15

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Genetics of Egg Cholesterol and Related Characteristics in Fayoumi Chickens

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ONE hundred and fifty pullets from69 dams and 11 sires were used to collect data for age at sexual maturity, body weight at sexual maturity, egg production until 26 weeks of production (until the analysis of egg components), 40, 44, 48, 52, and 70 weeks of age and annual egg production (52 weeks from sexual maturity), egg weight and yolk weight.

The following components were analyzed for each egg: mg cholesterol per g yolk, mg sodium, potassium, calcium, phosphorus, zinc, and iron per g yolk and mg cholesterol per 100 ml serum. The total cholesterol per yolk was also calculated. Results indicated that the heritabilities for mg cholesterol per g yolk and for serum cholesterol were low. Heritabilities for age at sexual maturity were intermediate while those for body weight at sexual maturity were high. Heritabilities for egg production until different ages and egg weights at these ages were also low to medium. Heritabilies for the mineral content of the yolk were all low except dor the sodium content which was intermediate. The genetic and phenotypic correlations between the different traits studied were also calculated and assessed.

The relationship between dietary cholesterol and coronary has been the subject of much controversy and investigation in recent years. The American Heart Association recommends that people with high serum cholesterol avoid eating egg yolks, since these are extremely high in cholesterol.

Several studies have indicated genetic differences in yolk cholesterol content. Fisher and Leveille (1957) found 55 to 66 mg cholesterol per gram of yolk fat; Edwards *et al.* (1960) were able to detect breed and strain differences in yolk cholesterol content. The lowest cholesterol content was for a White Leghorn strain (39 mg cholesterol/g fat) and the highest was for a New Hampshire strain (50.6 mg cholesterol/g fat). Harris and Wilcox (1963a) reported values of 24.0 to 26.1 mg cholesterol per g of chicken egg yolk. Turk and Barnett (1971) found no significant differences in yolk cholesterol content of eggs produced by different layer strains. Kicka *et al.* (1974a) reported mean yolk cholesterol values of 14.58, 13.56, and 13.40 mg cholesterol per g yolk in Fayoumis, White Baladis and White Leghorns respectively.

Cunningham *et al.* (1974) selected divergent lines for yolk cholesterol in a closed White Leghorn population. They reported the heritabilities of yolk cholesterol to be 0.22(based on the regression of offspring on parent). Washburn and Nix (1974a) estimated the heritability of yolk cholesterol in two randombred populations of meat-type hens. The mean sire heritability estimate for the Athens-Canadian randombred (AC) was 0.3, while for the Athens randombred population (ARB) it was 0.2.

Although there is some indication that ovarian follicle may produce some cholesterol in *vitro* (Popjak and Tietz, 1953), the result of most experiments have indicated that egg cholesterol originates from serum cholesterol (Conner *et al.*, 1965 and Andrews *et al.*, 1968). Washburn and Nix (1974a) found that the mean plasma cholesterol level in the AC population was 169 mg cholesterol / 100 ml plasma and 230 mg cholesterol/100 ml plasma for the ARB population. They also reported positive insignificant phenotypic correlations (0.03 to 0.14) between serum and yolk cholesterol in the same populations. They reported no genetic correlation between serum and yolk cholesterol in the AC population. However, a highly significant genetic correlation (0.59) was obtained in the ARB population. They also estimated the heritability for serum cholesterol levels to be 0.56 ± 0.14 for ARB population and -0.13 ± 0.19 for AC population (regression of offspring on sire).

A literature survey suggested that the high egg producers may put less cholesterol in each yolk, though they may excrete a larger total amount of cholesterol than poor producers over a specific time period. Harris and Wilcox (1963 a, b) found no correlation between yolk cholesterol and rate of lay. Yolk cholesterol was negatively correlated with yolk weight. Kicka *et al.* (1979) found that the phenotypic correlation between yolk cholesterol and both egg weight and yolk weight were negative.

The purpose of this study was to measure the cholesterol and mineral contents of the egg yolk and the serum cholesterol and to try to relate these measurements to the productivity of the Fayoumi fowl. It was also intended to study the inheritance of yolk cholesterol, serum cholesterol, yolk mineral content, and other reproductive and physiological traits, and their interrelations in the Fayoumi fowl.

Material and Methods

Data used in this study included 150 Fayoumi pullets from 69 dams and 11 sires. Dams with less than 3 daughters were excluded from the analysis. Data were calculated for age at sexual maturity (SM); body weight at sexual maturity (WSM); egg production at 40, 44, 48, 52, and 70 weeks of age; annual egg production and egg production at 26 weeks of production; egg weight and yolk weight.

The following components were analyzed in each two successive eggs collected for each hen during the 26th week of production: mg cholesterol per g yolk (yolk cholesterol was extracted by the modified method of Washburn and Nix, 1974b), and the total cholesterol was determined according to Courchaine *et al.* (1959). Serum cholesterol was determined by the method of Pierfitte and Barrier (1959). Mg phosphorus per g yolk was determined by a modified method of Fisk and Subbarow (1925). Mg sodium, potassium, calcium, zinc, magnesium, and iron per g yolk in the egg yolk was determined by the atomic absorption spectrophotometric technique according to Youssef *et al.* (1978). The heritabilities and their standard errors were estimated according to Becker (1967). The genetic and phenotypic correlations were also calculated according to Becker (1967). The standard errors of the genetic correlations were computed according to Robertson (1959). The method assumes a hierarchial classification with unequal subclass number. The separate data from two eggs (in sequence) for each hen were used in the estimation.

Results and Discussion

I. Averages of the different traits studied

The averages of the traits studied are shown in Table 1. The average age at sexual maturity of the Fayoumi hens was 215 days. These results are similar to the results obtained by Obeidah (1969). The average egg weight and egg production until 40, 44, 48, 52 and 70 weeks of age and the full record were higher than those found by Ezzeldin (1977) on the same flock of Fayoumi hens. These observed differences between her estimates and these estimates may be due to the differences in ages at sexual maturity.

The average mg cholesterol/g yolk and total cholesterol per yolk were 15.7 mg and 218.5 mg respectively. These values were lower than those reported by Harris and Wilcox (1963 a, b); Schiavo (1963); and Collins *et al.* (1968). These differences may be due to the breed and the differences in the rate of egg production. However, these results are in agreement with the values reported by Kicka *et al.* (1979). The average mg cholesterol per 100 ml serum at 26 weeks of production was 143.7. These results agree with Cherms *et al.* (1960). However, they are lower than those reported by Washburn and Nix (1974a). The average mineral contents per g yolk were 1.45; 0.52; 5.31; 0.91; 2:12; 0.24; and 0.11 mg per g yolk for Ca, Mg, P, Na, k, Fe, and Zn respectively.

II. Heritabilities

The heritability estimates of all traits studied are presented in Table 2. The combined heritability estimate for age at sexual maturity was 0.26. This is in agreement with the result obtained by Obeidah (1969) but lower than the result obtained by El-Hossari (1967). The component heritability estimate of body weight at sexual maturity was higher than the dam estimate. This is not in line with the estimate obtained by Ezzeldin (1977). The heritability estimates of egg weight were lower than previously reported values. This may be due to the small number of individuals used in this study, and also may be due to the hatch effect. The heritability estimates of the total number of eggs produced until 40, 44, 48, 52, and 70 weeks of age and the full record (365 days) were low and mostly negative. These estimates are similar to those obtained by Ezzeldin (1977). The sire heritability for yolk cholesterol was 0.14. This estimate is similar to that obtained by Washburn and

Nix (1974a). The sire heritability estimate of serum cholesterol was higher than any previously reported estimate. The sire heritability estimates of the mineral contents of Fayoumi egg yolks were not significantly different from zero. However, the dam heritability estimates for magnesium, phosphorus, and sodium were positive and high (0.31, 0.44 and 0.84 respectively).

TABLE 1. **Average of the different traits studied.**

Traits	Means ± S.E.
Age at sexual maturity (days)	214.6 ± 1.5
Body wt. at sexual maturity (g)	1158 ± 9
Egg wt. (g) /26 weeks of egg production	43.7 ± 0.2
Egg production until 40 wks. of age	26.8 ± 0.7
Egg production until 44 wks. of age	38.3 ± 0.8
Egg production until 48 wks. of age	50.2 ± 0.9
Egg production until 52 wks. of age	62.6 ± 1.1
Egg production until 70 wks. of age	96.3 ± 1.7
Full production (365 days)	109.7 ± 1.9
Mg cholesterol/g yolk	15.66 ± 0.41
Total cholesterol/yolk (mg)	218.51 ± 2.45
Mg cholesterol/100 ml serum	143.65 ± 1.70
Mg calcium/g yolk	1.45 ± 0.02
Mg zinc/g yolk	0.11 ± 0.003
Mg magnesium/g yolk	0.42 ± 0.01
Mg phosphorus/g yolk	5.31 ± 0.04
Mg sodium/g yolk	0.91 ± 0.02
Mg potassium/g yolk	2.12 ± 0.03
Mg iron/g yolk	0.24 ± 0.01

TABLE 2. **The heritability estimates (± SE) of the different traits studied.**

Traits	h^2s	h^2d	h^2 s+ d
Age at sexual maturity	0.01±0.17	0.52±0.50	0.26±0.24
Body weight at sexual maturity	0.75±0.40	0.23±0.39	0.50±0.28
Egg weight at 26 weeks of egg production	0.01±0.11	0.12±0.34	0.06±0.16
Egg production until 40 wks. of age	0.09±0.17	−0.15±0.42	−0.03±0.21
Egg production until 44 wks. of age	0.04±0.14	−0.48±0.38	−0.22±0.18
Egg production until 48 wks. of age	0.08±0.15	−0.45±0.38	−0.18±0.18
Egg production until 52 wks. of age	0.00±0.13	−0.34±0.40	−0.17±0.19
Egg production until 70 wks. of age	−0.07±0.15	0.57±0.52	0.25±0.24
Full record of egg production (365 days)	−0.05±0.13	0.11±0.47	0.03±0.22
Mg cholesterol/g yolk	0.14±0.17	−0.14±0.35	0.00±0.18
Mg cholesterol/100 ml serum	0.65±0.42	−1.35±0.49	−0.35±0.35
Mg calcium/g yolk	−0.02±0.08	−0.46±0.30	−0.24±0.14
Mg zinc/g yolk	0.02±0.08	−0.13±0.26	−0.06±0.12
Mg magnesium/g yolk	−0.11±0.10	0.31±0.44	0.10±0.20
Mg phosphorus/g yolk	−0.14+0.06	0.44±0.31	0.18±0.14
Mg sodium/g yolk	−0.20±0.09	0.84±0.44	0.32±0.19
Mg potassium/g yolk	0.09±0.14	−0.05±0.32	0.02±0.16
Mg iron/g yolk	0.01±0.11	−0.08±0.34	−0.04±0.16

III. Genetic and phenotypic correlations

1. *Genetic correlations*

The combined genetic correlatins (sire + dam) between the different traits studied are presented in Table 3. The genetic correlations between yolk cholesterol, serum cholesterol, egg production until 40,44, 48, and 52 weeks of age, mg Ca, mg Zn, and mg Fe with other traits were imaginary because the genetic variance for these traits were negative. The genetic correlation between age at sexual maturity and egg production was high and negative. The genetic correlation between age at sexual maturity and body weight at sexual maturity was very high and positive as expected. The genetic correlation. between age at sexual maturity and both mg Mg/g yolk and mg P/g yolk were also positive and significant. As expected the genetic correlation between egg weight and body weight at sexual maturity was high and positive. Jaffe (1966) also found positive genetic correlations between body weight and egg weight in two strains of White Leghorn.

TABLE 3. **Combined genetic correlations between traits studied (sire + dam).**

Traits	Egg Wt.	mg Mg/g yolk	mg P/g yolk	mg Na/g yolk	mg k/g yolk	Egg production until 70 wks.	Annual egg production	Body Wt. at sexual maturity
Age at sexual maturity	0.26**	0.53**	0.43**	0.06	3.70	—0.20*	—0.97**	1.02**
Egg Weight		0.69**	—0.21**	0.42**	3.40	—0.77**	—3.66	1.04**
mg Mg/g yolk			0.75**	1.61	—0.92**	1.05**	3.14	0.48**
mg P/gyolk				0.49**	2.25	0.43**	1.56	0.81**
mg Na/g yolk					—0.04	0.98**	2.79	0.06
mg K/g yolk						—1.46	—2.75	1.49
Egg production until 70 wks							1.65	—0.55**
Annual egg production								—0.90**

* Significant correlation ($P \leq 0.05$)

** Significant correlation ($P \leq 0.01$)

The genetic correlation between egg weight and egg production until 70 weeks of age was high and negative. This is expected if it is assumed that a hen will lay a certain mass of egg. If the numbers of these eggs increase, their weight will decrease. The genetic correlations of egg weight with both mg Mg/g yolk and mg Na/g yolk were positive and significant, while they were negative and significant with mg P/g yolk. The genetic correlations between egg production until 70 weeks of age with mg Mg, P, Na, and K per g yolk were positive and high. Since the heritability for Na content of egg yolk is high and the genetic correlations between the Na content and egg production and egg weight are high, it may be possible to utilize these relations in selection for further increasing the egg production and egg weight of the commercial layers. Highly positive genetic correlations between body weight at sexual maturity and both mg Mg and P per g yolk were also observed. The genetic correlations between body weight at sexual maturity and egg production until 70 weeks of age and the full record were negative and highly significant.

2. *Phenotypic correlations*

The phenotypic correlations of cholesterol per g yolk and serum cholesterol with other traits are presented in Table 4. The phenotypic correlations between cholesterol per g yolk and egg weight were negative and significant. Bartuve *et al.* (1971) and Cunninham *et al.* (1974) reported no relationship between egg weight and yolk cholesterol, while Harris and Wilcox (1963a) and Kicka *et al.* (1979) reported positive phenotypic correlations between yolk cholesterol and egg weight. The phenotypic correlations between cholesterol per g yolk and egg production until different ages decreased as the laying period increased.

TABLE 4. **Phenotypic correlations between cholesterol per g/yolk and serum cholesterol with other traits.**

Traits	mg cholesterol/g yolk	cholesterol/ 100 ml serum
Age at sexual maturity	—0.12	0.11
Body weight at sexual maturity	—0.04	—0.02
Egg weight at 26 weeks of production	—0.22**	—0.09
Yolk weight	—0.02	—0.08
Egg production until 40 weeks of age	0.23**	—0.09
Egg production until 44 weeks of age	0.16*	—0.10
Egg production until 48 weeks of age	0.16*	—0.10
Egg production until 52 weeks of age	0.13	—0.08
Egg production until 70 weeks of age	0.13	—0.16*
Full production (365 days)	0.07	—0.12
Yolk cholesterol	—	0.11

*Significant correlation ($P \leq 0.05$)

**Significant correlation ($P \leq 0.01$)

All correlations were positive and significant with egg production until 48 weeks of age. These estimates agree with those obtained by Collins *et al.* (1968) but disagree with the results of Cunningham *et al.* (1974); Washburn and Nix (1974a); and Kicka *et al.* (1979). They reported significant negative correlations between cholesterol per g yolk and egg production. The phenotypic correlations between serum cholesterol with most other traits were negative and insignificant. However, there was a significant negative correlation (-0.16) between serum cholesterol and egg production until 70 weeks of age. Similarly, Leveille and Fisher (1958), Smith (1959), Svacha (1959) and Johanson *et al.* (1959), observed negative correlations between egg production and serum cholesterol in chickens. The phenotypic correlations between serum cholesterol and yolk cholesterol were low and not significant. Washburn and Nix (1974a) found similar positive insignificant correlations between the two traits in the AC and ARB populations. However, Marion *et al.* (1960) found significant negative phenotypic correlations between the two traits.

The phenotypic correlations between ages at sexual maturity and egg production at different ages were all negative and highly significant except those with the full record (Table 5). Ezzeldin (1977) reported the same trend between the two traits in the same flock of Fayoumi chickens. The phenotypic correlations between mg Mg, N, and Fe/g yolk with egg product on at different ages were all positive and significant. The significant phenotypic correlations between the Na content of egg yolks and egg production may also prove to be an efficient tool for speeding selection for egg production.

TABLE 5. **Phenotypic correlations between between age at sexual maturity, mineral contents of egg yolk and egg production at different ages.**

Traits	Age at sexual maturity	Mg	Na	Fe
Egg production until 40 wks. of age . . .	—0.53**	0.17*	0.23**	0.22**
Egg production until 44 wks. of age . .	—0.47**	0.18*	0.23**	0.24**
Egg production until 48 wks. of age . .	—0.43**	0.17*	0.21**	0.24**
Egg production until 52 wks. of age . .	—0.40**	0.18*	0.23**	0.26**
Egg production until 70 wks. of age . .	—0.24**	0.25**	0.28**	0.32**
Full record (365 days)	—0.09	0.20*	0.20*	0.22**

*Significant correlation ($P \leq 0.05$)

**Significant correlation ($P \leq 0.01$)

The phenotypic correlations between the mineral contents of the egg yolk are presented in Table 6. Phosphorus was significantly correlated with all other minerals in the egg yolk. Also Na, Zn, and Mg were significantly correlated with all other minerals except Ca and K. Fe was significantly correlated with all other minerals except K. K was only correlated with Ca and P while Ca was only correlated with P, K, and Fe.

TABLE 6. **Phenotypic correlations between the mineral contents of egg yolk.**

Traits	Zn	Mg	P	Na	K	Fe
Ca . . .	0.06	0.14	0.21**	—0.03	—0.55**	—0.20*
Zn . . .		0.51**	0.25**	0.40**	0.08	0.24**
Mg. . .			0.42**	0.71**	0.07	0.40**
P . . .				0.44**	0.48**	0.24**
Na . .					0.02	0.48**
K . . .						0.11

**Significant correlation ($P \leq 0.01$)

*Significant correlation ($P \leq .05$)

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وراثة كوليستيرول البيضة والصفات المرتبطة فى الدجاج الفيومى ·

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تم استخدام ١٥٠ دجاجة ناتجة من ١٦٩ م ، ١١١ ب للحصول على البيانات الآتية : **العمر عند النضج الجنسى والوزن عند عمر النضج الجنسى ــ انتاج** البيض حتى ٢٦ اسبوع من بداية الانتاج (ميعاد تحليل مكونات البيضه) وكذلك انتاج البيض حتى ٤٠ ، ٤٤ ، ٤٨ ، ٥٢ ، ٧٠ اسبوع من العمر والانتاج السنوى من البيض (٥٢ اسبوع) من العمر النضج الجنسى ووزن البيضة ووزن الصفار ·

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ملجم كوليستيرول لكل جرام صفار ، ملجم صوديوم ، بوتاسيوم كالسيوم ، فسفور ، زنك وحديد لكل جرام صفار ·

كذلك تم تقدير كوليستيرول لكل ١٠٠ مل سيرم كذلك تم حساب كمية كوليستيرول الكلية الموجودة بالصفار للملجم ·

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