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Research Article

Research on the Factors Affecting Cholesterol Content and Some Other Characteristics of Eggs in Laying Hens*

The effects of genotype and rearing system

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Abstract: The effects of the age of the hen, genotype, rearing system and dietary structure on egg and serum cholesterol content and some other characteristics of eggs were investigated in laying hens. However, only the findings related to genotype and rearing system are given.

A total of 840 hens, 21weeks of age and consisting of 400 white layers (Babcock-300) and 440 brown layers (IsaBrown) were used. The 2 genotypes had been housed in different rearing systems, floor pens and cages. Ten different feed groups consisting of controls (I and II), 2% and 4% fiber increment (III, IV, V and VI), 2% and 4% fiber increment + 250 mg/kg vitamin C (VII, VIII, IX and X) formed the feed material of the trial. Energy shortfalls in the diets were made good by soybean oil in one half, and by animal fat (beef tallow) in the other.

Genotype and rearing system significantly affected egg and serum cholesterol content. The serum and egg yolk cholesterol contents of white layers were lower than those of brown layers. The effect of genotype on shell ratio and thickness was not significant. Differences between rearing systems were nonsignificant for egg weight, and shell weight and thickness. White layers were better than browns layers, and cage rearing was better than floor pen rearing for egg production, feed consumption and feed conversion. There were positive and significant correlations ($P < 0.05$) among egg cholesterol content and egg weight, and yolk weight, and also between serum cholesterol and egg production for each genotype. The correlations between serum and egg yolk cholesterol (mg/g and mg/egg) were negative for both genotypes, but were significant for white layers.

Key Words: Laying hen, cholesterol, genotype and rearing system.

Yumurta Tavuklarında Yumurtanın Kolesterol İçeriği ile Diğer Bazı Özelliklerine Etki Eden Etkenler Üzerinde Bir Araştırma

Genotip ve Yetiştirme Tipinin Etkileri

Özet: Bu çalışmada yaş, genotip, yetiştirme sistemi ve rasyon yapısının yumurta tavuklarında yumurta ve serum kolesterol içeriği ile yumurtanın diğer bazı özelliklerine etkileri araştırılmıştır. Ancak bu makelede sadece genotip ve yetiştirme tipi ile ilgili araştırma bulguları verilmiştir.

Çalışmada 400 adet Beyaz (Babcock-300) ve 440 adet Kahverengi (IsaBrown) olmak üzere 21 haftalık toplam 840 adet tavuk kullanılmış ve her iki genotipteki hayvanlar yer ve kafes olmak üzere iki farklı yetiştirme sistemlerinde barındırılmışlardır. Araştırmanın yem materyalini, Kontrol (I ve II), % 2 ve 4 sellüloz artırımı (III, IV, V ve VI) ve % 2 ve 4 sellüloz artırımı + 250 mg/kg Vitamin C artırımı (VII, VIII, IX ve X) olmak üzere 10 farklı yem grubu oluşturmuştur. Oluşturulan deneme karmalarının yarısında enerji açığı soya yağı diğer yarısında ise hayvansal yağ (sığır don yağı) ile kapatılmıştır.

Genotip ve yetiştirme sistemi yumurta ve serum kolesterol içeriğini önemli düzeyde etkilemiştir. Serum ve yumurta kolesterol içeriği Beyaz yumurta tavuklarında, Kahverengi yumurta tavuklarına göre, daha düşük saptanmıştır. Genotipin kabuk oranı ve kalınlığı üzerindeki etkisi önemli bulunmamıştır. Yetiştirme sistemi farklılığı yumurta ağırlığı, kabuk ağırlığı ve kalınlığını önemli düzeyde etkilememiştir. Yumurta verimi, yem tüketimi ve yemden yararlanma bakımından genotipler arasında Beyaz yumurta tavukları, yetiştirme tipleri arasında da kafeste yetiştirme daha iyi sonuç vermiştir. Her iki genotip için yumurta kolesterol içeriği (mg/yumurta) ile yumurta ve sarı ağırlığı; serum kolesterol içeriği ile yumurta verimi arasında pozitif ve önemli korrelasyonlar bulunmuştur. Serum ve yumurta kolesterol içeriği (mg/g ve mg/yumurta) arasındaki korrelasyon ise negatif bulunmuş olup bu ilişki Beyaz yumurta tavuklarında önemli çıkmıştır.

Anahtar Sözcükler: Yumurta tavuğu, kolesterol, genotip ve yetiştirme sistemi.

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Introduction

The role of animal products such as meat, eggs and milk is quite important in providing many essential nutrients for sufficient and balanced nutrition in humans. The high nutrient density of eggs relative to their caloric content makes them an excellent food for many people with special dietary needs. Despite the fact that recent scientific and technological advances in the poultry industry have made abundant and economic egg production possible, egg consumption has not noticeably increased in most countries (1). The most important reasons for this are consumption habits, the high cholesterol content of eggs and the belief that cholesterol-rich foods are important factors leading to heart disease and atherosclerosis (2). It is recommended that dietary cholesterol intake be less than 300 mg/day. An egg contains about 220 mg of cholesterol (3). The cholesterol content of the egg yolk may be affected by a number of factors such as the age of the hen, genotype, rearing system and diet, and can be lowered by environmental and nutritional manipulations (4).

In recent years, the consumer's desire for healthier foods has increased the demand for animal products containing low cholesterol and enriched with omega-3 fatty acids and conjugated fatty acid. In response to the perceived need, poultry research in recent years has focused on reducing egg yolk cholesterol to satisfy the health conscious consumer. Currently, it appears that it would be economically advantageous for the egg producer to be able to market a low cholesterol egg. Much research has been directed toward this goal. The first studies related to egg yolk cholesterol were conducted on a genetic basis (5,6). Egg cholesterol levels have been shown to vary with the species breed or strain of bird. The heritability estimates for yolk cholesterol range from 0.14 to 0.22 (7,8). Simmons and Somes (9) and Shafey et al. (10) found genotype differences among laying hens in terms of the amount of cholesterol per egg. The literature contains limited data on the variations in the cholesterol content of eggs from commercial layers, but existing reports on chicken egg cholesterol values show considerable variation (11,12). Therefore, this study was undertaken to determine what variations in cholesterol content may presently exist among eggs from commercial layer genotypes. In addition, there has been relatively little attention paid to the effect of rearing systems on egg and serum cholesterol contents (13,14). These researchers reported that eggs from caged layers tended to contain less cholesterol and to have lower cholesterol concentrations than eggs laid by birds in floor pens. Turk and Barnett (13) reported that these differences were not significant and required further investigations.

This research was conducted to determine the effects of age, genotype, rearing system and dietary structure on egg and serum cholesterol contents, egg quality criteria and performance.

Materials and Methods

A total of 840 hens, 21weeks old and consisting of 400 white layers (Babcock-300) and 440 brown layers (IsaBrown), were used. Experimental diets were isoenergetic (2750 kcal/kg ME) and isonitrogenous (17% CP). The experimental diets are shown in Table 1. Ten different diets were repeated 4 times, for 2 genotypes and 2 rearing systems, making a total number of 40 groups (10 x 2 x 2). Open-sided housing with triple-deck battery type cages in cage rearing and housing with 6 m^2 sections in floor pen rearing (all-litter) were used. In cage rearing, 200 hens were randomly divided into 10 groups (5 replicates/group and 4 hens/cage) in the white genotype, and 240 hens were randomly assigned to 10 groups (6 replicates/group and 4 hens/cage) in the brown genotype. Four hundred hens were divided into 20 groups (10 groups for the white genotype and 10 groups for the brown genotype) in floor pen rearing. To determine egg yolk cholesterol content, 6 eggs were collected from each group at the beginning, middle and end of the trial. Blood samples were taken at random from 6 hens per group 2 times (at the beginning and end of the trial) and the serum was separated. Feed consumption was assessed on a monthly basis for each group. Egg production and feed conversion were calculated as kg of feed consumed/kg egg in each month and hen-days in each month, respectively. Egg quality criteria were determined in 18 eggs per group every month. While egg cholesterol content was determined by gas chromatography (15), serum cholesterol content was determined spectrophotometrically using a commercial kit (IL Test™ Cholesterol Kits). The experiment lasted for 6 months.

All data were analyzed using JMP (16). Including the effects of the age of the hen, genotype, and rearing

Table 1. Experimental diets.

Group	Diet
I (control)	Energy source: soybean oil
II (control)	Energy source: animal fat
III	Soybean oil + 2% fiber increment
IV	Soybean oil + 4% fiber increment
V	Animal fat + 2% fiber increment
VI	Animal fat + 4% fiber increment
VII	Soybean oil + 2% fiber increment + Vitamin C
VIII	Soybean oil + 4% fiber increment + Vitamin C
IX	Animal fat + 2% fiber increment + Vitamin C
X	Animal fat + 4% fiber increment + Vitamin C

system in the model with dietary structure in the above criteria standardized the effects of age, genotype, rearing system and dietary structure. Although the full model was used in the statistical analysis, only the results related to genotype and rearing system are given in this article. The correlations between egg yolk cholesterol content and egg and yolk weights, egg production, and also between serum cholesterol contents and egg cholesterol contents and egg production, were calculated for both genotypes.

Results

The data for egg yolk and serum cholesterol contents are shown in Table 2. The cholesterol content (mg/g yolk and mg/egg) of white-shelled eggs was significantly lower than that of brown-shelled eggs ($P < 0.01$). Eggs from hens reared in cages contained significantly more cholesterol than did eggs laid by hens reared in floor pens (13.36 mg vs. 13.72 mg as mg/g yolk, and 188.8 mg vs. 203.2 mg as mg/egg, respectively). There was a significant ($P < 0.01$) genotype x rearing system (GxRS) interaction in the cholesterol content of eggs. On the other hand, the difference between genotypes in the cholesterol content of eggs in floor pen rearing was higher than that in cage eggs. Serum cholesterol contents among genotypes and rearing systems were significantly different ($P < 0.05$ for genotype, $P < 0.01$ for rearing system). Serum cholesterol content was significantly lower in floor pen rearing (120.9 mg/dl) than in cage rearing (142.2 mg/dl). White layers showed significantly ($P < 0.05$) lower serum cholesterol contents than brown layers (128.8 mg/dl vs. 134.4 mg/dl). The results for egg quality criteria are given in Table 3. Brown layers produced heavier eggs. The weight of white-shelled eggs was 3.04 g lower that that of brown-shelled eggs (63.54 g vs. 60.50 g). A significant ($P < 0.01$) difference between genotypes in terms of egg weight was determined. No difference ($P > 0.05$) was found between floor pen and cage rearing in terms of egg weight (62.00 ± 0.083 g and 62.03 ± 0.083 g, respectively). There was a significant ($P < 0.01$) difference between white and brown eggs with respect to yolk weight and ratio (15.25 ± 0.024 g and 15.41 ± 0.024 g in yolk weight, and 25.07 ± 0.034% and 24.17 ± 0.034% in yolk ratio, respectively). Yolk weight and ratio of eggs from hens reared in cages (15.63 ± 0.024 g and 25.08 ± 0.034%, respectively) were higher than those of eggs from hens reared in floor pens (15.03 ± 0.024 g and 24.16 ± 0.034%, respectively). Among the genotypes, eggs from brown layers had the highest albumen weight and ratio at 41.80 g and 65.94%, respectively. Albumen weight and ratio in floor pen hens (40.77 ± 0.066 g and 65.91 ± 0.036%, respectively) were significantly higher than those in cage hens (40.29 ± 0.067 g and 65.07 ± 0.036 %, respectively). Shell weight in brown eggs was greater than that in white eggs. With respect to the shell ratio,

Table 2. Egg yolk and serum cholesterol content (Mean ± SEM).

		Egg cholesterol content		
		mg/g yolk	mg/egg	Serum cholesterol content (mg/dl)
Genotype	White	13.32 ± 0.064	191.9 ± 1.175	128.8 ± 3.445
	Brown	13.76 ± 0.064	200.2 ± 1.178	134.4 ± 3.445
Rearing system	Floor pen	13.36 ± 0.064	188.8 ± 1.178	120.9 ± 3.445
	Cage	13.72 ± 0.064	203.2 ± 1.175	142.2 ± 3.445
Genotype (G)		**	**	*
Rearing system (RS)		**	**	**
GxRS		**	**	NS

*: $P < 0.05$, **: $P < 0.01$, NS: Not significant ($P > 0.05$)

Table 3. Egg quality criteria (Mean ± SEM).

	Genotype			Rearing system		
	White	Brown	Significance	Floor pen	Cage	Significance
Egg Weight (g)	60.50 ± 0.083	63.54 ± 0.082	**	62.00 ± 0.083	62.03 ± 0.083	NS
Yolk Weight (g)	15.25 ± 0.024	15.41 ± 0.024	**	15.03 ± 0.024	15.63 ± 0.024	**
Yolk Ratio (%)	25.07 ± 0.034	24.17 ± 0.034	**	24.16 ± 0.034	25.08 ± 0.034	**
Albumen Weight (g)	39.25 ± 0.067	41.80 ± 0.066	**	40.77 ± 0.066	40.29 ± 0.067	*
Albumen Ratio (%)	65.04 ± 0.037	65.94 ± 0.036	**	65.91 ± 0.036	65.07 ± 0.036	**
Shell Weight (g)	5.99 ± 0.011	6.30 ± 0.011	**	6.15 ± 0.011	6.14 ± 0.011	NS
Shell Ratio (%)	9.92 ± 0.013	9.91 ± 0.013	NS	9.94 ± 0.013	9.89 ± 0.013	**
Albumen Height (mm)	10.35 ± 0.027	9.63 ± 0.026	**	10.12 ± 0.026	9.85 ± 0.026	**
Shell Strength (kg/cm^2)	3.22 ± 0.016	3.30 ± 0.016	**	3.34 ± 0.016	3.18 ± 0.016	**
Shell Thickness (µm)	0.399 ± 0.001	0.400 ± 0.001	NS	0.399 ± 0.001	0.400 ± 0.001	NS

**:P < 0.01, *:P < 0.05, NS: Not significant.

there was no significant difference between the genotypes (P > 0.05). Although the rearing system affected (P < 0.01) the shell ratio, shell weight was not influenced by the rearing system (P > 0.05). Albumen height in brown eggs and cage rearing was significantly lower than that in white eggs and cage rearing (10.35 g vs. 9.63 g for white and brown genotypes, and 10.12 g vs. 9.85 g for floor and cage systems). Shell strength in brown eggs and floor pen rearing was higher than that in white eggs and cage rearing (P < 0.01). No significant difference was found among genotypes and rearing systems in terms of shell thickness.

Effects of genotype and rearing system on feed consumption, egg production and feed conversion (performance parameters) are given in Table 4. Brown layers consumed more feed than white layers (122.0 g vs. 117.3 g). However, feed conversion was almost the same between the genotypes. Hens reared in cages (113.9 g) consumed less than hens reared in floor pens (125.4 g), and feed conversion in cages was much better than that in the floor pens. Genotype by rearing system interaction was also significant for feed consumption (P < 0.01). The difference among genotypes in the floor pen systems was higher than that in the cage system (GxRS). White layers had higher egg production than brown layers. There was no significant difference among rearing systems with respect to egg production. Similarly to feed consumption, genotype by rearing system was significant

Table 4. Performance Parameters (feed consumption, feed conversion and egg production).

Variations		Feed consumption (g/hen per day)	Feed conversion (kg feed/kg egg)	Egg production (%, hen-day)
Genotype	White	117.3 ± 0.652	2.35 ± 0.018	83.44 ± 0.449
	Brown	122.0 ± 0.652	2.37 ± 0.018	81.40 ± 0.450
Rearing system	Floor pen	125.4 ± 0.652	2.48 ± 0.018	82.62 ± 0.449
	Cage	113.9 ± 0.652	2.25 ± 0.018	82.23 ± 0.450
Genotype (G)		**	NS	**
Rearing system (RS)		**	**	NS
GxRS		**	NS	**

**:P < 0.01, NS: Not significant.

for egg production ($P < 0.01$). On the other hand, the effect of genotype on egg production was noticeable in cage rearing. Relations between egg cholesterol content and egg weight, yolk weight, and egg production were calculated (Table 5). While it was determined that there were significant ($P < 0.05$) negative correlations between mg/g yolk cholesterol content and egg weight and yolk weight for both genotypes (-0.559 and –0.499 in white layers, -0.753 and –0.703 in brown layers, respectively), there were significant ($P < 0.05$) positive high correlations between mg/egg cholesterol content and egg weight and yolk weight (0.922 and 0.945 for white layers, 0.908 and 0.923 for brown layers, respectively). The study showed that mg/egg cholesterol was highly correlated with egg and yolk weights in both genotypes (0.908 g and 0.923 g for brown layers, and 0.922 g and 0.945 g for white layers, respectively). It was determined that there were negative correlations between mg/g yolk cholesterol content and egg production (-0.293 for white layers, and -0.557 for brown layers), and there were positive correlations between mg/egg cholesterol content and egg production (0.417 for white layers, and 0.860 for brown layers). Negative correlations between the serum cholesterol content and egg cholesterol content (mg/g yolk and mg/egg) were determined for both genotypes (Table 6). These values were –0.634 and –0.343 for white layers, and -0.107 and –0.103 for brown layers, respectively. However, there were nonsignificant ($P > 0.05$) correlations between egg yolk cholesterol content (mg/g yolk and mg/egg) and serum cholesterol content in brown layers. Significant ($P < 0.05$) positive correlations (0.669 for white layers and 0.240 for brown layers) were determined between serum cholesterol content and egg production.

Discussion

Many factors affect the cholesterol content of egg and serum. Genotype and rearing system are just 2 of these factors. In this experiment, egg yolk and serum cholesterol contents in white layers (Babcock-300) were lower than those in brown layers (IsaBrown). Similar findings were reported by Turk and Barnett (13). The cholesterol content of eggs from laying hens reared in floor pens was lower than that of those reared in cages. However, this finding was in contrast to Scholtyssek's (17) result. He concluded that cage rearing gave a better result than the other rearing system in terms of egg cholesterol content.

Turk and Barnett (13) reported that these differences between cage and floor pen rearing were not significant and that they require further investigation. In the present study, as with the egg yolk cholesterol results, similar results were obtained for serum cholesterol content. Some researchers reported that cage rearing was a stress factor, and that it played a major role in increasing serum cholesterol (13,17).

Table 5. Correlations between egg yolk cholesterol content and egg weight, yolk weight, egg production for each genotype.

Genotype	Egg cholesterol content	Egg weight (g)	Yolk weight (g)	Egg production (%)
White	mg/g yolk	-0.559 *	-0.499 *	-0.293 *
	mg/egg	0.922 *	0.945 *	0.417 *
Brown	mg/g yolk	-0.753 *	-0.703 *	-0.557 *
	mg/egg	0.908 *	0.923 *	0.860 *

*: $P < 0.05$

Table 6. Correlations between serum cholesterol content and egg colesterol content and egg production.

Genotype		mg/g yolk cholesterol	mg/egg cholesterol	Egg production (%)
White	Serum cholesterol (mg/dl)	- 0.634 *	-0.343 *	0.699 *
Brown	Serum cholesterol (mg/dl)	-0.107 NS	-0.103 NS	0.240 *

*:$P < 0.05$, NS: Not significant.

The influence of genotype on some other egg quality criteria was significant, except for shell ratio and thickness. While egg, yolk, albumen and shell weights, albumen ratio and shell strength in brown eggs were higher than those in white eggs, yolk ratio and albumen height in white eggs were higher than those in brown eggs. Genotype differences that result in changes in egg size should be expected to result in changes in the weight of the egg components. Similarly, some researchers determined that egg, yolk, albumen and shell weights of brown eggs were greater than those of white eggs (18-20).

The present study and that by Fletcher et al. (21) have shown that the shell weight of brown-shelled eggs was higher than that of white-shelled eggs. However, this finding was in contrast to those of other researchers (22,23). Differences among rearing systems for egg quality criteria were significant, except for egg weight, and shell weight and thickness. While cage rearing increased yolk weight and yolk ratio, it reduced albumen weight, shell weight and ratio, shell strength and albumen height. In contrast, Moore et al. (24) determined that shell thickness was higher in cage rearing than in floor rearing. With respect to egg weight, no difference between rearing systems was found by Moore et al. (24) or Roland et al. (25); whereas Logan (26) determined that eggs from hens reared in cages were 0.02 g heavier than those from hens reared in floor pens, but that this was not significant. The latter researcher's result was similar to ours. In addition, Moore et al. (24) determined that albumen height and shell ratio did not differ according to rearing system (cage-floor pen), in contrast to the result obtained from this study.

Egg production was 2.04% higher in white layers than in brown layers. This magnitude of egg production was similar to that observed by other researchers (20,27,28). Although egg production of laying hens reared in floor pens was 0.39% higher than that of the laying hens in cages, this difference between rearing systems was nonsignificant. While this result agrees with others reported by a number of researchers (20,29), it stands in contrast to the work of Moore et al. (24).

There was a significant difference between the genotypes in feed consumption, but not in feed conversion. This nonsignificance in feed conversion may be explained by the fact that the weight of brown eggs was greater than that of white eggs. Similar conclusions were drawn by Curtis et al. (30), Hurwitz (31), and Washburn (32). In addition, Ensminger (27) reported that many factors such as disease, season, environmental temperature, egg production, and dietary structure were influential at a significant level together with strain. Significant differences were obtained between rearing systems in terms of feed consumption and feed conversion. The feed consumption of hens reared in floor pens was higher than that of hens reared in cages, and cage rearing resulted in better feed conversion. These findings are in agreement with those of other researchers (25,26). In contrast to these results, Sugandi et al. (29) determined that floor rearing improved feed conversion. In floor rearing, feed loss should be taken into consideration.

In this study, it was determined that there were significant negative correlations between egg yolk cholesterol (mg/g yolk) and egg weight and yolk weight for both genotypes. Similarly, some researchers found a negative correlation between egg yolk cholesterol and egg weight, and yolk weight (33-35). Marks and Washburn (8) and Becker et al. (36) determined a positive correlation between these 2 criteria. Correlations between yolk cholesterol (mg/egg) and egg weight, and yolk weight were positive and significant for both genotypes. Similar correlations were also noted by Beyer and Jensen (37), who determined correlations of 0.78 and 0.79 between egg cholesterol content and egg weight and yolk weight, respectively.

While the correlations between egg yolk cholesterol content (mg/g yolk) and egg production were negative and significant, those between egg cholesterol (mg/egg) and egg production were positive and significant for both genotypes. While Scholtyssek (17) reported a similar result, Collins et al. (38) determined a different result. Bartov et al. (33) reported that the total amount of cholesterol per egg, as well as the cholesterol concenteration per gram of yolk, were significantly higher in eggs laid by hens having a low rate of production. In the present study, a negative correlation between yolk cholesterol and serum cholesterol was observed in each genotype, being significant in white layers, and nonsignificant in brown layers. The correlations between serum cholesterol and egg production were significant and positive in both genotypes. Harris and Wilcox (39) observed a negative correlation between egg production and serum

cholesterol content, while Washburn and Nix (7) observed a nonsignificant positive correlation.

In conclusion, egg and serum cholesterol contents can be manipulated by genotype and rearing system manipulations. White-shelled eggs, which have a lower yolk weight and egg yolk cholesterol content, may be recommended for humans, who have cholesterol problems. In addition, white layers had higher egg production (%) and consumed less feed compared to brown layers. Thus, white layers have an advantage in terms of performance parameters. When the aim of animal breeders is to reduce management activities, hens should be reared in floor pens. High albumen height, albumen weight and ratio, and shell strength in the floor system represent an advantage for eggs' market value.

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