Changes in egg quality traits associated with long-term selection for lower yolk cholesterol content in Japanese quail

J. Baumgartner[1], Z. Končeková[1], J. Benková[1], D. Peškovičová[1], J. Simenovová[2], J. Csuka[1]

[1]Slovak Agricultural Research Centre Nitra, Slovak Republic
[2]Department of Food Technology, Mendel University of Agriculture and Forestry Brno, Czech Republic

Abstract: In the present paper we describe the basic results of long-term selection for low yolk cholesterol content in Japanese quail and its influence on development and relationship with other egg quality traits during nineteen selected generations. The changes in a selected low cholesterol line were compared with changes in an unselected control line to obtain the real selection response to estimated traits. There was a significant decrease in yolk cholesterol content from 1 815 mg/100 g of fresh yolk (P generation) to 1 522 mg/100 g yolk (S19 generation). According to the value of regression coefficient *b* the decrease per one generation was 15.71 mg/100 g yolk. The decrease in cholesterol of the edible part of egg was also effective and it significantly decreased by 11.29 mg/100 g of the edible part of egg in each generation. There were only insignificant changes in egg weight, but we found a significant increase in yolk weight during selected generations. According to the regression analysis the increase in yolk weight was 0.019 mg/100 g per one generation. There were a positive but insignificant increase also in albumen weight, shell weight and weight of the edible part of egg. We found a small and insignificant decrease in shape index. We determined very high and significant positive correlations between cholesterol content in yolk and cholesterol content in the edible part of egg (0.801+++) and significant negative correlations between yolk cholesterol content and egg weight (–0.515+), yolk weight (–0.468+) and weight of the edible part of egg (–0.475). There were only low, positive and insignificant correlations between yolk cholesterol content and yolk egg proportion and egg shape index.

Keywords: selection; yolk cholesterol; egg quality traits; correlations; Japanese quail

Concerning the cholesterol problem caused by the influence of negative publicity of dietary cholesterol on human health a significant decrease in egg consumption per inhabitant was recorded in the world (Herron and Fernandez, 2004; Elkin, 2006; Sparks, 2006). Kritchevsky and Kritchevsky (2000) reported that chicken eggs supply about 30% of dietary cholesterol in the American diet. Nevertheless, a revaluation of its role in human nutrition is needed (Kritchevsky, 2004). The reason for this situation is that the egg yolk belongs to the richest sources in human nutrition and because in spite of various controversies in excessive consumption the dietary cholesterol is classified as a risk factor of human nutrition in general (Kritchevsky and Kritchevsky, 2000; Wegemans et al., 2001; Kritchevsky, 2004) and especially in specific groups of people, e.g. diabetics (Hu et al., 1999). In very extensive research Wegemas et al. (2001) found that the dietary cholesterol raised the ratio of total to HDL-cholesterol and hence "the advice to limit the consumption of cholesterol-rich foods may therefore still be valid". On the basis of these results any decrease in cholesterol content in egg yolk is desirable because the lower the yolk cholesterol content in egg, the more eggs could be recommended for consumption whereas the WHO norm of the maximum recommended intake of dietary cholesterol per capita/day 300 mg/day is still valid. It is possible to decrease the yolk cholesterol content either genetically, i.e. by selection, or by the nutrition of hens and also by the combination of both approaches, i.e. by special nutrition together with genetically fixed lower yolk cholesterol concentration (Elkin, 2006). Some recent papers studied also the effects of housing systems and age of hens or dietary factors on the cholesterol concentration and egg quality traits of the hens (Pišteková et al., 2006; Yildiz et al., 2006; Zemková et al., 2007).

Whereas of the mentioned above we started in 1992 an experiment with Japanese quail to investigate the feasibility of lowering the egg yolk cholesterol level by selection (Baumgartner and Simeonovová, 1992; Baumgartner, 1995). In contrary with selection for growth or egg production characteristics in Japanese quail or hens (Hyánková et al., 2001; Aggrey et al., 2003; Sezer and Tarhan, 2005; Wolc et al., 2007) in the literature there is only very little information about the selection response of egg yolk cholesterol content (Marks and Washburn, 1977; Ansah et al., 1985; Simenovová et al., 1992; Baumgartner, 1995; Elkin, 2006). Concerning this problem only very few and only short-term selection experiments were conducted. The main reason for this situation is a very laborious and expensive analysis of yolk cholesterol content. There were attempts to influence the yolk cholesterol content in egg by selection for a lower yolk to albumen ratio but the selection was less effective than the selection for a higher yolk to albumen ratio (Miyoshi and Mitsumoto, 1980; Hartmann et al., 2000; Elkin, 2006). Concerning the changes in fitness traits no changes in hatchability between the high and low cholesterol were observed (Washburn and Marks, 1977). We shall present this problem in another paper.

The result of the longest experiment on yolk cholesterol content is only four (meat type chickens) or three (egg type chickens) generations selected experiment published by Marks and Washburn (1977) or three selected generations published by Ansah et al. (1985). The criterion for selection was mg cholesterol/g yolk and was based on both family and individual records, with males selected on the basis of full and half-sib sisters. The overview of the current situation in reducing the egg cholesterol content by genetic approaches and nutritional strategies was recently published by Elkin (2006).

In the literature there is even less or no information about the changes in egg quality traits associated with selection for lower yolk cholesterol content in Japanese quail. In Leghorn type hens Ansah et al. (1985) found a significant decrease in egg weight in all three selected generations in the low yolk cholesterol line in comparison with unselected control but no changes in yolk weight.

Several reports were published about genetic correlations between various egg quality traits (Washburn, 1990; Hartmann et al., 2000; Minvielle and Oguz, 2002; Elkin, 2006), but we have not found any information about genetic correlations between the egg yolk cholesterol content and other egg quality traits. Concerning our report, interesting are recent results of Basmacioglu and Ergul (2005), who reported the phenotypic correlations between the egg yolk cholesterol content and egg weight as –0.559 and –0.753 and between the yolk cholesterol content and yolk weight as –0.499 and –0.703 in white or brown egg laying hens.

The first attempt could be seen in the literature showing the results of long-term selection for low yolk cholesterol content and its influence on development and relationship with other egg quality traits during selected generations. The changes in a selected low cholesterol line were compared with changes in an unselected control line to obtain the objective selection response to estimated traits.

MATERIAL AND METHODS

An outbreed, egg type, wild colour plumage line of Japanese quail kept at Poultry Breeding Station in Ivanka pri Dunaji since 1984 was the base population for this study (Baumgartner and Hetényi, 2001). In the parental generation 60 adult quail hens at 14–16 weeks of age were tested according to yolk cholesterol in fresh yolk and 25 females whose eggs had the lowest yolk cholesterol concentration were selected to establish a low cholesterol line (S). Other non-selected 60 quail hens were reproduced and used as an unselected control cholesterol line (C). Sufficient quail chickens were hatched to provide approximately 60 females per line at 12 weeks of age in each generation. This selection procedure was repeated for all 19 generations. Therefore in each generation approximately 25 females with the lowest yolk cholesterol content from 60 tested quail hens were used to reproduce the next generation of S line and 25 randomly unselected females were used to reproduce C line. The selection was based on a low level of yolk cholesterol (mg cholesterol per 100 g yolk) according to the method used by Ansah et al. (1985). The females and males were selected according to a selection index, in the case of females on the basis of individual records plus their full and paternal half-sibs:

$$(y = 0.5x_1 + 0.3x_2 + 0.2x_3)$$

where:

x_1 = the value of yolk cholesterol content of the tested female
x_2 = the average cholesterol content of full sisters
x_3 = the cholesterol content of paternal half-sibs (half sisters)

The males were selected according to the records of their full and half-sib sisters:

$$(y = 0.5x_1 + 0.5x_2)$$

where:

x_1 = the average cholesterol content of full sisters
x_2 = the average of cholesterol content of paternal half-sibs (half sisters)

Because one male was mated with two females, for every two females one male was selected for reproduction. In each generation the quail chicks were grown in special rearing batteries up to 5 weeks of age and then they were caged individually. The quails were fed a special quail diet mixture for growing and adult quails by VÚKP Ivanka, manufactory Šamorín. From week 0 to week 3 the young quails received a growing ration containing 24.32% crude protein and 12.05 MJ metabolizable energy (ME). From week 3 to 5 the mixture ration (grower + layer diet) contained 21.0% crude protein and 12.0 MJ of ME. The adult quails from 5 weeks of age were fed the layer ration containing 20.2% of crude protein and 11.80 MJ of ME.

Cholesterol values were obtained from three consecutively laid eggs when the birds were about 14–16 weeks old. After the measuring of egg, yolk, albumen, shell and edible part of egg weight (g), yolk/egg proportion (%) and egg shape index (with × 100/length in (%)) a standard homogeneous sample of egg yolk was used from each quail layer for the chemical analysis of egg yolk cholesterol content. From parental to S_3 generation the yolk cholesterol content was estimated by a spectrophotometric method developed by Ingr and Simeonová (1983) based on measuring the absorbance of the colour product (625 nm) which originated after the reaction of cholesterol with acetic anhydride and concentrated sulphuric acid in ethyl acetate medium (Liebermann-Buchard reaction, Bio-Lachema-Test, Brno, Czech Republic). After the S_4 generation we determined the yolk cholesterol concentration using an enzymatic colorimetric test with lipid clearing factor (cholesterol liquicolor CHOD-PAP-test, Human Gesellschaft für Biochemica und Diagnostica mbH, Taunusstein, Germany).

Statistical analyses

Linear regression and correlation analysis in S and C line, and also from the corrected values of S line to C line (mean of S/mean of C in actual generation × mean of P generation), were computed from the averages of egg quality traits to estimate the influence of selection generation on the values of investigated traits:

$$Y = a + bx$$

where:

Y = value of estimated egg quality trait
a = Y-intercept
b = slope factor or regression coefficient
x = number of generation (Sokal and Rohlf, 1969)

RESULTS AND DISCUSSION

Development of the genetic trend (averages and linear regression (a, b) and correlation (r) coefficients) of estimated egg quality traits in S line selected for lower yolk cholesterol content during nineteen generations is shown in Table 1. In initial P generation the variability of observed traits is also given ($\bar{x}$, $S_{\bar{x}}$ and v (%)). This variability of estimated traits is equal also for C line because of the same initial population.

According to the given results, the variability of investigated traits (v (%)) varied from 19.63% and 19.64% of yolk cholesterol content in fresh yolk or in the edible part of egg to 3.75% in egg shape index. Therefore the variability of the selected trait (yolk cholesterol content) was the largest of all investigated traits.

Table 1. Development of the genetic trend (averages and linear regression (a, b) and correlation (r) coefficients) of estimated egg quality traits in S line selected for lower yolk cholesterol content during nineteen generations. In initial P generation the variability of observed traits is also given ($\bar{x}$, $S_{\bar{x}}$ and v (%))

Generation	Number of quail hens tested	Cholesterol (mg/100 g)		Weight of whole eggs and egg components (g)					Yolk yield of egg weight (%)	Egg shape index (%)
		yolk	edible part of egg	egg	yolk	albumen	shell	edible part of egg		
P	60 $\bar{x}$	1 815	629.8	9.60	3.056	5.751	0.776	8.807	31.86	78.71
	$S_{\bar{x}}$	45.9	16.00	0.116	0.050	0.071	0.012	0.125	0.276	0.381
	v (%)	19.63	19.64	9.34	12.60	9.59	12.24	10.98	6.72	3.75
1	58	1 804	605.8	9.20	2.856	5.649	0.711	8.505	31.06	79.69
2	56	1 776	599.4	9.81	3.053	5.992	0.772	9.045	31.07	78.43
3	57	1 784	626.4	9.52	2.985	5.517	0.956	8.502	31.32	79.05
4	60	1 627	600.7	8.78	2.888	4.859	7.030	7.747	32.87	79.77
5	60	1 675	555.9	10.25	3.413	5.785	1.048	9.201	33.19	79.24
6	59	1 638	587.9	9.37	3.016	5.361	0.997	8.382	32.32	79.78
7	60	1 652	578.2	10.27	3.237	6.021	1.022	9.248	31.46	77.74
8	60	1 579	549.8	10.64	3.369	6.255	1.028	9.623	31.62	77.02
9	59	1 665	595,6	10.11	3.252	5.859	0.998	9.105	32.15	78.03
10	51	1 508	532.8	10.41	3.327	6.107	0.981	9.435	31.94	77.91
11	43	1 422	496.8	10.27	3.237	6.021	1.022	9.248	31.46	77.74
12	63	1 607	677.9	10.16	3.330	5.830	0.981	9.188	32.77	78.25
13	58	1 557	561.5	9.84	3.200	5.681	0.966	8.872	32.55	78.41
14	60	1 502	556.3	9.55	3.030	5.551	0.960	8.585	31.75	77.72
15	60	1 546	553.7	9.99	3.050	5.632	0.966	8.680	30.53	78.43
16	60	1 520	461.7	10.19	3.320	5.840	1.034	9.152	31.91	78.52
17	60	1 514	433.8	10.64	3.240	6.331	1.078	9.565	30.38	77.17
18	60	1 502	522.6	10.65	3.380	6.272	1.017	9.629	31.54	76.41
19	60	1 483	519.4	10.41	3.290	6.060	1.013	9.390	31.52	77.90
	a	1 787	628.1	9.430	3.040	5.559	0.818	8.573	32.155	79.33
	b	–17.050	–7.100	0.053	0.014	0.025	0.013	0.040	–0.032	–0.098
	r	–0.866	–0.793	0.605	0.428	0.421	0.664	0.492	–0.228	–0.635
	P	+++	+++	++	NS	NS	++	NS	+	++

+$P < 0.05$; ++$P < 0.001$; +++$P < 0.001$

Concerning the hatchability problems according to a decrease in the yolk cholesterol content in S line, we found a small decrease in this trait during the selection of generations.

We can see that there was a decrease in yolk cholesterol content from 1 815 mg/100 g of fresh yolk (P generation) to 1 483 mg/100 g yolk (S19 generation). According to the value of regression coefficient b the decrease per one generation was 17.05 mg, the regression and also the correlation coefficients of the dependence of production on time were both very highly significant. It means that the selection for yolk cholesterol content was effective and significant. The decrease in cholesterol of the edible part of yolk was also effective and it decreased by 7.1 mg/100 g in each genera-

Table 2. Development of the genetic trend (averages and linear regression (*a*, *b*) and correlation (*r*) coefficients) of estimated egg quality traits in unselected C line during nineteen generations. In initial P generation the variability of observed traits is also given ($\bar{x}$, $S_{\bar{x}}$ and *v* (%))

Generation	Number of quail hens tested	Cholesterol (mg/100 g)		Weight of whole eggs and egg components (g)					Yolk yield of egg weight (%)	Egg shape index (%)
		yolk	edible part of egg	egg	yolk	albumen	shell	edible part of egg		
P	60 $\bar{x}$	1 815	629.8	9.60	3.056	5.751	0.776	8.807	31.86	78.71
	$S_{\bar{x}}$	45.9	16.00	0.116	0.050	0.071	0.012	0.125	0.276	0.381
	v (%)	19.63	19.64	9.34	12.60	9.59	12.24	10.98	6.72	3.75
1	60	1 846	620.7	9.25	2.870	5.665	0.715	8.535	31.03	78.34
2	60	1 832	618.5	9.84	3.059	6.002	0.774	9.061	31.03	78.14
3	58	1 819	650.0	9.95	3.261	5.865	0.825	9.126	32.74	77.84
4	60	1 836	701.5	8.37	2.837	4.570	0.942	7.424	33.90	77.96
5	60	1 773	604.1	10.59	3.533	5.847	1.194	9.406	33.38	77.79
6	60	1 733	626.0	9.68	3.137	5.549	1.005	8.688	32.42	78.33
7	59	1 703	598.5	10.26	3.246	5.968	1.028	9.181	31.64	77.36
8	60	1 774	626.9	10.15	3.214	5.899	1.030	9.113	31.65	77.34
9	60	1 960	742.7	9.79	3.377	5.430	0.989	8.807	34.42	76.51
10	60	1 694	611.3	9.91	3.215	5.699	0.995	8.915	32.45	77.61
11	92	1 640	592.3	9.87	3.201	5.648	1.023	8.846	32.41	76.53
12	75	1 821	677.3	10.16	3.336	5.625	0.972	8.859	33.07	77.14
13	58	1 820	644.1	9.58	3.070	5.552	0.968	8.621	31.98	78.14
14	60	1 827	633.2	9.43	3.003	5.546	0.965	8.467	31.83	77.77
15	60	1 884	675.2	9.60	3.006	5.588	1.001	8.549	31.29	78.13
16	60	1 808	551.7	9.97	3.217	5.776	1.06	9.010	32.16	77.00
17	60	1 750	608.5	10.61	3.286	6.244	1.084	9.53	30.94	77.22
18	60	1 763	622.2	10.79	3.435	6.285	1.081	9.714	31.83	77.19
19	60	1 768	620.2	10.55	3.320	6.140	1.089	9.464	31.44	77.16
a		1 809	642.2	9.49	3.085	5.542	0.848	8.626	32.47	78.15
b		−1.603 0.134 0.134 1.603	−1.012	0.043	0.011	0.020	0.013	0.029	−0.031	−0.057
r		−0.134	−0.143	0.462	0.347	0.327	0.665	0.354	−0.195	0.557
P		NS	NS	+	NS	NS	++	NS	NS	+

+$P < 0.05$; ++$P < 0.001$

tion. Both coefficients were very highly significant.

The egg weight during selected generations increased from 9.6 g in parental up to 10.41 g in S_{19} generation. Similar results were found also in unselected C line (Table 2). Yolk and albumen weight and also yolk yield of egg weight were unaffected by the selection of ge-nerations but we found a significant increase in shell weight and also in the edible part of egg weight and a small but significant decrease in shape index.

Table 3. Development of the genetic trend (averages and linear regression (*a*, *b*) and correlation (*r*) coefficients) of S line corrected to the values of C line (mean of S/mean of C in actual generation × mean of P generation)

Generation	Number of quail hens tested	Cholesterol (mg/100 g)		Weight of whole eggs and egg components (g)					Yolk yield of egg weight (%)	Egg shape index (%)
		yolk	edible part of egg	egg	yolk	albumen	shell	edible part of egg		
P	60	1 815	629.8	9.60	3.056	5.751	0.776	8.807	31.86	78.71
1	58	1 774	591.3	9.55	2.842	5.633	0.707	8.776	31.89	80.07
2	56	1 760	580.9	9.57	3.047	5.982	0.770	8.791	31.90	79.00
3	57	1 780	603.7	9.19	2.732	5.190	1.108	8.205	30.48	79.93
4	60	1 608	614.4	10.07	2.940	5.166	1.126	9.190	30.89	80.54
5	60	1 715	511.5	9.29	3.297	5.724	0.920	8.615	31.68	80.18
6	59	1 716	552.1	9.29	2.900	5.179	0.989	8.497	31.76	80.17
7	60	1 761	558.6	9.61	3.228	6.074	1.016	8.871	31.68	79.10
8	60	1 615	482.2	10.6	3.531	6.632	1.026	9.300	31.83	78.38
9	59	1 542	477.6	9.91	3.132	6.322	1.007	9.105	29.76	80.27
10	51	1 616	464.4	10.08	3.443	6.544	0.967	9.321	31.36	79.01
11	43	1 574	416.7	9.99	3.273	6.419	1.021	9.207	30.93	79.95
12	63	1 602	499.3	9.60	3.324	6.042	0.990	9.134	31.57	79.84
13	58	1 553	489.5	9.86	3.336	5.813	0.964	9.063	32.43	78.98
14	60	1 492	488.8	9.72	3.057	5.556	0.955	8.930	31.78	78.66
15	60	1 489	454.0	9.99	3.095	5.676	0.932	8.942	31.09	79.01
16	60	1 526	386.4	9.81	3.426	5.905	1.009	8.946	31.61	80.26
17	60	1 570	309.1	9.63	3.195	6.419	1.072	8.839	31.28	78.66
18	60	1 546	438.9	9.48	3.326	6.259	0.957	8.730	31.57	77.91
19	60	1 522	434.7	9.47	3.260	5.981	0.942	8.738	31.94	79.46
	a	1 794	612.8	9.592	2.968	5.607	0.894	8.796	1.716	79.90
	b	–15.71	–11.29	0.009	0.019	0.029	0.007	0.010	0.009	–0.047
	r	–0.870	–0.850	0.276	0.541	0.390	0.370	0.215	0.123	–0.370
	P	+++	+++	NS	+	NS	NS	NS	NS	NS

+$P < 0.05$; ++$P < 0.001$; +++$P < 0.001$

Dependences of the averages of traits on time (linear regression (*a*, *b*) and correlation (*r*) coefficients) of estimated egg quality traits in unselected cholesterol C line during nineteen generations are shown in Table 2. The cholesterol content in yolk and in edible part was not significantly influenced by the generation. It means that the unselected C line was stable concerning the values of yolk cholesterol content. In the other egg quality traits we found a similar trend like in S line. We found a significant generation increase only in egg and shell weight and a decrease in egg shape index but the changes were relatively small.

Important information on dependences of the averages of traits on time (linear regression (*a*, *b*) and correlation (*r*) coefficients) of S line corrected to the values of C line is given in Table 3.

We can see that there was a decrease in yolk cholesterol content from 1 815 mg/100 g of fresh yolk (P generation) to 1 522 mg/ 100 g yolk (S19 generation). According to the value of regression coefficient *b*, the decrease per one generation was 15.71 mg/100 g yolk, the regression and also the correlation coefficients were both very highly significant. It means that the genetic selection for yolk cholesterol content was effective and significant. A

Table 4. Correlations between the averages of egg quality traits in S line corrected by C line (computed from the averages of investigated traits in 20 generations, $n = 20$, $df = 18$)

Variable	Yolk cholesterol content in edible part (mg/100 g)	Egg weight (g)	Yolk weight (g)	Albumen weight (g)	Shell weight (g)	Edible part of egg (g)	Yolk/egg proportion (%)	Egg shape index (%)
Yolk cholesterol content (mg/100 g)	0.801+++	−0.515+	−0.468+	−0.310NS	−0.415NS	−0.475+	0.141NS	0.175NS
Yolk cholesterol content in edible part (mg/100 g)	–	−0.373NS	−0.571++	−0.533+	−0.459+	−0.376NS	0.123NS	0.177NS
Egg weight (g)	–	–	0.432NS	0.438NS	0.234NS	0.916+++	−0.187NS	−0.073NS
Yolk weight (g)	–	–	–	0.765+++	0.137NS	0.603++	0.300NS	−0.471+
Albumen weight (g)	–	–	–	–	0.011NS	0.583++	−0.029NS	−0.544+
Shell weight (g)	–	–	–	–	–	0.135NS	−0.503+	−0.195NS
Edible part of egg(g)	–	–	–	–	–	–	−0.042NS	−0.090NS
Yolk/egg proportion (%)	–	–	–	–	–	–	–	−0.425NS

+$P < 0.05$; ++$P < 0.001$; +++$P < 0.001$

reduction in cholesterol of the edible part of yolk was also effective and it decreased by 11.29 mg per 100 g in each generation. Both coefficients were also very highly significant.

There were only insignificant changes in egg weight during selected generations. But we found a significant increase in yolk weight according to selected generations. Concerning the regression analysis the increase in yolk weight was 0.019 mg per one generation. There was a positive but insignificant increase also in albumen weight, shell weight and weight of the edible part of egg. We found a small and insignificant decrease in shape index.

The reduction in yolk cholesterol content per one selected generation during nineteen generations in comparison with the control shown in our results (b = 15.71 mg/100 g yolk) was lower in comparison with the data of Ansah et al. (1985), who found in Leghorn type chickens in three selected generations for lower yolk cholesterol content a decrease in the yolk cholesterol level by 26.6 mg/100 g per one selected generation in comparison with the control line. In comparison with the data of Marks and Washburn (1977) in four (meat type chickens) and three (egg type chickens) generations selection experiment of divergent selection for yolk cholesterol content chickens who found no evident decrease in comparison with unselected control in both low selected lines are our results very encouraging.

Correlations between the averages of egg quality traits in S line corrected by C line are given in Table 4. There were very high and significant positive correlations between cholesterol content in yolk and cholesterol content in the edible part of egg and significant negative correlations between yolk cholesterol content and egg weight, yolk weight and weight of the edible part of egg. There were small, positive and insignificant correlations between yolk cholesterol content and yolk egg proportion and egg shape index.

Similar correlations were found between yolk cholesterol content in the edible part of egg and other egg quality traits. But the correlation between yolk cholesterol content in the edible part of egg and egg weight and weight of the edible part of egg was negative and insignificant, and with yolk weight, albumen weight and shell weight negative and significant. Correlations between yolk cholesterol content in the edible part of egg and yolk egg proportion and egg shape index were small, positive and insignificant.

Table 5. Uncorrected (USG) and corrected (CSG) selection gain, cumulative selection difference (CSD), coefficients of heritability (h^2 as regression coefficients b) and correlation coefficients (r) of yolk cholesterol content in line 1l (n = 20, df = 18)

Generation	P	1	2	3	4	5	6	7	8	9
USG	0	11	39	31	188	140	174	163	236	150
CSG	0	42	56	35	209	98	95	51	195	295
CSD	0	171	177	403	585	761	790	877	916	985
Generation	10	11	12	13	14	15	16	17	18	19
USG	307	393	208	258	313	269	295	301	313	332
CSG	186	218	214	263	325	338	288	236	261	437
CSD	1 035	1 058	1 110	1 237	1 284	1 323	1 368	1 407	1 446	1 465

h^2 = from uncorrected selection gain = 0.237+++; r = 0.901+++
h^2 = from corrected selection gain = 0.243+++; r = 0.867+++; r = 0.867+++

Concerning the correlations between the observed traits it is generally known that selection for one or more traits may affect the other characters (Bell, 1997; Muir and Aggrey, 2003; Roberts, 2004). The principles theory of these phenomena was well described by Bell (1997). Because the egg quality traits are genetically correlated (Washburn, 1990; Hartmann et al., 2000; Minvielle and Oguz, 2002; Elkin, 2006), the influence of selection for low yolk cholesterol content on their changes found in our experiment should be expected.

Comparison of our results with other authors is very difficult because of the lack of information. Ansah et al. (1985) found an increase in yolk weight in three generations of chickens selected for low yolk cholesterol content, which is similar to our results. Our data on correlations between yolk cholesterol content and other egg quality traits are generally similar to the data of Basmacioglu and Ergul (2005), who reported the phenotypic correlations between egg yolk cholesterol content and egg weight as –0.559 and –0.753 and between yolk cholesterol content and yolk weight as –0.499 and –0.703 in white or brown egg laying hens.

REFERENCES

Aggrey S.E., Ankra-Badu G.A., Marks H.L. (2003): Effect of long-term divergent selection on growth characteristics in Japanese quail. Poult. Sci., 82, 538–542.

Ansah G.A., Chan C.W., Touchburn S.P., Buckland R.B. (1985): Selection for low cholesterol in Leghorn-type chickens. Poult. Sci., 64, 1–5.

Basmacioglu H., Ergul M. (2005): Research on the factors affecting cholesterol content and some other characteristics of eggs in laying hens. Turk. J. Vet. Anim. Sci., 29, 157–164.

Baumgartner J. (1995): Genetic variation of egg yolk cholesterol content. Živoč. Výr., 40, 233–239.

Baumgartner J., Simeonovová J. (1992): Breed or line differences of cholesterol content in Japanese quail eggs. In: Proc. 19th World's Poultry Congress, Amsterdam, Netherlands, 3, 265–267.

Baumgartner J., Hetényi L. (2001): Japanese quail. [RIAP] Nitra, Slovak Republic, 4, 75 pp.

Bell G. (1997): Selection: the Mechanism of Evolution. Chapman and Hall: New York, USA. 805 pp.

Elkin R.G. (2006): Reducing shell egg cholesterol content. I. Overview, genetic approaches, and nutritional strategies. Worlds Poult. Sci. J., 62, 665–687.

Hartmann C., Johansson K., Strandberg E., Wilhelmson M. (2000): One generation divergent selection on large and small yolk proportion in a White leghorn line. Brit. Poult. Sci., 41, 280–286.

Herron K.I., Fernadez M.L. (2004): Are the current dietary guided lines regarding egg consumption appropriate. J. Nutr., 134, 187–190.

Hu F.B., Stamper M., Rimm E.B., Manson J.E., Ascherio A., Coldicz G.A., Rosner B.A., Spiegelman D., Speizer F.E., Sacks E.R., Hennekens C.H., Willettt W.C. (1999): A prospective study of egg consumption and risk of cardiovascular disease in men and women. J. Am. Med. Assoc., 281, 1387–1394.

Hyánková L., Knížetová H., Dědková L., Hort J. (2001): Divergent selection for shape of growth curve in Japanese quail. 1. Responses in growth parameters and food conversion. Brit. Poult. Sci., 42, 583–589.

Ingr I., Simenovová J. (1983): Rychlé stanovení cholesterolu ve vaječném žloutku BIO- LA-testem. Vet. Med., 28, 97–103.

Kritchevsky S.B. (2004): A review of scientific research and recommendation regarding eggs. J. Am. Coll. Nutr., 23, 596–600.

Kritchevsky S.B., Kritchevsky D. (2000): Egg consumption and coronary heart disease: An epidemiological overview. J. Am. Coll. Nutr., 19, 549–555.

Marks H.L., Washburn K.W. (1977): Divergent selection for yolk cholesterol in laying eggs. Brit. Poult. Sci., 18, 179–188.

Minvielle F., Oguz Y. (2002): Effects of genetics and breeding on egg quality of Japanese quail. Worlds Poult. Sci. J., 58, 291–295.

Miyoshi S., Mitsumoto T. (1980): Selection for high and low yolk-albumen ration in chickens. II. The direct response to selection on the yolk-albumen ratio for seven generation. Japan. Poult. Sci., 5, 219–227.

Muir W., Aggrey S.E. (2003): Poultry Genetics, Breeding and Biotechnology. CABI Publishing, 706 pp.

Pištěková V., Hovorka M., Večerek V., Straková E., Suchý P. (2006): The quality comparison of eggs laid by laying hens kept in battery cages and in a deep litter system. Czech J. Anim. Sci., 51, 318–325.

Roberts J.R. (2004): Factors affecting egg internal quality and egg shell quality in laying hens. J. Poult. Sci., 41, 161–177.

Sezer M., Tarhan S. (2005): Model parameters of growth curves of three meat-type lines of Japanese quail. Czech J. Anim. Sci., 50, 22–30.

Simeonovová J., Baumgartner J., Vinterová J. (1992): Cholesterol content in egg yolk of Japanese quail. Živoč. Výr., 37, 615–624. (in Czech)

Sokal R.R., Rohlf F.J. (1969). Biometry. Freedman and Company, San Francisco, USA, 1–776.

Sparks N.H.C. (2006): The hens egg – its role in human nutrition changing? Worlds Poult. Sci. J., 62, 308–315.

Wegemans R.M., Zock P.L., Katan M.M. (2001): Dietary cholesterol from eggs increases the ratio total cholesterol to high-density lipoprotein cholesterol in humans: a meta- analysis. Am. J. Clin. Nutr., 73, 13–23.

Yildiz G., Sacakli P., Gungor T. (2006): The effect of dietary Jerusalem artichoke (*Helianthus tuberosus* L.) on performance, egg quality characteristics and egg cholesterol content in laying hens. Czech J. Anim. Sci., 51, 349–354.

Wasburn K.W. (1990): Genetic variation in egg composition. In: Crafword R.D. (ed.): Poultry Breeding and Genetics. Elsevier, Amsterdam, Oxford, New York, Tokyo, 781–804.

Washnurn K.W., Marks K.W. (1977): Changes in fitness traits associated with selection for divergence in yolk cholesterol concentration. Brit. Poult. Sci., 18, 189–199.

Wolc A., Lisowski M., Swaczkowski T. (2007): Heritability of egg production in laying hens under cumulative, multitrait and repeated measurement animal models. Czech J. Anim. Sci., 52, 254–260.

Zemková Ľ., Simeonovová J., Lichovníková M., Somerlíková K. (2007): The effects of housing systems and age of hens on the weight and cholesterol concentration of the egg. Czech J. Anim. Sci., 52, 110–115.

Received: 2007–03–29
Accepted after corrections: 2007–11–16

Corresponding Author

Ing. Ján Baumgartner, DrSc., Slovak Agricultural Research Center, 900 28 Ivanka pri Dunaji, Slovak Republic
Tel. +00421 245 931 21, e-mail: baumgartner@atlas.sk