methionine	0.07	0.07	0.07	0.07	0.07	0.07
Limestone	7.73	7.73	7.73	7.73	7.73	7.73
Tricalcium phosphate	0.87	0.87	0.87	0.87	0.87	0.87
Antibiotics	0.00	0.05	0.00	0.00	0.00	0.00
Green tea powder	0.00	0.00	0.50	1.00	1.50	2.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]						
ME (kcal/kg)	2,751	2,750	2,744	2,736	2,729	2,722
Crude protein (%)	15.01	15.00	14.94	14.87	14.79	14.72
Calcium (%)	3.25	3.25	3.25	3.25	3.25	3.25
Avail. P	0.25	0.25	0.25	0.25	0.24	0.24

[1] Vit-min. mix provided following nutrients per kg of diet: Vitamin A, 9,000,000 IU; Vitamin D_3, 2,100,000 IU; Vitamin E, 15,000 IU; Vitamin K, 2,000 mg: Vitamin B_1, 1,500 mg; Vitamin B_2, 4,000 mg; Vitamin B_6, 3,000 mg; Vitamin B_{12}, 15 mg; Pan-acid-Ca, 8,500 mg; Niacin, 20,000 mg; Biotin, 110 mg; Folic-acid, 600 mg; Fe, 40,000 mg; Co, 300 mg; Cu, 3,5000 mg; Mn, 55,000 mg; Zn, 40,000 mg; I, 600 mg; Se, 130 mg.
[2] Calculated values.

MATERIALS AND METHOD

Animals and experimental design

A total of 180 "Tetran Brown" layers aged 40 weeks were assigned to 6 treatments in a completely randomized design. For this experiment, two layers were housed in one cage (24 cm×38 cm×45 cm). Each treatment had 5 replicates, of which one was consisted of 3 adherent cages. The six dietary treatments were negative control (basal diet without green tea powder), positive control (basal diet +0.05% chlortetracycline), and diets containing 0.5, 1.0, 1.5 and 2.0% green tea powder. The experimental diets and drinking water were supplied *ad libitum*. The room temperature was maintained at 20±2°C through the air conditioner and lighting was intermediate. The layers were given one week of adjustment period before the 8-week trial began.

Experimental diet and feeding

The green tea powder used in this experiment was provided from the Green Tea Experimental Station (Bosung, Korea). The composition of green tea was analyzed according to the AOAC method (1990). Chemical compositions of green tea represented 94.01% DM, 21.37% CP, 0.67% EE, 17.35% CF and 5.39% crude ash on an as fed basis. The experimental diets (Table 1) were formulated to meet or exceed nutrient requirements of laying hens (NRC, 1994). All the eggs produced each day were collected and counted for record. Egg collection was manual, performed daily at 17:00 pm each day. All the eggs produced on a certain day of the week were weighed individually. The egg production rate, egg weight, egg mass, feed conversion ratio and egg shell thickness were determined on weekly basis. Thiobarbituric acid value (TBA) and egg yolk color were measured for the last 2 consecutive weeks of the experiment. Analysis on fatty acid composition of the egg yolk, egg yolk cholesterol and sensory evaluation on eggs were carried out at the end of the experiment.

Measurements

Feed intake and feed conversion : Feed intake was determined weekly by measuring feed residues. Feed conversion was calculated by dividing feed intake by egg mass.

Egg production rate, egg weight and egg mass : Egg production rate was calculated by dividing total number of eggs by hen-day and expressed in percent on weekly basis. Egg weight was measured by electronic scale HM-200 (A&D Co., Ltd, Japan). Egg mass was calculated by multiplying the average egg weight by egg production rate.

Eggshell thickness : Fifteen eggs from each treatment were selected for eggshell thickness measurement. Egg yolk, albumen and shell membranes were removed from broken eggs. Shell thickness was measured by Peacock dial pipe gauge FHK (Model P-1, Ozaki, Meg. Co., Ltd, Japan) and represented as average thickness of large band, sharp end and middle band of the shell.

Table 2. Effects of green tea powder on laying performance

Parameters	Control	Antibiotics	Green tea powder level (%)			
			0.5	1.0	1.5	2.0
Egg production rate (%)	88.52±1.03[1]	87.56±1.45	88.40±1.33	91.13±0.89	89.57±0.98	87.96±1.64
Egg weight (g)	63.19±0.24^{ab}	63.66±0.26^{a}	61.46±0.22^{c}	62.87±0.31^{ab}	63.73±0.32^{a}	62.19±0.59^{bc}
Egg mass (g)	55.99±0.73^{ab}	55.77±1.08^{ab}	54.33±0.82^{b}	57.22±0.62^{a}	57.16±0.77^{a}	54.76±1.37^{ab}
Feed intake (g/hen/day)	121±1.63^{c}	124±1.62^{bc}	125±2.04^{b}	125±1.88^{b}	128±1.91^{a}	123±2.01^{bc}
FCR (kg/kg)	2.20±0.04^{b}	2.25±0.06^{ab}	2.35±0.06^{a}	2.18±0.02^{b}	2.27±0.04^{ab}	2.27±0.05^{ab}
Egg shell thickness (μm)	373±8.56^{a}	366±2.83^{ab}	361±4.77^{bc}	361±5.26^{bc}	356±4.36^{b}	361±5.69^{bc}

$^{a, b, c}$ Means with different superscripts within the same row are significantly different ($p<0.05$).

[1] Standard error.

Chemical analysis

Catechin components of the green tea : For this analysis, the method devised by Ikeda et al. (2003) was used: Approximately 100 mg green tea powder was dissolved into 100 ml double distilled water and heated in a water bath at 80°C for 30 min. After cooling, it was filtered through Whatman No.1 paper. The filtrate was transferred to a separating funnel and chloroform added. After washing 3 times with chloroform, the solution was separated into 2 layers. The water layer was collected, and catechin component was fractionated with 25 ml of ethyl acetate. The ethyl acetate fraction was evaporated at 30°C in a rotary evaporator under the nitrogen flow. Finally, the concentrate was dissolved in methanol and passed through a membrane filter (0.45 μm polyvinylidene diflouride) and Sep-Pack C_{18} cartridge. The catechin components were isolated by HPLC (Model 501, Waters, Milford, USA). The catechin components of green tea were determined as follows: total catechin 15.72%, (+) Catechin 0.94%, Epicatechin 1.42%, Epigallocatechin 1.59%, Epicatechin gallate 2.41% and Epigallocatechin gallate 9.36%.

Cholesterol content in egg yolk : A total of 30 eggs (5 eggs from each treatment) were collected for cholesterol analysis. The cholesterol content was determined by the method of Brunnekreeft et al. (1983). Approximately 0.5 g egg yolk and 100 μg of α-cholestane was homogenized with 0.5 N KOH solution and saponified for 30 minutes at 55°C. The cholesterol was extracted with hexane and analyzed by gas chromatography (HP 5890 series II, USA) equipped with HP-1 (cross-linked methyl silicone, 25 m×0.32 mm×0.17 μm) capillary column.

Yolk rancidity : Oxidation degree of egg yolk was determined as described by Vernon et al. (1970). For this analysis 20 g egg yolk mixture (pooled 2 egg yolk from one replicate) was blended with the cold extraction solution containing 20% trichloroacetate in 2 M phosphoric acid, and the slurry was allowed to precipitate. The supernatant was diluted to 100 ml DW and filtered through Whatman No.1 paper. Then 5 ml of the filtrate was transferred to a test tube (15×30 mm) where 5 ml of 0.005 M 2-thiobarbituric solution was added. The solution was mixed by inversion and kept in the dark for 15 h at room temperature. The resulting color was measured at a 530 nm with Spectrophotometer (KONTRON 942, Italy).

Egg yolk color : Five eggs (one egg per replicate, total of 30 eggs) from each treatment were selected for egg yolk color determination. The egg albumen, eggshell and shell membranes were removed from broken eggs and the egg yolk color was measured using Chromameter, CR-200 (Minolta, Japan).

Fatty acid composition of egg yolk : Five eggs (one egg per replicate, total of 30 eggs) from each treatment were collected for fatty acid analysis. Each egg was cracked into a 50 ml glass beaker and prior to introducing the egg yolk to the beaker, the egg shell, albumen and yolk membrane were removed, then 5 gram of egg yolk were taken by plastic spoon and dissolved into 100 ml of Folch solution (Chloroform: methanol 2:1 v/v) and filled with nitrogen (N) gas. After 30 min extraction at room temperature with shaking, the extract was filtered through a Buchner filter. After adding 70 ml of distilled water, the extract was separated by a liquid phase extraction method and the organic layer was collected for vacuum condensation. The concentrated solution was transferred to a test tube and dried under N gas followed by addition of 3 ml of 5% sulfuric acid-methanol then extracted 3 times with 3 ml of petroleum ether, dried again under nitrogen gas and melted with petroleum ether (100 μg) and analyzed through Gas chromatograph (GC).

Sensory evaluation for table eggs : A total of 30 boiled eggs (5 eggs from each dietary group, total of 30 eggs) laid on the 56th day of feeding, were organoleptically evaluated by a panel of 15 judges on the six point hedonic scale in terms of appearance, color, juiciness, texture, flavor and overall acceptability.

Statistical analysis

Differences among treatment means were analyzed using Duncan's Multiple Range Test (Duncan, 1955) with SAS program (SAS, 1990).

RESULTS AND DISCUSSION

Productive performance

Egg production rate, egg weight, egg mass, feed intake,

Table 3. Effect of green tea powder on cholesterol content and TBA value of egg yolk

Treatments	Total cholesterol (mg/g)	TBA value (μmol/100 g)
Control	11.62±0.62[1ab]	2.38±0.21[1a]
Antibiotics	12.86±0.57[a]	1.84±0.18[b]
Green tea powder 0.5%	11.25±0.53[ab]	1.97±0.25[b]
Green tea powder 1.0%	11.49±0.52[ab]	1.78±0.22[b]
Green tea powder 1.5%	11.47±0.50[ab]	1.87±0.12[b]
Green tea powder 2.0%	10.25±0.72 [b]	1.90±0.25[b]

[a, b] Means with different superscripts within the same column are significantly different ($p<0.05$).
[1] Standard error.

feed conversion ratio and eggshell thickness are given in Table 2. The egg production rate tended to increase in layers fed diets containing 1.0% and 1.5% green tea powder, but there were no significant differences in egg production rate of the layers fed 0.5 to 2.0% green tea and control diets throughout the experimental period ($p>0.05$). Biswas et al. (2000) reported that 0.6% Japanese green tea addition to layer diet had no effect on egg production rate of "White Leghorn" hens in a long term feeding experiment. In contrast, Yang et al. (2003) reported that "Tetran Brown" hens fed diets containing 4.0 and 6.0% green tea by-product showed significantly increased egg production rate. The higher egg production of green tea fed groups in present study could probable be due to high content of catechins (15.72%) of green tea powder. There were no significant differences in egg weight between two layer groups fed the diets containing 1.0% or 1.5% green tea powder ($p>0.05$), but, egg weight of the layers fed 0.5% green tea diet was decreased significantly compared to that of the control ($p<0.05$). Yamane et al. (1999) reported that 0.67% Japanese green tea extracts mixed to drinking water slightly reduced the egg weight of the hens. Biswas et al. (2000) also noted no significant reduction of egg weight when layers were fed diets containing 0.6% Japanese green tea supplementation. In our study, hens fed diets containing 0.5% inclusion of green tea had significantly lower egg mass compared to the layers fed 1.0 and 1.5% green tea supplemented diets. This reduction of egg mass was due to low egg production and egg weight obtained from the 0.5% green tea dietary group.

The feed intake of the layers fed 1.5% green tea diet was significantly higher than those fed control diets ($p<0.05$). However, there were no significant differences in feed intake of layers fed diets containing 0.5, 1.0 and 2.0% green tea supplementations ($p>0.05$). Cao et al. (2005) reported that 4 g/kg inclusion green tea polyphenols in the broiler diet not affected on feed intake of the chicks. Muramatsu et al. (1986) and Yoshino et al. (1994) reported that 1.0 or 2.0% green tea extract inclusions in mouse diets had no effect on feed intake of mice. In the present study, the feed conversion ratio of the 0.5% green tea group was significantly higher than that of the negative control group ($p<0.05$). However, there were no significant differences in feed conversion ratio among layers fed diets containing 1.0, 1.5% or 2.0% green tea powder and the control groups ($p>0.05$).

The eggshell thickness of the layers fed diets containing green tea powder was significantly thinner than that of the negative control group ($p<0.05$).But, no significant differences were observed in eggshell thickness of groups fed 0.5 to 2.0% green tea and antibiotics diets ($p>0.05$). This result was similar to Yang et al. (2003) who reported that eggshell thickness was reduced slightly when layers were fed diets containing 2.0 to 6.0% green tea by-product supplementations.

Yolk cholesterol and yolk rancidity

Effects of green tea powder on egg yolk cholesterols and rancidity value (TBA) are shown in Table 3. There were no significant differences in cholesterol contents of egg yolk between layers fed diets containing 0.5, 1.0 and 1.5% green tea powder and control diets ($p>0.05$). However, administration of 2.0% green tea diet significantly suppressed egg yolk cholesterol levels compared to that of the positive control diet ($p<0.05$). Biswas et al. (2000) reported that 0.6% Japanese green tea addition to layer diets tended to reduce egg yolk cholesterol concentrations. Yang et al. (2003) also reported that over 4.0% green tea by-product inclusion in layer diets remarkably depressed the cholesterol content of the egg yolk. Muramatsu et al. (1986) suggested that the reduction of the cholesterol content in the tissue could have negative impact on the formation of micelles, mediating absorption of bile acids.

TBA value of egg yolk was significantly reduced in the layers fed diets containing 0.5 to 2.0% green tea supplementations compared to that of the negative control (Table 3). Biswas et al. (2000) reported that TBA value of egg yolk was maintained low in the eggs from the layers fed the diet containing 0.6% Japanese green tea when eggs were stored for 10 days in ambient temperature. Yoshino et al. (1994) reported that 1.0% addition of green tea extract for mice tended to reduce the TBA value of the blood plasma. In this study, no significant differences were observed in the TBA values of egg yolk from groups fed green tea and antibiotic supplemented diets ($p>0.05$). The reduction of TBA vale of egg yolk could be caused by possible transfer

Table 4. Effect of green tea powder on egg yolk color

Items	Control	Antibiotics	Green tea powder level (%)			
			0.5	1.0	1.5	2.0
Lightness (L)[1]	50.70±1.89	50.36±1.82	51.62±1.45	50.21±1.41	50.89±1.89	51.58±1.24
Redness (a)	-1.10±0.83^{ab}	-1.84±0.97^{b}	-1.05±1.13^{ab}	-0.67±1.03^{a}	-1.12±1.15^{ab}	-0.63±0.85^{a}
Yellowness (b)	55.22±2.20^{ab}	52.60±1.82^{b}	55.56±1.94^{ab}	55.22±1.75^{ab}	56.26±2.26^{ab}	58.14±1.44^{a}

$^{a, b}$ Means with different superscripts within the same row are significantly different ($p<0.05$).

[1] Standard curve for egg yolk color: L 97.10; a -0.17; b +1.99.

Table 5. Effects of green tea on fatty acid composition of egg yolk (%)

Fatty acids	Control	Antibiotics	Green tea powder level (%)			
			0.5	1.0	1.5	2.0
C14:0	0.38±0.20^{a}	0.36±0.14^{ab}	39±0.25^{a}	0.34±0.22^{ab}	0.32±0.14^{b}	0.36±0.17^{ab}
C16:0	26.44±0.80^{ab}	26.67±0.66^{ab}	27.41±0.98^{a}	26.01±1.10^{b}	25.39±0.64^{b}	26.37±1.18^{ab}
C16:1 ω7	4.12±0.74^{ab}	3.70±0.45^{ab}	4.28±0.89^{a}	3.37±1.10^{ab}	3.28±0.50^{b}	3.95±0.82^{ab}
C18:0	8.49±0.74^{b}	9.21±0.59^{ab}	8.81±0.62^{b}	8.89±0.81^{ab}	9.68±0.87^{a}	8.99±0.87^{ab}
C18:1 ω9	42.09±1.56	43.46±1.69	42.06±1.92	42.86±1.46	40.34±1.19	43.37±1.21
C18:2 ω6	14.24±1.56^{ab}	11.98±1.54^{b}	13.1±2.01^{ab}	14.48±1.68^{ab}	16.28±1.55^{a}	12.88±1.22^{ab}
C18: 3 ω6	0.26±0.22^{a}	0.18±0.20^{ab}	0.22±0.20^{ab}	0.22±0.20^{ab}	0.51±0.22^{a}	0.48±0.17^{ab}
C20: 4 ω6	2.42±0.53^{b}	1.60±0.32^{ab}	2.31±0.45^{b}	2.38±0.55^{b}	2.80±0.62^{a}	2.39±0.45^{b}
C20:5 ω3	0.03±0.17	0.06±0.24	ND	ND	ND	ND
C22:6 ω3	0.66±0.22	0.98±0.74	0.65±0.20	0.67±0.26	0.80±0.35	0.68±0.20

$^{a, b}$ Means with different superscripts within same row are significantly different ($p<0.05$).

C14:0 (myristic acid), C16:0 (palmitic acid), C16:1 (palmitoleic acid), C18:0 (stearic acid), C 18:1ω9 (oleic acid), C18:2ω6 (linoleic acid). C18:3ω6 (linolenic acid), C20:4ω6 (arachidonic acid), C20:5ω3 (eicosapentaenoic acid), C22:6ω3 (docosahexaenoic acid).

ND: Not detected.

of the catechins into egg yolk and proved inhibitory effects of oxidation in the egg during the storage period.

Egg yolk color

Effects of green tea feeding on egg yolk color changes are shown in Table 4. There were no significant differences in the lightness value (L) of egg yolk between the layers fed diets containing 0.5 to 2.0% green tea and antibiotic supplementations ($p>0.05$). The diets between 0.5 to 1.5% of green tea inclusions had no effect on yellowness of egg yolk ($p>0.05$). However, the redness and yellowness of egg yolk from the layer were increased significantly in layers fed a diet containing 2.0% green tea supplementation ($p<0.05$).

The fatty acid composition of egg yolk

The fatty acid compositions of egg yolks are shown in Table 5. The myristic acid was significantly reduced in the layers fed 1.5% green tea diet compared to that of the control ($p<0.05$). In contrast, the composition of linoleic acid was higher in 1.5% green tea groups, but no significant differences were observed among the rest of the green tea treatments ($p>0.05$). The palmitic and palmitoleic acid contents were higher in 0.5% green tea-fed group than 1.0% and 1.5% green tea-fed groups ($p>0.05$). Dyeberg et al. (1975) reported an optimum level of docosahexaenoic acid belonging to the α-3 group played an important role in control of blood pressure and blood cholesterol content. Yang et al. (2003) reported that 4.0% and 6.0% green tea by-product supplementation in layer diet had increasing effects of the docosahexanoic acids in egg yolk. However, our study indicated that 0.5 to 2.0% green tea inclusion in layer diet had no effect on docosahexanoic acids contents of the egg yolk ($p>0.05$). The stearic and eicosatetraenoic acids were significantly increased in the layers fed a diet containing 1.5% green tea supplementation ($p<0.05$).

Sensory evaluation of egg

Sensory evaluation of the boiled eggs from layers fed diets containing different level of green tea is shown in Table 6. The appearance and yolk color of boiled eggs increased significantly in the layers fed diets containing 1.5% green tea supplementations compared to that of the control ($p<0.05$). But, there were no significant differences in terms of juiciness, texture and overall acceptability of the boiled eggs from layers fed diets containing 0.5 to 2.0% green tea inclusions ($p>0.05$). However, the flavor of boiled eggs was increased significantly in layers fed 1.0% of green tea diet compared to the control ($p>0.05$). We assumed that 1.0 and 1.5% green tea inclusions to the layer diet affected positively in appearance, yolk color and flavor of the boiled eggs.

IMPLICATIONS

The results of this study demonstrated that 1.0 to 2.0%

Table 6. Effect of green tea powder on sensory evaluation of eggs

Items \ Treat	Control	Antibiotics	Green tea powder level (%)			
			0.5	1.0	1.5	2.0
Appearance	3.13±0.27[b]	3.33±0.22[b]	3.80±0.24[ab]	3.67±0.24[ab]	4.47±0.23[a]	3.53±0.24[b]
Color	3.20±0.21[b]	3.40±0.23 [b]	3.87±0.27[ab]	3.33±0.26[ab]	4.47±0.22[a]	3.80±0.21[b]
Juiciness	2.73±0.24	2.93±0.20	3.40±0.20	3.20±0.21	3.33±0.26	3.06±0.24
Texture	3.00±0.24	3.27±0.20	3.27±0.20	3.20±0.21	3.13±0.26	3.07±0.23
Flavor	3.06±0.23[b]	3.27±0.22[ab]	3.46±0.28[ab]	3.86±0.23[a]	3.53±0.26[ab]	3.07±0.24[b]
Acceptability	3.07±0.24	3.26±0.20	3.60±0.23	3.40±0.21	3.40±0.25	3.33±0.21

[a, b, c] Means with different superscripts within same row are significantly different ($p<0.05$).

green tea supplementation to layer diet had favorable effects on laying performance and egg quality profiles. The eggshell thickness was slightly decreased by green tea feeding but not enough to affect market requirements for commercial eggs. Administration of 2.0% of green tea in the diet significantly suppressed cholesterol levels of the egg yolk. The results of this study demonstrated that green tea supplementation in layer diets could have a positive effect on egg color and increase appearance value of the eggs.

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