Journal of Animal and Feed Sciences, 9, 2000, 687 – 696

Concentration of plasma cholesterol and total lipids in hens of various laying lines during the laying period *

L. Máchal

Mendel University of Agriculture and Forestry Brno
Zemědělská 1, 613 00 Brno, Czech Republic

(Received 21 February 2000; accepted 4 October 2000)

ABSTRACT

The concentration of total lipids and cholesterol in the plasma of 72 clinically healthy hens of 3 laying lines (BPR, RIR and SU) was studied during the laying period (days 121, 149, 189, 240, 310 and 358 of age). The average total lipid concentration in all lines was the lowest prior to and at the beginning of egg production (6.46, 8.19 and 11.39 g/l). The average concentrations of both plasma total lipids and plasma cholesterol were the highest in the peak of the laying period (23.77, 29.42, 32.09 g/l and 3.99, 4.10, 4.12 mmol/l, respectively).

Prior to and at the beginning of egg production the correlation between the concentrations of plasma total lipids and cholesterol and the intensity of egg production were positive (r_p = 0.01 to 0.42). With the increasing intensity of egg production and at its peak this correlation was negative for total lipids (r_p = -0.48 to -0.03), for cholesterol in line SU it was negative (r_p = -0.22 to -0.20), in late lines it was positive during peak egg production (r_p = 0.18 to 0.47).

The concentrations of total lipids and cholesterol were found to affect both the stage of egg production and the line.

KEY WORDS: hens, blood plasma, total lipids, cholesterol, laying period, egg production

* Supported by MSM 432100001

INTRODUCTION

Blood plasma hyperlipaemia accompanies the sexual maturing of hens of domestic fowl. According to Salageanu (1989) the maximal concentration of plasma total lipids and cholesterol of hens at the beginning of egg production is 470.8 and 74.34 mg/100 ml, respectively, gradually decreasing to 439.5 and 128.83 mg/100 ml on day 360 of age and to 343.63 and 132.58 mg/100 ml on day 540 of age. Nasr-el-din et al. (1988) studied the concentration of triiodthyronine, thyroxin, glucose, total lipids and proteins in the blood serum. They found that thyroid hormones, total lipids and proteins reached their peak levels before the onset of egg production, the level of glucose, however, was lower. On the other hand, Cerolini et al. (1990) observed a lower level of plasma lipids at the age of 18 weeks, rapid growth at the age of 30 weeks and gradual growth up to the 67th week of age. Máchal et al. (1994) point out that there is a great difference in the concentration of total plasma lipids between the lines of laying hens (17.88-29.96 g/l).

The concentration of plasma cholesterol is affected by various factors. The negative correlation between the level of egg production and concentration of plasma cholesterol has been known for a relatively long time (Mangle et al., 1978). The concentration of plasma cholesterol of hens (Cunningham et al., 1974) and of Japanese quail can be reduced by selection. After divergent selection in 7 generations of Japanese quail for the reduction of plasma and yolk cholesterol, Marks and Washburn (1991) found that plasma cholesterol decreased by one-third and yolk cholesterol by 15-20%. However, according to Hargis (1988), when the level of cholesterol decreases by 5-7%, natural selection puts on pressure to increase this level, which is necessary for the developing embryo. A number of authors suggested that lipaemia, or the concentration of plasma cholesterol, could be influenced by changing the diet, or by administering special preparations (Martinéz et al., 1992; Van Elswyk et al., 1994). Kováč et al. (1991) confirmed that the concentration of plasma cholesterol of laying hens depends on the level of metabolisable energy (ME) in the feed ration and that it decreases with the content of ME. Mate et al. (1996) pointed out that the concentration of plasma cholesterol in hens could increase for several days due to stress.

Suchý et al. (1995) found that the plasma cholesterol concentration in individual hens ranged between 3.55 and 10.25 mmol/l (Suchý et al., 1999) and that during the laying period average values ranged between 2.73 and 6.18 mmol/l. In contrast, Hall and McKay (1994) reported only small deviations in plasma cholesterol concentrations among individual hens.

The objective of the present study was to define the fluctuation of plasma total lipids and cholesterol concentrations in association with egg production and body weight of hens of various lines.

MATERIAL AND METHODS

The fluctuation of plasma total lipids and cholesterol concentrations in hens, the number of eggs laid, and body weight of hens during the laying period were studied in initial lines of Moravia laying hybrids. We took 72 clinically healthy hens of 3 commercial lines from the 17th generation selected in cage technology: 23 hens of the Bar Plymouth Rock (BPR-1) male line, 24 hens of the Rhode Island Red (RIR-2) male line, and 25 hens of the Sussex Light (SU-3) female line. By the end of the studied period, two hens each of BPR-1 and RIR-2 had died.

At the age of 17 weeks the hens were placed individually in the laying house into the same battery of cages. They were fed 3 times a day; from day 17 to 19 of age with a NP O mixture, from day 20 to the 40th week of age with the NP 1 mixture. In the second half of the laying cycle they were fed the NP 2 mixture. Nipple drinkers provided watering.

During the laying period, at the age of 121, 149, 189, 240, 310 and 358 days, blood from the wing vein was sampled. As part of individual efficiency testing, daily egg production was also recorded. Blood was sampled 424 times (altogether) during the investigations to determine the concentrations of plasma total lipids and cholesterol. Blood samples were taken from hens of all 3 lines, always on the same day between 8 and 11 a.m. After sampling from the wing vein, plasma was separated immediately by centrifugation and within 24 h the concentration of total plasma lipids and cholesterol was determined photometrically using Bio-La-bio-assays. On the day of blood sampling the hens were weighed individually.

Egg production in the studied period was evaluated at 5-6-day intervals to eliminate any immediate technological influences. The day of blood sampling was in the middle of this interval, which was the same for hens of all 3 lines at a given age.

The t-test was used to determine the significance of differences in the averages of the concentration of plasma total lipids and cholesterol in the course of the laying period. The dynamics of changes in the concentration of total lipids and cholesterol were evaluated by two-way variance analysis. The corelations between the concentration of plasma total lipids and cholesterol and the number of eggs laid by hens of the respective lines were also evaluated.

RESULTS AND DISCUSSION

The earliness of the hens of all 3 lines can be defined on the basis of the number of laid eggs in the individual periods (Table 1). While the average number of eggs laid by hens of the early female line SU-3 in the first period of investigations from day 121 to day 141 of age was high, i.e. 10.7 eggs, hens of the male line RIR-05

TABLE I

Average number of eggs in the 5 and 6 weeks periods and body weight in hens different lines during the laying period (line BPR - 1, RIR - 2 and SU - 3)

Age days	Number of eggs		
	BPR - 1 n = 23	RIR - 2 n = 24	SU - 3 n = 25
	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$
121	1.21 ± 0.24	4.88 ± 1.31	10.70 ± 3.37
149	29.07 ± 8.80	35.20 ± 11.04	36.68 ± 3.40
189	32.35 ± 8.22	22.00 ± 3.50	26.12 ± 15.58
240	25.48 ± 5.95	26.55 ± 3.61	17.08 ± 3.81
310	37.17 ± 5.07	30.71 ± 7.03	25.56 ± 4.34
358	22.41 ± 8.90	21.21 ± 11.71	15.84 ± 13.98

laid 4.88 eggs and hens of the late male line BPR-1 only 1.20 eggs. Figure 1 shows the earliness and intensity of egg production of hens of the initial lines BPR-1, RIR-2 and SU-3. In these hens, the development of body weight corresponded with the earliness of the line. Although the highest average body weight on the 121st day of age was observed in hens of the earliest line SU-1 (1.69 kg), on the 358th day, i.e. at the end of the investigations, it was the lowest (2.32 kg) (Figure 2).

Studies of the fluctuation of plasma lipaemia in hens of the RIR-2, SU-3 and BPR-1 lines revealed a relatively low concentration of total lipids at the age of 17 weeks (8.19, 11.39 and 6.46 g/l, respectively; Table 2). The average concentrations gradually grew and were always the highest at peak egg production of the respective line (RIR - 23.77 g/l, SU - 32.09 g/l and BPR - 29.42 g/l), which was reached at different ages. The effect of the line and age of the hen on values of the concentration of plasma total lipids and cholesterol was evaluated using two-factorial analysis of variance. Highly significant differences were found in the two factors at different ages ($F = 45.63$ and 10.72), and highly significant differences in the concentration of total lipids were found also among the lines ($F = 19.94$).

The explanation for the differences in the dynamics of the concentration of plasma total lipids lies primarily in the varied earliness of the line. In hens of the early female line, the maximal average concentration of total lipids (32.09 g/l) was the earliest of all, i.e. at the age of 149 days, and was closely associated with sexual maturity (Figure 3). The maximal average concentration of plasma total lipids was the latest in hens of the late male line BPR-1, i.e. at the age of 240 and 310 days (sexual maturity and peak egg production are late). This finding corresponds with the data of Salageanu (1989) and Cerolini et al. (1990). At the same time the previously reported finding (Máchal et al., 1994) that there are considerable inter-line differences in the concentrations of plasma total lipids

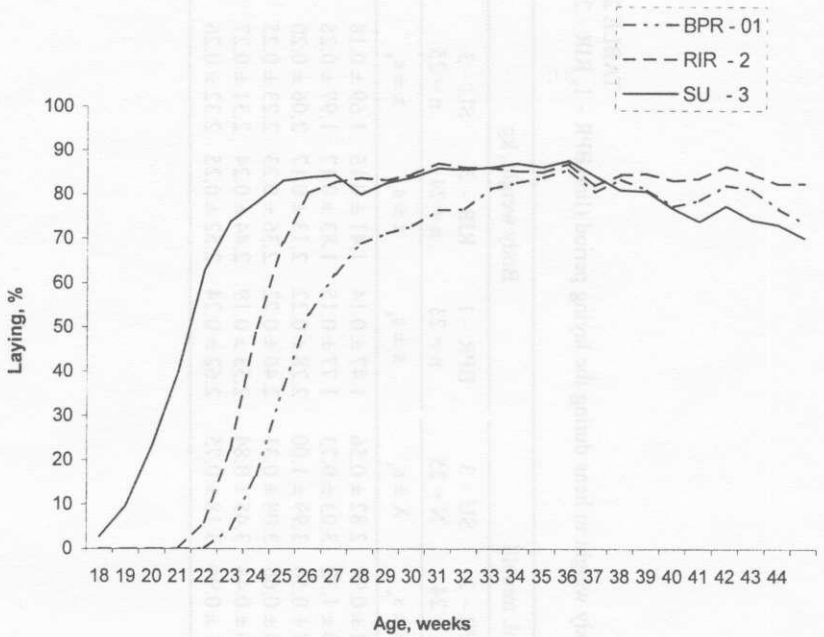

Figure 1. The parcial laying curve in hens during the laying periode (line BPR - 1, RIR - 2 and SU - 3)

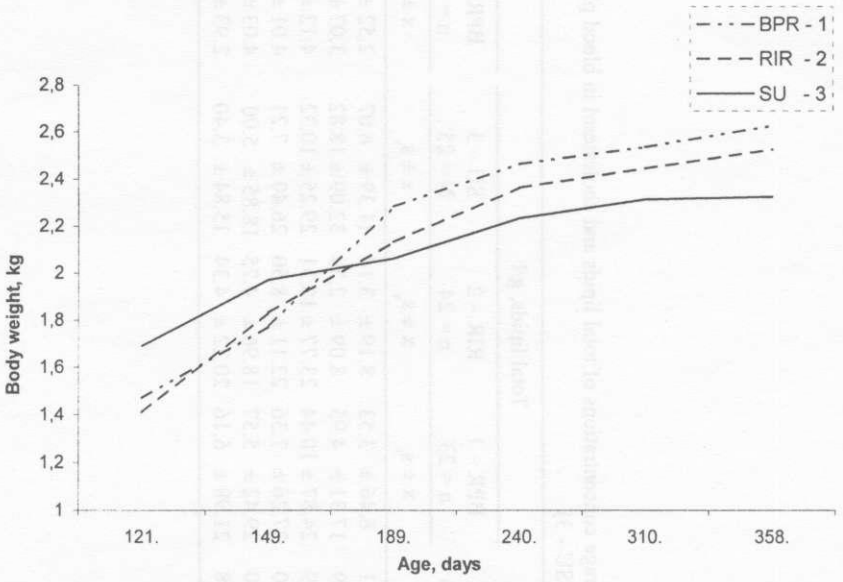

Figure 2. Body weight in hens during the laying periode (line BPR - 1, RIR - 2 and SU - 3)

TABLE 2

Average concentrations of total lipids and cholesterol in blood plasma and body weight in hens during the laying period (line BPR - 1, RIR - 2 and SU - 3)

Age days	Total lipids, g/l			Cholesterol, mmol/l			Body weight, kg		
	BPR – 1 n = 23	RIR – 2 n = 24	SU – 3 N = 25	BPR – 1 n = 23	RIR – 2 n = 24	SU – 3 N = 25	BPR – 1 n = 23	RIR – 2 n = 24	SU – 3 n = 25
	$x \pm s_x$	$x \pm s_x$	$x \pm s_x$	$x \pm s_x$	$x \pm s_x$	$X \pm s_x$	$x \pm s_x$	$x \pm s_x$	$x \pm s_x$
121	6.46 ± 3.53	8.19 ± 3.14	11.39 ± 6.07	2.52 ± 0.49	3.22 ± 0.94	2.82 ± 0.56	1.47 ± 0.14	1.41 ± 0.15	1.69 ± 0.18
149	17.31 ± 4.95	8.09 ± 2.29	32.09 ± 18.82	3.07 ± 0.69	3.60 ± 1.32	3.03 ± 0.73	1.77 ± 0.15	1.83 ± 0.17	1.97 ± 0.26
189	24.87 ± 10.44	23.77 ± 10.31	29.25 ± 10.32	4.12 ± 1.25	3.07 ± 0.56	3.99 ± 1.00	2.28 ± 0.22	2.13 ± 0.17	2.06 ± 0.20
240	27.26 ± 7.36	22.11 ± 8.50	26.40 ± 7.21	4.01 ± 1.17	2.74 ± 0.66	3.08 ± 0.31	2.46 ± 0.22	2.36 ± 0.23	2.23 ± 0.25
310	29.42 ± 5.57	18.96 ± 4.75	18.85 ± 5.00	4.03 ± 0.89	4.10 ± 0.44	3.45 ± 0.84	2.53 ± 0.19	2.44 ± 0.24	2.31 ± 0.27
358	21.98 ± 6.16	20.22 ± 4.34	15.84 ± 3.40	2.93 ± 0.52	3.01 ± 0.94	3.18 ± 0.75	2.62 ± 0.24	2.52 ± 0.25	2.32 ± 0.26

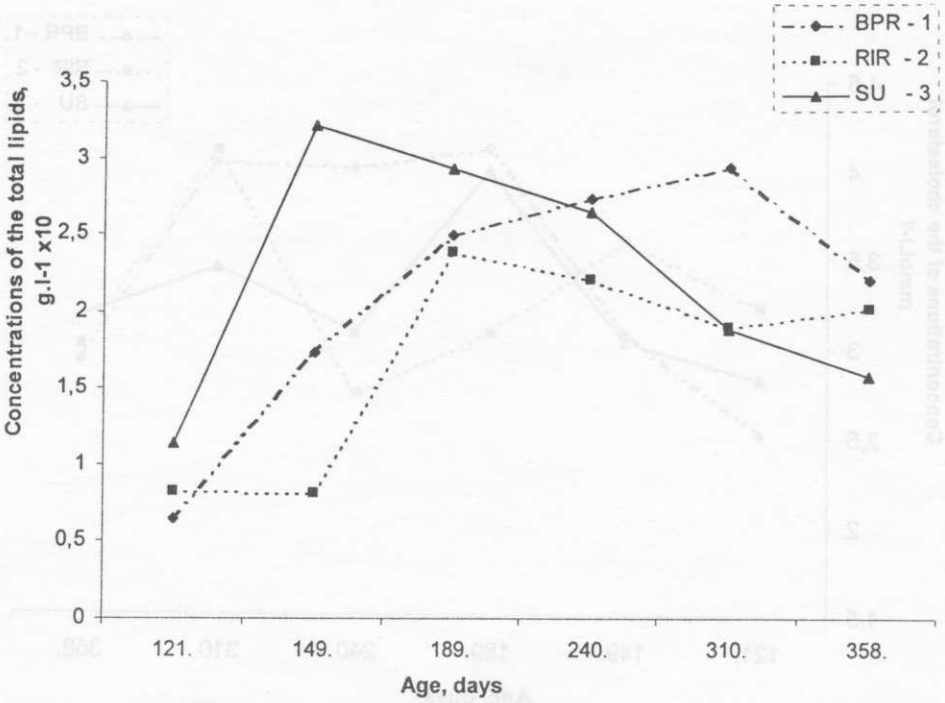

Figure 3. The dynamics of the blood total lipids in hens during the laying periode (line BPR - 1, RIR - 2 and SU - 3)

was confirmed. The lowest concentrations of plasma cholesterol were found in hens of the SU-3 and BPR-1 lines (i.e. 2.52 and 2.82 mmol/l, respectively) at the age of 17 weeks (Figure 4). The highest average concentration of plasma cholesterol was observed in the period of peak egg production (SU-3 - 3.99 mmol/l and BPR-1 - 4.12 mmol/l). The concentration of cholesterol of hens of the male line RIR-2 was the highest at the age of 310 days, i.e. 4.10 mmol/l. Therefore, during the laying period, lipaemia values changed from low values at the age of 17 weeks (Peebles et al., 1996) to high values in the stage of sexual maturity and peak egg production (particularly the concentration of total lipids). From the moment of peak egg production, plasma lipaemia decreased, which is at variance with the investigations of Cerolini et al. (1990), for instance, who reported increasing values up to the age of 67 weeks. According to our findings, the course of plasma lipaemia generally corresponds to the course of the laying curve. The findings of Hall and McKay (1994) about the small deviations in plasma cholesterol concentrations among individual hens do not corroborate the values of standard deviations from average values of plasma lipaemia, calculated for

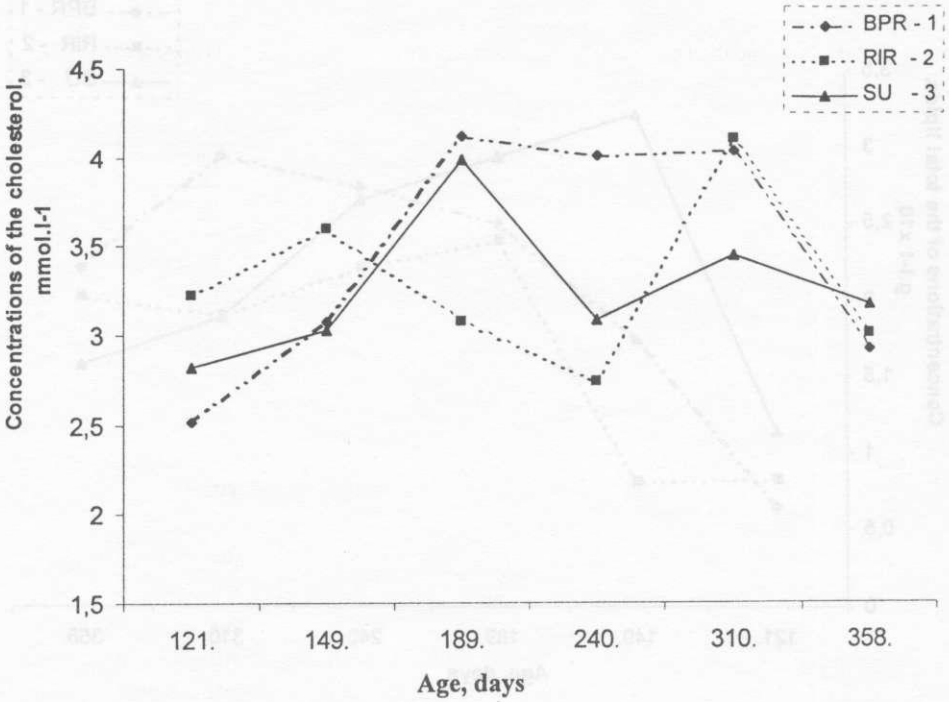

Figure 4. Thedynamics of the blood cholesterol in hens during the laying periode (line BPR - 1, RIR - 2 and SU - 3)

the respective periods in the present study. In our studies, the variability ranged around 30%.

The number of eggs laid at the beginning of egg production was positively correlated with the concentrations of both plasma total lipids and plasma cholesterol (r_p = 0.01 to 0.42) and was the most marked in the late line BPR-1 (r_p = 0.33 and 0.42, respectively; Table 3). With increasing egg production, and at its peak, the correlations between the number of laid eggs and concentration of plasma total lipids calculated for hens of all the 3 lines were always negative (sometimes significant), i.e. r_p = -0.48 to -0.03). The correlation between the number of laid eggs and concentration of plasma cholesterol was negative with increasing egg production, but particularly in hens of the early female line SU-3 also during peak egg production (r_p = -0.22 to 0.01). The period of negative correlations during egg production was shorter in hens of both late male lines and the calculated values were also lower (r_p = -0.19 to 0.07). Outside the period of intensive increase in egg production and at its peak, positive correlations between the number of laid eggs and concentrations of plasma total lipids and

TABLE 3

Dynamic of the phenotypic correlations between total lipids and cholesterol concentrations in blood plasma of the hens and their egg lay in particular intervals of the laying period (line BPR - 1, RIR - 2 and SU - 3)

Age days	Total lipids : Egg laying			Cholesterol : Egg laying		
	RIR - 2	SU - 3	BPR - 1	RIR - 2	SU - 3	BPR - 1
121	0.04	0.09	0.33	0.06	0.01	0.42*
149	- 0.24	0.18	- 0.12	- 0.12	0.17	- 0.07
189	- 0.34	- 0.33	- 0.48*	0.28	- 0.20	- 0.19
240	- 0.20	- 0.03	- 0.10	0.22	- 0.22	0.47*
310	0.23	- 0.23	0.10	0.23	- 0.21	0.18
358	0.23	- 0.23	0.34	- 0.24	- 0.01	0.04

* P=0.05

cholesterol were found, particularly in the late male lines where they were around $r_p = 0.10$ and 0.47.

The tendency of changes in the relations between the number of laid eggs and concentration of the studied blood parameters appears to be interesting. Changes in correlations from positive to negative, and vice versa, during the laying period usually occurred one month earlier in hens of the female line than in hens of the late male lines. Rather than by the age of the hen, it was affected by the stage of egg production and also by the immediate physiological nutrition-based condition of the bird. Plasma lipaemia may be one of the criteria for monitoring the level of interaction between the genotype and the environment on the level of the pre-clinical response of an individual. It appears to be a criterion for evaluating whether the genetic potential can be expressed in the given environmental conditions. At the same time, it can be a guide for a selection programme in the respective lines.

REFERENCES

Cerolini S., Baldi A., Cavalchini L.G., 1990. Blood and plasma biochemical variables in laying hens of different strains and ages. Arch. Geflügelk. 54, 190-194

Cunningham D.L., Krueger W.F., Fanguy R.C., Peabody J.W., 1974. Preliminary results of bidirectional selection for yolk cholesterol level in laying hens. Poultry Sci. 53, 384-391

El Sayed M.S., Brackenbury J.H., 1988. Sexual maturity and physical exercise alter fibrinolytic activity in birds (chickens). Comp. Biochem. Physiol., A Comp. Physiol. 90A, 409-411

Hall L.M., McKay J.C., 1994. Variation in plasma cholesterol concentration over time in the domestic fowl. Brit. Poultry Sci. 35, 631-634

Hargis P.S., 1988. Modifying egg yolk cholesterol in the domestic fowl - a review. World Poultry Sci. J. 44, 17-29

Máchal L., Ingr I., Kalová J., Jeřábek S., 1994. The dependence of the hatchability, laying and egg weight on the egg cholesterol level and total lipids concentration in the blood plasma in the hens of laying strains. Arch. Tierzucht 37, 567-575

Mangle N.S., Datta I.C., Khan A.G., Rajput Y.S., 1978. A note on the chemical constituens of blood in relation to production traits in White Leghorn breed. Indian J. Anim. Sci. 48, 691-693

Marks H.L., Washburn K.W., 1991. Plasma and yolk cholesterol levels in Japanese quail divergently selected for plasma cholesterol response to adrenocorticotropin. Poultry Sci. 70, 429-433

Martinéz V.M., Newman R.K., Newman C.W., 1992. Barley diets with different fat sources have hypocholesterolemic effects in chicks. J. Nutr. 122, 1070-1076

Mate D., Turek P., Nagy J., 1996. Effect of stress on the cholesterol level in the blood serum of laying hens and in egg yolk (in Slovak). Slovenský vet. Časop. 21, 259-261

Nasr-el-din R.A., Yousef A.A., Mahmoud M.F., Ibrahim I.A., 1988. Thyroid hormones, total lipids and total proteins in blood serum before and during laying in Hisex Brown chickens. J. Anim. Physiol. Anim. Nutr. 59, 167-170

Peebles E.D., Cheaney J.D., Vaughn K.M., Latour M.A., Smith T.W., Haynes R.L., Boyle C.R., 1996. Changes in gonadal weights, serum lipids, and glucose during maturation in the juvenile Northern Bobwhite quail (*Colinus virginianus)*. Poultry Sci. 75, 1411-1416

Salageanu G., 1989. Blood lipid dynamics in fowls raised for eggs. Lucrari Stii., Insti. Agr. - Nicolae Balcescu, Bucuresti, Ser. C – Med. Vet. 32 (1), 33-39

Suchý P., Ingr I., Straková E., 1995. A relationship between cholesterol concentrations in eggs and blood plasma of hens (in Czech). Czech J. Anim. Sci. 40, 11-14

Suchý P., Straková E., Hrubý A., 1999. Variations in cholesterol concentrations in the blood plasma of hens throughout the laying period (in Czech). Czech J. Anim. Sci. 44, 109-111

Van Elswyk M.E., Hargis B.M., Williams J.D., Hargis P.S., 1994. Dietary menhaden oil contributes to hepatic lipidosis in laying hens. Poultry Sci. 73, 653-662

STRESZCZENIE

Stężenie choresterolu i sumy lipidów w plazmie krwi kur, pochodzących z różnych linii, w okresie nieśności

Oznaczano stężenie sumy lipidów i choresterolu w plazmie krwi trzech linii niosek (BPR, RIR i SU) w 121, 149, 189, 240, 310 i 358 dniu życia u 72 klinicznie zdrowych kur. Średnie stężenie sumy lipidów w plazmie wszystkich linii było najniższe przed i na początku nieśności (6,46; 8,19 i 11,39 g/l), najwyższe, podobnie jak i choresterolu, w szczycie okresu nieśności (23,77; 29,42 i 32,09 g/l oraz 3,99; 4,10 i 4,12 mmol/l, odpowiednio).

Przed i na początku okresu nieśności korelacja pomiędzy stężeniem sumy lipidów i choresterolu a poziomem nieśności była dodatnia (r_p = 0,01 i 0,42). Wraz ze zwiększającym się poziomem nieśności i w jej szczycie korelacja z sumą lipidów była ujemna (r_p = -0,48 do -0,03), z choresterolem u kur linii SU również ujemna (r_p = -0,22 do -0,20), u kur pozostałych linii dodatnia w szczycie nieśności (r_p = 0,18 do 0,47).

W podsumowaniu stwierdzono, że stężenie sumy lipidów i choresterolu zależy zarówno od okresu nieśności, jak i linii kur.