



Comparative Performance of Hens Fed Diets Containing Korean, Japanese and Chinese Green Tea

D. Uganbayar, I. S. Shin¹ and C. J. Yang*

Department of Animal Science & Technology, Sunchon National University, Suncheon, 540-742, Korea

ABSTRACT : This experiment was carried out to investigate the effects of Korean, Japanese and Chinese green tea on laying performance and egg quality in hens. A total of 168 "Tetran Brown" hens aged 40 weeks were assigned to 7 treatments in a completely randomized design. Each treatment had 4 replicates accommodating 6 layers per replication. The seven dietary treatments were: 1) control diet with no green tea added, 2) diet containing 1.0% Korean green tea (1.0% KGT), 3) diet containing 2.0% Korean green tea (2.0% KGT), 4) diet containing 1.0% Japanese green tea (1.0% JGT), 5) diet containing 2.0% Japanese green tea (2.0% JGT), 6) diet containing 1.0% Chinese green tea (1.0% CGT), and 7) diet containing 2.0% Chinese green tea (2.0% CGT). Egg production rate of the layers fed diets containing 1.0 or 2.0% green tea powders were significantly increased compared to that of the control ($p < 0.05$). The egg weight of layers was significantly reduced in layers fed 1.0% CGT ($p < 0.05$). The feed intake was significantly decreased in KGT and CGT groups at 2.0% inclusion levels ($p < 0.05$). The egg shell thickness and shape index of JGT treatment was significantly lower than that of the control ($p < 0.05$). There were no significant differences in albumen index, yolk index and Haugh unit of eggs for layers fed diets containing green tea powders regardless of origin ($p > 0.05$). Green tea feeding to layers tended to reduce the overall cholesterol content of egg yolk. Particularly, 1.0 or 2.0% CGT significantly depressed the total cholesterol content of egg yolk ($p < 0.05$). In conclusion, incorporation of 1.0 or 2.0% Korean, Japanese and Chinese green tea into layer diets regardless of origin had favorable effects on laying performance and egg quality profiles. Among the three green tea sources, the Chinese green tea powder had the highest reducing effect on cholesterol content in egg yolk. (**Key Words :** Green Tea, Hen, Egg Production, Feed Intake, Egg Shell Thickness, Yolk Cholesterol)

INTRODUCTION

The rapid decline of egg consumption over the past 30 years is the most challenging problem facing the egg industry in many parts of the globe. Consumers' attitudes towards lipid and oil have changed and egg consumption has declined because of fears that egg yolk cholesterol will raise blood cholesterol levels (Connor and Connor, 1983). The negative perception related to a high cholesterol content of eggs (195-250 mg/egg) is undoubtedly a major contributing factor (Yaffee et al., 1991) in the decrease of egg consumption. Nowadays, several attempts have been made to recover the egg consumption by changing egg composition through feeding nutritionally-modified diets.

Green tea (*Camellia sinensis*), an anti-aging herb, has

been used for centuries by the Korean, Japanese and Chinese people. Beside the human consumption, the low grades of green tea and green tea wastes were used as feed ingredients for fish (Kono et al., 2000), broiler (Kaneko et al., 2001; Cao, 2005), calves (Ishihara et al., 2001) and pigs (Suzuki, 2002), and the positive effects of green tea on animal performance have been discovered already. Yang and Koo (1997) reported that green tea feeding reduced the serum and liver cholesterol contents of rats. Yamane et al. (1999) reported that green tea inclusion in layer diets improved the Haugh unit score of the eggs in a short-term (6 week) experiment. Feeding green tea powder to laying hens could modify components of the edible part of eggs, leading to characteristics favorable to consumers such as high durability of the thick albumen and less cholesterol of egg yolk (Biswas et al., 2000). Green tea by-product is also widely used for feed supplements in animal diets. Green tea waste can be used as a protein source without any detrimental effects on the performance of lactating cow (Kondo et al., 2004). Yang et al. (2003 a, b) reported that

* Corresponding Author: C. J. Yang. Tel: +82-61-750-3235, Fax: +82-61-750-3239, E-mail: yangcj@sunchon.ac.kr

¹ American Soybean Association, Susong-Dong, Chongro-Ku, Seoul, 110-755, Korea.

Received September 26, 2005; Accepted January 26, 2006

Table 1. Formula and chemical composition of basal diet (%)

Item	(%)
Corn grain	58.88
Wheat grain	5.00
Wheat bran	3.00
Soybean meal	14.42
Rapeseed	2.00
Corn gluten meal	3.28
Fish meal	1.00
Animal fat	1.50
Salt	0.20
Tricalcium phosphate	0.82
Limestone	8.92
Oyster shell	0.30
Methionine	0.14
Cholin chloride	0.10
Vitamin premix	0.10
Mineral premix	0.10
Phytase	0.06
Total	100.00
Chemical composition ¹	
ME (kcal/kg)	2,700.00
C.P (%)	15.00
Calcium (%)	3.25
Avail. P (%)	0.25

Vitamin premix provided following nutrients per kg of diet: Vitamin A, 9,000,000 IU; Vitamin D₃, 2,100,000 IU; Vitamin E, 15,000 IU; Vitamin K, 2,000 mg; Vitamin B₁, 1,500 mg; Vitamin B₂, 4,000 mg; Vitamin B₆, 3,000 mg; Vitamin B₁₂, 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, 35,000 mg; Mn, 55,000 mg; Zn, 40,000 mg; 1,600 mg; Se, 130 mg.

¹ Calculated values.

addition of green tea by-product to broiler and layer diets reduced cholesterol contents in the meat and egg yolk. In our previous work (Uuganbayar et al., 2005), we found that Korean green tea inclusion in a layer diet depressed the cholesterol content of egg yolk. Therefore, the objective of this study was to compare the effects of Korean, Japanese and Chinese green tea powders on laying performance and egg quality profiles and to clarify the reducing effect of green tea on cholesterol content in animal products such as egg yolk.

MATERIALS AND METHODS

Animals and design

A total of 168 "Tetran Brown" laying hens aged 40 weeks post-hatching were assigned to 7 treatments in a completely randomized design. For this experiment, two layers were housed in one cage (24 cm×38 cm×45 cm size) and each treatment had 4 replicates, of which one was consisted of 3 adherent cages. The room temperature was maintained at 20±2°C and the relative humidity ranged from 60% to 65%. The lighting condition was of intermediate level and the drinking water and the experimental diets were provided *ad libitum*. The bird

management and handling followed the general practices used in commercial layer farm. The trial lasted for 8 weeks.

Experimental feed and feeding

Korean and Chinese green tea powders used in this experiment were provided from the Green Tea Experimental Station (Bosung, Korea) and Japanese green tea powder was supplied by the Central Research Laboratories (Taiyo Kagaku Co., Ltd, Japan). The seven experimental diets were: 1) control diet with no green tea added, 2) diet containing 1.0% Korean green tea (1.0% KGT), 3) diet containing 2.0% Korean green tea (2.0% KGT), 4) diet containing 1.0% Japanese green tea (1.0% JGT) 5) diet containing 2.0% Japanese green tea (2.0% JGT), 6) diet containing 1.0% Chinese green tea (1.0% CGT), and 7) diet containing 2.0% Chinese green tea (2.0% CGT). Before feeding to birds, the green tea powders were mixed into a commercial diet which was purchased from a local feed mill. The nutrient composition of the control diet (Table 1) was in accordance with suggestions in the Nutrient Requirements for Laying Hens (NRC, 1994). Egg collection was manually performed at 17:00 pm on a daily basis. All eggs produced each day were collected and counted. Egg production rate, egg weight, egg mass, feed conversion ratio and eggshell thickness were determined on a weekly basis. Egg quality parameters (i.e. albumen index, yolk index, Haugh unit) and egg yolk color were measured in every second week. Analysis of cholesterol content and thiobarbituric acid value (TBA) of egg yolk and sensory evaluation on boiled eggs were carried out at the end of the experiment

Catechin components of the green tea

For catechin analysis, the method devised by Ikeda et al. (2003) was used: approximately 100 mg green tea powder was dissolved in 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 was added. After washing 3 times with chloroform, the solution was separated into 2 layers. The water layer was collected, and the catechin component was fractionated with 25 ml of ethyl acetate. The ethyl acetate fraction was evaporated at 30°C in a rotary evaporator under nitrogen. Finally, the concentrate was dissolved in methanol and passed through a membrane filter (0.45 µm polyvinylidene difluoride) and a Sep-Pack C₁₈ cartridge. The catechin components were isolated by HPLC (Model 501, Waters, Milford, USA).

Measurements

Feed intake and feed conversion : Feed residues were measured on a weekly basis to determine feed intake. Feed conversion ratio was calculated by dividing feed intake by

Table 2. Catechin components of green tea powder (% , dry matter basis)

Components	Green teas		
	Korean	Japanese	Chinese
(+) Catechin	0.88	0.68	0.62
Epigallocatechin	1.46	1.39	1.71
Epicatechin	1.41	1.87	1.46
Epigallocatechin gallette	10.61	10.60	8.96
Epicatechin gallette	1.37	1.06	1.30
Total	15.73	15.60	14.05

egg mass.

Egg production rate, egg weight and egg mass : Egg production rate was obtained by dividing total number of eggs by hen-day and expressed as a percentage. All eggs produced on a certain day of the week were collected separately by treatment group and weighed individually with an electronic scale, HM-200 (A&D Co., Ltd, Japan). Egg mass was calculated on a weekly basis by multiplying the average egg weight by egg production rate.

Eggshell thickness : A total of 35 eggs (5 eggs from each treatment) were selected every week. The egg yolk, albumen and shell membranes were removed from broken eggs and 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.

Shape index, Albumen index, Yolk index and Haugh unit : A total of 35 eggs (5 eggs from each treatment) were examined for shape index (the ratio of width to length of egg). The same eggs were used for measurement of albumen and yolk indexes. The albumen index (the ratio of average albumen height to the average of the width and length), yolk index (the ratio of yolk height to its average width) and Haugh unit (the ratio of albumen height and egg weight) were measured for each selected egg.

Cholesterol content of egg yolk : A total of 35 eggs (5 eggs from each treatment) were collected for cholesterol analysis. The cholesterol content of egg yolk was determined by the method of Brunnekreeft et al. (1983): approximately 0.5 g egg yolk and 100 µg of α -cholestane were homogenized with 0.5 N KOH solution and saponified for 30 min at 55°C. The total cholesterol was extracted with hexane and analyzed by gas chromatography (HP 5890

series II, USA) equipped with a HP-1 (cross-linked methyl silicone, 25 m×0.32 mm×0.17 µm) capillary column.

Yolk rancidity : Oxidation degree of egg yolk (TBA value) was determined as described by Vernon et al. (1970) with some modifications. For this analysis 20 g egg yolk mixture (pooled 2 egg yolks 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 placed in a water bath at 80°C for 30 min. After cooling, the resulting color was measured at 530 nm in a VIS-Spectrophotometer (Model 20D⁺, Milton Roy, USA).

Egg yolk color : A total of 35 eggs (5 eggs from each treatment) were selected for egg yolk color determination. Egg albumen, egg shell and shell membrane were removed from each broken eggs and egg yolk color was measured using a Chromameter-CR 200 (Minolta, Japan).

Sensory Evaluation for table egg : A total of 35 boiled eggs (5 eggs from each dietary group) laid on the 56th day of feeding were organoleptically evaluated by a panel of 12 judges on the six point hedonic scale in terms of appearance, color, juiciness, texture, flavor and overall acceptability.

Statistical analysis

The data obtained from this study were analysed by the SAS Package Program (1990) to estimate variance components for a completely randomized design. Duncan's multiple comparison tests (1955) were used to examine significant differences between treatment means. Differences were statistically assessed at $p < 0.05$.

RESULTS AND DISCUSSION

Catechin components of the green tea

The result of analysis for catechin components of green teas used in this experiment is shown in Table 2. Total catechin contents were 15.73% for Korean green tea, 15.60% for Japanese green tea and 14.04% for Chinese green tea. Of the total catechin components, the

Table 3. Effect of Korean, Japanese and Chinese green tea powder on productive performance

Items	Treatments	Control	KGT		JGT		CGT	
			1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Egg production rate (%)		83.01±6.30 ^{c1}	86.68±3.62 ^{ab}	88.31±5.00 ^{ab}	87.65±5.49 ^{ab}	88.40±4.66 ^{ab}	91.59±2.74 ^a	86.54±2.79 ^{ab}
Egg weight (g)		62.54±0.88 ^{ab}	61.93±1.10 ^{abc}	62.03±1.21 ^{ab}	62.72±1.76 ^{ab}	61.61±1.57 ^{bc}	61.39±1.15 ^c	63.25±0.82 ^{ab}
Egg mass (g)		51.91±3.81 ^b	53.68±2.97 ^{ab}	54.78±3.46 ^{ab}	54.97±2.93 ^{ab}	54.46±3.30 ^{ab}	56.23±1.73 ^a	54.73±1.72 ^{ab}
Feed intake (g/hen/day)		121±3.94 ^a	122±6.33 ^a	110±5.90 ^c	120±5.34 ^{ab}	112±4.91 ^{bc}	114±6.08 ^{bc}	110±6.37 ^c
FCR (kg/kg)		2.42±0.22	2.32±0.17	2.08±0.19	2.29±0.15	2.09±0.15	2.07±0.10	2.07±0.13

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

¹ Standard error.

Table 4. Effect of Korean, Japanese and Chinese green tea powder on egg quality parameters

Items	Treatments	Control	KGT		JGT		CGT	
			1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Egg shell thickness (μm)		360 \pm 3.18 ^{a1}	358 \pm 2.97 ^a	359 \pm 3.17 ^a	338 \pm 3.14 ^b	341 \pm 2.59 ^b	357 \pm 3.76 ^a	352 \pm 3.14 ^{ab}
Shape Index		75.65 \pm 1.34 ^a	74.83 \pm 1.78 ^{ab}	75.40 \pm 1.35 ^{ab}	73.32 \pm 1.33 ^c	72.88 \pm 1.47 ^c	73.39 \pm 1.48 ^{bc}	73.60 \pm 1.36 ^{bc}
Albumen index		0.103 \pm 0.004	0.108 \pm 0.001	0.120 \pm 0.004	0.116 \pm 0.005	0.114 \pm 0.007	0.112 \pm 0.009	0.102 \pm 0.003
Yolk index		0.445 \pm 0.014	0.448 \pm 0.003	0.453 \pm 0.008	0.450 \pm 0.004	0.449 \pm 0.008	0.453 \pm 0.009	0.451 \pm 0.008
Haugh unit		87 \pm 2.71	87 \pm 2.78	91 \pm 2.20	90 \pm 1.83	90 \pm 1.96	89 \pm 2.68	86 \pm 1.52

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

¹ Standard error.

Table 5. Effect of Korean, Japanese and Chinese green tea powder on egg yolk cholesterol (mg/g)

Item	Treatments	Control	KGT		JGT		CGT	
			1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Total cholesterol		13.53 \pm 0.22 ^{a1}	12.95 \pm 0.21 ^{ab}	12.33 \pm 0.42 ^{ab}	13.13 \pm 0.19 ^a	12.01 \pm 0.48 ^{ab}	11.14 \pm 1.22 ^b	11.22 \pm 0.60 ^b

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

¹ Standard error.

epigallocatechin gallate (EGCg) was predominant, which accounted for 67.5% (Korean green tea), for 67.9% (Japanese green tea) and for 63.8% (Chinese green tea) of the total catechin contents. This result agreed with Roberts (1962) who reported that epigallocatechin gallate (EGCg) is the main catechin compounds accounting for more than half of the total catechin. The catechin components of green tea showed dose-dependent inhibitory activity against end stage lipid peroxide decomposition product formation and early lipid oxidation (Pearson et al., 1998). According to green tea studies, we assumed that catechin components of green tea might have a reducing effect on the lipid oxidation level of eggs and be able to reduce the cholesterol content of egg yolk when green tea powders were used as feed ingredients for laying hens.

Egg production rate, egg weight, egg mass, feed intake and feed conversion ratio

Egg production rate, egg weight, egg mass, feed intake and feed conversion ratio of the layers fed diets containing Korean, Japanese and Chinese green tea are presented in Table 3. Throughout the experimental period, the egg production rate was significantly increased in layers fed diets containing green tea supplementation compared to that of the control ($p < 0.05$). Biswas et al. (2000) reported that the egg production rate of hens was increased by 0.6% Japanese green tea inclusion level in the layer diet. The egg production rate also was increased by feeding laying hens diets containing 0.5 to 2.0% Korean green tea powder (Uuganbayar et al., 2005). Therefore, we assumed that the catechin components of green tea may be reabsorbed through the intestinal wall, and in such away it could affect positively both digestive function and egg formation process of laying hens.

The egg weight of 1.0% Chinese green tea-fed group was significantly lower, but the egg mass was significantly

higher than that of the control ($p < 0.05$). The increase of egg mass in the 1.0% Chinese green tea treatment should be due to higher egg production. Feeding layers the 1.0% green tea diets did not affect feed intake of hens regardless of origin ($p > 0.05$). However, the 2.0% Japanese green tea diet tended to reduce the feed intake of laying hens, and Korean and Chinese green teas at 2.0% inclusion level significantly reduced the feed intake of hens compared to those of layers fed the control diet ($p < 0.05$). Similar studies showed that 2.5% Japanese green tea addition to the diet did not affect feed intake and water consumption of rats (Lin et al., 1998). Biswas and Wakita (2001) reported that 1.5% Japanese green tea inclusion in a broiler diet reduced the feed intake of the chicks.

Our study demonstrated that 1.0 or 2.0% green tea inclusion in the layer diet improved the feed conversion ratio of hens ($p < 0.05$). Among all green tea-fed groups, the highest feed conversion ratios were observed in Chinese green tea treatments at 1.0% or 2.0% of inclusion level ($p < 0.05$). Yang et al. (2003) reported that 4.0 or 6.0% green tea by-product addition in a layer diet also improved the feed conversion ratio of hens.

Egg shell thickness, shape index, albumen index, yolk index and Haugh unit

Effects of Korean, Japanese and Chinese green tea powder on egg quality traits are shown in Table 4. The egg shell thickness and shape index were significantly reduced in layers fed 1.0 or 2.0% Japanese green tea diets compared to that of the control ($p < 0.05$). However, there were no significant differences in egg shell thickness of layers fed diets containing Korean and Chinese green tea inclusions compared to that of the control ($p > 0.05$). The albumen index, yolk index and Haugh unit of eggs were not different between green tea and control treatments ($p > 0.05$). Yamane et al. (1999) and Biswas et al. (2000) reported that Japanese

Table 6. Effect of Korean, Japanese and Chinese green tea powder on TBA value of egg yolk ($\mu\text{mol/g}$)

Treatments		KGT		JGT		CGT		
		Control	1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Storage period	7 day	2.42±0.66 ^{a1}	2.35±0.42 ^{ab}	2.36±0.48 ^{ab}	1.99±0.52 ^{ab}	2.03±0.71 ^{ab}	1.87±0.38 ^b	2.24±0.53 ^{ab}
	14 day	3.44±0.28 ^a	2.79±0.36 ^{ab}	2.59±0.75 ^{ab}	2.91±0.64 ^{ab}	3.09±0.53 ^{ab}	2.77±0.74 ^{ab}	3.01±0.52 ^{ab}

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

¹ Standard error.

Table 7. Effects of Korean, Japanese and Chinese green tea powder on egg yolk color

Items	Treatments	KGT		JGT		CGT	
	Control	1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Lightness (L)	46.21±0.43 ¹	56.54±0.39	45.91±0.30	45.79±0.37	45.75±0.28	46.02±0.45	45.85±0.31
Redness (b)	1.36±0.29	0.74±0.28	0.83±0.26	0.95±0.19	1.14±0.21	1.08±0.94	1.36±0.28
Yellowness (b)	51.02±0.72	51.46±0.68	51.13±0.66	51.16±0.68	51.36±0.56	50.64±0.92	50.30±0.75

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

Standard curve for color measurement was $L = 97.10 - 0.17a - 1.99b$.

¹ Standard error.

Table 8. Effect of Korean, Japanese and Chinese green tea powder on sensory evaluation of eggs

Items	Control	KGT		JGT		CGT	
		1.0%	2.0%	1.0%	2.0%	1.0%	2.0%
Appearance	2.35 \pm 0.12 ^{b1}	2.35 \pm 0.27 ^b	2.82 \pm 0.25 ^{ab}	2.47 \pm 0.23 ^{ab}	2.81 \pm 0.28 ^{ab}	2.94 \pm 0.20 ^{ab}	3.12 \pm 0.23 ^a
Color	2.64 \pm 0.17 ^b	3.00 \pm 0.19 ^{ab}	3.29 \pm 0.21 ^a	2.88 \pm 0.19 ^{ab}	3.31 \pm 0.21 ^a	3.06 \pm 0.18 ^{ab}	3.18 \pm 0.23 ^{ab}
Juiciness	3.00 \pm 0.21	3.41 \pm 0.17	3.18 \pm 0.23	3.00 \pm 0.26	3.62 \pm 0.33	2.88 \pm 0.23	3.00 \pm 0.30
Texture	2.94 \pm 0.18	3.12 \pm 0.23	2.71 \pm 0.24	3.00 \pm 0.30	2.62 \pm 0.24	2.94 \pm 0.16	3.24 \pm 0.22
Flavor	3.12 \pm 0.17	2.76 \pm 0.18	2.76 \pm 0.24	2.82 \pm 0.15	3.06 \pm 0.17	3.00 \pm 0.12	3.12 \pm 0.23
Acceptability	2.71 \pm 0.17	3.18 \pm 0.20	2.94 \pm 0.20	3.06 \pm 0.14	3.07 \pm 0.19	3.24 \pm 0.18	3.29 \pm 0.24

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

¹ Standard error.

green tea inclusion in the layer diet improved the Haugh unit score of eggs. They indicated that the improvement of HU score with green tea feeding was accompanied by a greater albumen height and physical stability of egg albumen. In our study, the albumen height of green tea treatments tended to be higher but the differences were not significant when compared with the control treatment ($p > 0.05$).

Cholesterol content of egg yolk

Effect of Korean, Japanese and Chinese green tea powders on total egg yolk cholesterol content is shown in Table 5. The total cholesterol content of egg yolk was slightly reduced in the layers fed 1.0 or 2.0% Korean and Japanese green tea diets but without significant differences ($p > 0.05$). Among green tea treatments, Chinese green tea treatments at both 1.0% and 2.0% inclusion levels significantly lowered egg yolk cholesterol content compared to that of the control ($p < 0.05$). It was demonstrated in other studies that high catechin content of the green tea may have an inhibitory effect on intestinal absorption of lipid (Ikeda et al., 1992). Therefore, a green tea diet for animals may prevent an excessive accumulation of lipid in the liver and other tissue including egg yolk. The reduction of tissue cholesterol may be explained by

negative impact on the formation of micelles, mediating absorption of bile acids (Muramatsu et al., 1986). Therefore, the absorption of bile acids may lead to the reduction in liver cholesterol, which might affect the total cholesterol content of egg yolk.

Rancidity (TBA value) of egg yolk

Effect of Korean, Japanese and Chinese green tea powder on rancidity value (TBA) of egg yolk is shown in Table 6. TBA value of the egg yolk tended to be lower in green tea treatments compared to the control treatment. In the first week of storage, 1.0% Chinese green tea diet had a significantly lower TBA value of egg yolk than that of the control ($p < 0.05$). After 2 weeks of storage, the TBA value of eggs was reduced in green tea treatments compared to the TBA of the control treatment ($p > 0.05$). Biswas et al. (2000) reported that 0.6% Japanese green tea addition in the layer diet reduced the TBA value of eggs. This reduction of the TBA value of egg yolk might be caused by a possible transfer of green tea catechins into egg yolk which might have an inhibitory effect on lipid oxidation level of the egg yolk.

Egg yolk color

Table 7 shows the effect of Korean, Japanese and

Chinese green tea powders on egg yolk color. The lightness of egg yolk in layers fed the 1.0% Korean green tea diet tended to increase compared to the egg yolk color of the layers fed diets containing Japanese and Chinese green tea powders. The redness of egg yolk tended to be higher in the control treatment compared to the green tea treatments, but the differences were not significant ($p>0.05$). There were no significant differences in yellowness of egg yolk for 1.0 or 2.0% green tea treatments regardless of the origin ($p>0.05$). Lee (2005) noted a slight increase in redness of meat when "Hanwoo" beef cattle were fed diets containing 0.02% green tea by-product supplementation. However, this tendency was not observed in eggs from layers fed diets containing green teas.

Sensory evaluation of eggs

The sensory evaluation of the boiled eggs from layers fed green tea diets is shown in Table 8. Sensory evaluation in terms of juiciness, texture, flavor and acceptability of boiled eggs did not vary between the green tea-fed treatments and control treatments ($p>0.05$). The appearance of boiled eggs was significantly improved in layers fed the 2.0% Chinese green tea diet compared to that of the control ($p<0.05$). The yolk color of boiled eggs was increased in layers fed both Korean and Japanese green tea diets at 2.0% inclusion levels ($p<0.05$). In our previous studies, it was demonstrated that 1.5% Korean green tea inclusion in the layer diet improved the appearance and egg yolk color of boiled eggs (Uuganbayar et al., 2005).

IMPLICATIONS

The results of our study demonstrated that 1.0 or 2.0% Korean, Japanese and Chinese green tea inclusion levels in the layer diet improved the egg production rate without altering most of the egg quality traits. Green tea powder addition to the layer diet tended to reduce the TBA value of egg yolk regardless of origin. Incorporation of 1.0 or 2.0% Korean and Japanese green tea in the layer diet tended to reduce the egg yolk cholesterol, while 1.0 or 2.0% Chinese green tea inclusion significantly depressed the cholesterol content of egg yolk; these effects require further investigation.

ACKNOWLEDGEMENTS

We thank Il-Chul Park, Jong-Il Oh, and Key-Jun Park, the graduate and undergraduate students of College of Agriculture and Life Science, Sunchon National University, Korea for their technical assistance to this experiment.

REFERENCES

Biswas, Md. A. H., Y. Miyazaki, K. Nomura and M. Wakita. 2000.

- Influences of long-term feeding of Japanese green tea powder on laying performance and egg quality in hens. *Asian-Aust. J. Anim. Sci.* 13(7):980-985.
- Biswas, Md. A. H. and M. Wakita. 2001. Effect of dietary Japanese green tea powder supplementation on feed utilization and carcass profiles in broilers. *Jpn. Poult. Sci.* 38(1):50-57.
- Brunnekreeft, J. W., G. J. Boerma and B. Leijnse. 1983. Direct determination of total cholesterol by column gas chromatographic analysis without previous derivatisation compared with WHO-CDC reference method. *Ann. Clin. Biochem.* 20:360-363.
- Cao, B. H., Y. Karasawa and Y. M. Guo. 2005. Effects of green tea polyphenols and fructooligosaccharides in semi-purified diets on broiler's performance and caecal microflora and their metabolites. *Asian-Aust. J. Anim. Sci.* 18:85-89.
- Connor, S. L. and W. E. Connor. 1983. The importance of dietary cholesterol in coronary heart disease. *Prev. Med.* 12:115.
- Duncan, D. B. 1955. Multiple range and multiple F test. *Biometrics.* 11:1
- Kaneko, K., K. Yamasaki, Y. Tagawa, M. Tokunaga, M. Tobisa and M. Furuse. 2001. Effects of dietary Japanese green tea powder on growth, meat ingredient and lipid accumulation in broilers. *Jpn. Poult. Sci.* 38:77-85.
- Kondo, M., M. Nakano, A. Kaneko, H. Agata, K. Kita and H. Yokota. 2004. Ensiled green tea waste as partial replacement for soybean meal and alfalfa hay in lactating cows. *Asian-Aust. J. Anim. Sci.* 17(7):960-966.
- Kono, M., K. Furukawa, Y. M. Sagesaka, K. Nakagawa and K. Fujimoto. 2000. Effect of green tea grounds as dietary supplements on cultured yellowtail and ayu. *J. Jpn. Soc. Food Sci.* 47:932-937.
- Ikeda, I., M. Kobashi, T. Hamada, K. Tsuda, H. Goto, K. Imaizumi, A. Nozawa, A. Sugimoto and T. Kakuda. 2003. Heat-epimerized tea catechins rich in gallic catechin gallate and catechin gallate are more effective to inhibit cholesterol absorption than tea catechins rich in epigallocatechin gallate. *J. Agric. Food Chem.* 57:7303-7307.
- Ishihara, N., D. C. Chu, S. Akachi and L. R. Juneja. 2001. Improvement of intestinal microflora balance and prevention of digestive and respiratory organ diseases in calves by green tea extracts. *Livest. Prod. Sci.* 68:217-229.
- Lee S. G. 2005. Effect of dietary green tea by-product on productivity in Korean beef cattle and consulting. M. Sci. thesis, Sunchon National University, Sunchon, Korea.
- Lin, Y. L., C. Y. Cheng, Y. P. Lin, Y. W. Lau, I. M. Juan and J. K. Lin. 1998. Hypolipidemic effect of green tea leaves through induction of antioxidant and phase II enzymes including superoxide dismutase, catalase, and glutathione S-transferase in rats. *J. Agric. Food Chem.* 46:1893-1899.
- Muramatsu, K., M. Fukuyu and Y. Hara. 1986. Effect of green tea catechins on plasma cholesterol level in cholesterol- fed rats. *J. Nutr. Sci. Vitaminol.* 32:613-622.
- NRC. 1994. Nutrient Requirements of Poultry. 9th. Ed. National Academy Press. Washington, DC.
- Pearson, D. A., E. N. Frankel and R. Aeschbach. 1998. Inhibition of endothelial cell mediated low-density lipoprotein oxidation by green tea extracts. *J. Agric. Food Chem.* 46:1445-1449.
- Roberts, E. A. H. 1962. The chemistry of flavonoid compounds. 1st ed. Preamon press, New York. pp. 468-483.
- SAS. 1990. SAS users guide: Statistics. Version 6, Fourth edition.

- SAS Institute Inc., Cary, NC.
- Suzuki, K., H. Kadowaki, M. Hino and K. Tamura. 2002. The influence of green tea in pig feed on meat production and quality. *Jpn. J. Swine Sci.* 39:59-65.
- Uuganbayar, D., I. H. Bae, K. S. Choi, I. S. Shin, J. D. Firman and C. J. Yang. 2005. Effects of green tea powder on laying performance and egg quality in laying hens. *Asian-Aust. J. Anim. Sci.* 18:1769-1774.
- Vernon, C. W., G. F. Krause and E. M. Bailey. 1970. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *J. Food Sci.* 35:582-585.
- Yamane, T., H. Goto, D. Takahashi, H. Takeda, K. Otowaki and T. Tsuchida. 1999. Effects of hot water extracts of tea on performance of laying hens. *Jpn. Poult. Sci.* 36:31-37.
- Yaffee, M., H. Schutz, J. Stone, S. Brokhari and G. Zeidler. 1991. Consumer perception and utilization of eggs and egg products. *Poult. Sci.* 70:188-192.
- Yang, C. T. and M. L. Koo. 2000. Chinese green tea lowers cholesterol level through an increase fecal lipid excretion. *Life Sciences.* 66(5):411-423.
- Yang, C. J., Y. C. Jung and D. Uuganbayar. 2003a. Effect of feeding diets containing green tea by-products on laying performance and egg quality in hens. *Kor. J. Poult. Sci.* 30(3):183-189.
- Yang, C. J., I. Y. Yang, D. H. Oh, I. H. Bae, S. G. Cho, I. G. Kong, D. Uuganbayar, I. S. Nou and K. S. Choi. 2003b. Effect of green tea by-product on performance and body composition in broiler chicks. *Asian-Aust. J. Anim. Sci.* 16(6):867-872.