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The Relationships between Egg Yolk Cholesterol, Egg Production and Age of the Hen in Three Australian Layer Strains

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Abstract. This paper reports the relationships between egg yolk cholesterol and egg weight, yolk weight, egg production and age of the hen in three strains of Australian commercial layers. Genotypes differed in egg weight, yolk weight, rate of lay, yolk cholesterol concentration (mg cholesterol/g yolk) and egg cholesterol content. Differences among strains were not significant when cholesterol was calculated as the concentration of the egg (mg cholesterol/g egg). Smaller eggs contained a significantly lower cholesterol content than larger eggs. The percentage increase in egg cholesterol content of large eggs was approximately equivalent to the percentage increase in their egg and yolk weights. Age of the hen was significantly positively correlated with yolk cholesterol concentration, egg cholesterol content and daily egg cholesterol output. Egg cholesterol content at 30 weeks of age was approximately 19% lower than that produced at 56 weeks of age whereas average egg weight was only 9% less at that age. It was concluded that differences in yolk cholesterol that occurred among strains of laying hens were mainly due to differences in responses in egg traits and not to responses in daily cholesterol output. A greater proportion of lower cholesterol eggs can be produced by choosing laying strains that are more highly productive at a younger age.

Introduction

The proportions of egg components are influenced by the genetic background and age of hens [1-5]. Genetic variations in egg yolk cholesterol have been found to be associated with egg production [6-9], egg weight [10] and yolk size [11].

The relationship between egg yolk cholesterol and age of the hen has been reported by Gissel *et al.* [12] who found a decrease in egg cholesterol content as age of the hen increased. Eggs from different strains of birds were used in their investigations. In contrast, Menge *et al.* [13] found that both cholesterol content (mg/egg) and cholesterol concentration (mg/g egg) increased with age of the hens, whilst Palafox [14] found that yolk cholesterol concentration was not affected by age of the bird.

This paper reports the relationships between egg yolk cholesterol and egg production, egg mass, egg weight, yolk weight and age of the hen in three strains of Australian commercial layers.

Materials and Methods

Three different strains of Australian commercial pullets were used starting when they were 26 weeks old. Birds from the same strain were housed in a block of six cages with two birds per cage and each block was treated as a replicate. Fifty-four blocks were used and each strain of birds was randomly assigned to eighteen blocks. Feed and water were available ad libitum. Diets were supplied as mash. All birds were fed the same wheat based diet (17.9 % protein; 11.5 MJ/kg calculated metabolizable energy). A photoperiod of 14 h commenced when the birds were caged at 22 weeks of age and was maintained throughout the trial in a gabled roofed, naturally ventilated shed. Egg production was recorded for each replicate. Egg weight was based on the weight of a complete collection for one day each week and calculations were based on 4-week periods. For egg cholesterol, replicates were assigned into 6 groups of three replicates for each strain. Three eggs were randomly sampled from each replicate at 30, 32, 34, 36, 39, 47, 49, 52 and 56 weeks of hen age and egg cholesterol was determined. Eggs were weighed and then the yolk was separated, weighed, homogenised and placed in an air tight container prior to analysis. Cholesterol was determined by the method of Ishikawa *et al.* [15]. Egg mass and average daily cholesterol output were calculated from total egg production. Data collected were subjected to analysis of variance, correlation and regression [16]. When significant variance ratios were detected, differences between treatment means were tested using the least significant difference procedures.

Results

Different strains of birds had different mean egg weight, yolk weight and egg production but not egg mass (Table 1). Strains 2 and 3 produced significantly ($P < 0.01$) heavier and fewer eggs than strain 1. The yolk weight produced by strain 2 birds was significantly ($P < 0.05$) heavier than that of strain 1, while the yolk weight of strain 3 was intermediate.

Table 1. Egg weight, yolk weight, egg production and egg mass of different strains of laying hen

Strain	Egg weight (g)	Yolk weight (g)	Rate of lay (egg/hen/day)	Egg mass (g)
S1	54.2[b]	16.2[b]	0.89[a]	48.1
S2	58.2[a]	17.5[a]	0.83[b]	48.3
S3	58.2[a]	16.8[ab]	0.84[b]	48.9
LSD[1] ($P < 0.05$)	1.0	1.1	0.02	1.2

[1]Least significant differences ($P < 0.05$) with 135 degrees of freedom.
[a,b]Treatment means within columns followed by different letters are significantly different ($P < 0.05$).

The effects of strain of bird and age of laying hen on egg yolk cholesterol and daily cholesterol output are shown in Table 2. Strain 3 had a significantly ($P <0.01$) higher yolk cholesterol concentration (mg cholesterol/g yolk) than those of the other strains. The egg cholesterol content (mg cholesterol/yolk or egg) produced by strain 3 birds was significantly ($P <0.05$) higher than that of strain 1. However, there were no significant differences among strains in egg cholesterol when expressed as a percentage on an egg weight basis (mg cholesterol/ g egg) or as daily cholesterol output. Yolk cholesterol concentration produced by hens at the age of 52 was significantly ($P < 0.05$) higher than those produced by hens younger than 47 weeks of age. There were no significant differences between yolk cholesterol concentrations produced by hens younger than 47 weeks of age. Egg cholesterol content was significantly ($P <0.05$) higher in eggs produced by hens over 49-weeks of age than those produced by hens younger than 39 weeks of age. There were no significant differences between egg cholesterol contents produced by hens younger than 39 weeks of age. The daily cholesterol output by hens at the age of 49 and 52 weeks was significantly ($P <0.05$) higher than those produced at 30 and 32 weeks of age. There were no significant differences between daily cholesterol output by hens older than 34 weeks of age.

Significant correlations were found between age and yolk cholesterol concentration, egg cholesterol content and daily egg cholesterol output (0.30, 0.57 and 0.36, $P <0.01$) between yolk cholesterol concentration and egg cholesterol content (0.74, $P <0.001$), between yolk weight and egg cholesterol content (0.73, $P <0.001$), between egg weight and egg cholesterol content (0.62 $P <0.01$), and between daily egg cholesterol output and egg weight, yolk weight, yolk cholesterol concentration and egg cholesterol content (0.45, 0.64, 0.59 and 0.84, $P < 0.01$). Rate of lay was negatively correlated with yolk cholesterol concentration and egg cholesterol content (-0.35 and -0.39, $P < 0.01$). Egg traits were affected by strain of birds (Table 3). The three strains, egg cholesterol content was highly correlated with yolk cholesterol concentration (ranging from 0.71 to 0.85, P<0.01), egg weight (ranging from 0.42 to 0.61, P<0.01), yolk weight (ranging from 0.63 to 0.86, P <0.01) and age of the bird (ranging from 0.51 to 0.72, P <0.01).

Table 2. The effects of strain and age of laying hens on egg yolk cholesterol and daily cholesterol output

Treatment	Cholesterol			
	Concentration (mg/g yolk)	Content (mg/egg)	% of egg weight	Daily output (mg/day)
Strain				
S1	11.8[b]	190.8[b]	0.352	169.6
S2	11.9[b]	208.1[a]	0.358	172.3
S3	12.6[a]	211.9[a]	0.363	177.2
LSD[1](P< 0.05)	0.4	15.3	0.028	13.9
Age (week)				
30	11.3d	186.2cd	0.348bcd	161.9bc
32	12.1bc	176.6cd	0.323d	155.7c
34	12.2bc	196.4cd	0.359abc	173.3abc
36	11.9cd	194.4cd	0.340bcd	169.7abc
39	11.5cd	196.8cd	0.334cd	171.3abc
47	11.6cd	201.2bc	0.349bcd	164.4abc
49	12.7ab	226.2ab	0.388ab	186.2a
52	13.0a	232.8a	0.398a	191.9a
56	12.4ab	221.8ab	0.380abc	182.2ab
LSD[1](P <0.05)	0.7	26.7	0.05	24.3

For footnotes see Table 1.

Average daily egg cholesterol output was highly correlated with egg mass (ranging from 0.40 to 0.60, P<0.01), yolk mass (ranging from 0.49 to 0.75, P<0.01), yolk weight (ranging from 0.50 to 0.70, P<0.01) and yolk cholesterol concentration (ranging from 0.51 to 0.70, P<0.01). Egg weight was highly correlated with yolk weight (ranging from 0.47 to 0.71, P<0.01). Significant correlations were also found for each strain between age of the bird and egg weight (ranging from 0.77 to 0.81, P<0.01) and between rate of lay and egg mass (ranging from 0.85 to 0.87, P<0.01).

Different correlations were obtained for each genotype between egg cholesterol content and rate of lay (ranging from 0.06 to -0.64) and egg mass (ranging from -0.06 to 0.32), and between yolk cholesterol concentration and egg weight (ranging from 0.06 to 0.45), rate of lay (ranging from -0.56 to -0.20), egg mass (ranging from -0.08 to -0.18), yolk weight (ranging from -0.10 to 0.46) and age of bird (ranging from 0.17 to 0.59), and between yolk cholesterol mass and age of the bird (ranging from 0.23 to 0.51), egg weight (ranging from 0.28 to 0.51) and rate of lay (ranging from -0.07 to 0.53) (Table 3).

Data from this experiment were used to develop multiple regression equations for predicting yolk cholesterol concentration, egg cholesterol content and daily cholesterol output for all birds (combining results from the three strains) and each individual strain using egg weight, yolk weight and age of bird. These equations are presented in Table 4. The correlation coefficients were increased when rate of lay was also entered in the model (Table 4).

Table 3. The effect of strain of laying hen on the correlations between egg production parameters and egg cholesterol

	Cholesterol								
	Concentration (mg/ g yolk)			Content (mg/egg)			Daily output (mg/day)		
Strain/	1	2	3	1	2	3	1	2	3
Egg parameter									
Egg weight	0.10	0.06	0.45	0.42	0.61	0.60	0.28	0.53	0.51
Yolk weight	-0.10	-0.01	0.46	0.63	0.63	0.86	0.68	0.50	0.70
Rate of lay	-0.20	-0.41	-0.56	0.06	-0.54	-0.64	0.53	- 0.01	-0.07
Age of bird	0.17	0.51	0.59	0.62	0.51	0.72	0.48	0.23	0.51
Egg mass	-0.08	-0.18	-0.18	0.32	-0.05	-0.06	0.62	0.41	0.40
Yolk mass	-0.18	-0.29	-0.11	0.46	0.13	0.22	0.75	0.49	0.66

Significance of correlation coefficient (N=54 at P <0.05=0.26; P <0.01=0.34; P <0.001=0.43).

Table 4. The relationship between yolk cholesterol, egg weight, yolk weight, bird age and rate of lay

Cholesterol[1]	Regression equation[2]	t value			Correlation coefficient[3]			
		C1	C2	C3	$R^2$1	F1	$R^2$2	F2
All birds								
YC =	9.53 + 0.101 C1 - 0.239 C2 + 0.342 C3	1.92	-1.83	2.34	14.7	*	18.8	**
EC =	-41.4 + 1.47 C1 + 8.83 C2 + 5.16 C3	1.80	4.33	2.27	59.0	**	61.3	**
CM =	15.8 + 0.140 C1 + 8.78 C2 + 0.68 C3	0.18	4.58	0.32	41.6	**	54.7	**
Strain 1								
YC =	12.6 + 0.099 C1 - 0.470 C2 + 0.604 C3	1.07	-1.75	1.58	16.8	NS	17.2	NS
EC =	20.6 + 1.17 C1 + 4.31 C2 + 7.44 C3	0.85	1.08	1.57	44.2	**	44.3	*
CM =	6.6 - 0.45 C1 + 11.6 C2 + 0.86 C3	-0.32	2.84	0.18	46.2	**	62.5	**
Strain 2								
YC =	7.25 + 0.184 C1 - 0.395 C2 + 0.242 C3	1.40	-1.27	0.77	15.2	NS	26.4	NS
EC =	-88.2 + 3.15 C1 + 6.43 C2 + 2.95 C3	1.43	1.30	0.60	47.8	**	54.9	**
CM =	-55.6 + 2.87 C1 + 4.48 C2 - 3.77 C3	1.60	1.11	-0.84	33.3	*	37.3	*
Strain 3								
YC =	8.3 + 0.046 C1 + 0.015 C2 + 0.375 C3	0.71	0.07	2.07	36.9	*	43.2	*
EC =	-58.8 + 0.68 C1 + 12.4 C2 - 6.58 C3	0.66	3.77	2.26	79.4	**	81.6	**
CM =	22.8 + 0.04 C1 + 8.51 C2 - 1.72 C3	0.04	2.48	0.56	48.6	**	66.6	**

1 YC= Yolk cholesterol concentration (mg cholesterol/g yolk);
EC= Yolk cholesterol content (mg cholesterol/egg);
CM= Cholesterol mass (mg cholesterol/hen/day).

2 C1 = Egg weight; C2 = Yolk weight; C3 = Bird age.

3 $R^2$1= correlation coefficient for yolk cholesterol using egg weight, yolk weight and age of the bird age in the model.
F1 = significance of $R^2$1; $R^2$2 = correlation coefficient for yolk cholesterol when rate of lay was also entered into the model;
F2= Significance of $R^2$2. * = ($P < 0.05$). ** = ($P < 0.01$). NS = Not significant.

Discussion

Results of this study have demonstrated that eggs produced by older hens have, on average, a higher yolk weight, yolk cholesterol concentration and hence egg cholesterol content. The positive correlations between age and yolk cholesterol concentration is in agreement with results by others [13, 17, 18]. In contrast, Palafox [14], Jones [19], Turk and Barnett [20] and Spencer *et al.* [21] reported no relationship between yolk cholesterol concentration and age of the bird. The increase in egg cholesterol content with age of the bird is thus attributable to an increase in yolk cholesterol concentration and yolk weight. This finding was consistent with results by others [1, 4] who showed that as the age of the laying hen increased, egg size and egg mass increased but the number of eggs produced decreased. Egg and yolk produced at 56 weeks of age (58.3 and 17.9 g, respectively) were approximately 8.7 and 10.5% heavier than those produced at 30 weeks of age (53.7 and 16.2 g, respectively), whereas egg cholesterol content produced over the same period (221.8 and 186.2 mg cholesterol/egg at 56 and 30 weeks of age, respectively) was approximately 19% higher than that produced at the younger age. This finding is in agreement with Turk and Barnett [20], but not with Nichols *et al.* [18] who reported an inverse relationship between yolk weight and yolk cholesterol content.

The finding that yolk cholesterol (mg/g yolk or mg/yolk) was inversely correlated to egg production was consistent with findings of others [6, 8, 17, 22]. However, Bartov *et al.* [23] did not find that a relationship existed between egg weight, yolk weight, yolk cholesterol concentration or rate of production. Results from this study have demonstrated that the negative correlation between egg cholesterol and egg numbers resulted in no difference in total daily cholesterol output among the three strains of birds at the same age. Washburn and Marks [9] reported similar findings in their selected low and high cholestrol lines. These findings suggest that factors which may directly affect the production of egg and its components have an indirect effect on egg cholesterol but that daily egg cholesterol output was only affected by the age of the bird.

The different correlations between egg cholesterol and different egg traits among the three strains reflect the differences of genetic makeup of these birds (Table 3). The correlations between age and rate of lay, yolk cholesterol (mg/g yolk or mg/yolk), egg weight and yolk weight suggested that the lower egg cholesterol produced by strain 1 birds was associated with lower egg and yolk weights and higher rate of lay when compared with higher egg and yolk weights and lower rate of lay of strain 3 birds. Evidence of variation in the correlation between egg cholesterol content and egg production was also reported by other researchers [6, 7, 8, 17, 22]. The differences in egg cholesterol content found in eggs produced by strains 2 were attributed to differences in yolk weights only, but differences in egg cholesterol content in strains 1 and 3 may be attributed to differences in yolk weight and yolk cholesterol concentration. Sheridan *et al.* [11] reported that genetic variations in egg cholesterol were related to differences in the proportion of egg yolk. The nonsignificant differences in egg mass and daily cholesterol output among strains of birds despite the significant differences in egg and yolk weights, egg production and cholesterol concentration and content of the yolk may suggest that the yolk cholesterol is not influenced by total cholesterol output. Yolk cholesterol is affected by other egg traits such as rate of lay that are controlled by the genetic background of the hen. It seems that genetic variations may differ in their effect on the number of eggs produced and that will influence their effect in egg cholesterol. These results suggest that the discrepancy found in the literature regarding the relationship between yolk cholesterol and egg traits may be related to differences in egg producing ability of their genotype. Selection for higher egg weight may be expected to increase yolk cholesterol content of individual eggs. Selection for higher egg production may be expected to decrease yolk cholesterol content of individual eggs.

It was concluded that age and strain of bird significantly influenced egg production, egg weight, yolk weight and consequently egg cholesterol content. Factors which may directly affect the production of egg and its components have an indirect effect on egg cholesterol content but not daily egg cholesterol output. Younger hens produced more smaller eggs with less deposition of cholesterol in each egg. A greater

proportion of lower cholesterol eggs can be produced by choosing laying strains that are more highly productive at a younger age.

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العلاقة بين كوليسترول صفار البيض وإنتاج البيض وعمر القطيع في ثلاث سلالات استرالية بياضة

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ملخص البحث : أجريت تجربة لدراسة العلاقة بين كوليسترول صفار البيضة ووزن البيضة ووزن الصفار وإنتاج البيض وعمر القطيع البياض، وذلك في ثلاث سلالات استرالية تجارية بياضة. أظهرت الدراسة اختلافاً بين السلالات في وزن البيضة ووزن الصفار ومعدل وضع البيض وتركيز الكوليسترول في الصفار (ملجم كوليسترول / حم بيض). وكذلك أن البيض الصغير يحتوى على كمية أقل من الكوليسترول قياساً بالبيض الكبير ، وأن نسبة الزيادة في كوليسترول البيضة ذات الحجم الكبير كانت تقريباً مساوية لنسبة الزيادة في وزن البيضة ووزن الصفار. وكانت هناك علاقة طردية بين عمر الدجاجة وكلٍ من تركيز الكوليسترول في الصفار ومحتوى البيضة من الكوليسترول وأيضا الكوليسترول المنتج يومياً للبيضة . وأظهرت أيضا الدراسة انخفاضاً في محتوى البيضة من الكوليسترول في البيض الناتج من دجاجات عمرها ٣٠ أسبوعاً بما يساوي تقريباً ١٩% عن البيض الناتج من دجاجات عمرها ٥٦ أسبوعاً ، بينما كان الانخفاض في وزن البيضة حوالى ٩% فقط عند العمر نفسه.

يتضح من ذلك أن الاختلافات التي تحدث بين السلالات في محتوى البيضة من الكوليسترول ترجع أساساً إلى صفات البيضة وليست الى كمية الكوليسترول المنتجة يومياً للبيض. وبذلك يمكن الحصول على نسبة أكبر من البيض المنخفض فى الكوليسترول باختيار السلالات البياضة التي تعطي أعلى إنتاجية لها في الأعمار الصغيرة.