Defective eggs and their relationship to egg yield, egg and body weight in hens of five original laying lines

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ABSTRACT: We investigated 3 985 individually housed hens of five original laying lines of two breeds RIR and BPR. The proportion of abnormal eggs out of the eggs laid before the age of 240 days ranged between 7.0% and 9.7%, in dependence on the line. The average number of cracked eggs ranged between 2.5% and 4.4%, double-yolk eggs between 2.2% and 3.0% and shell-less eggs between 2.0% and 2.7%. The correlation between the number of eggs laid at the beginning of the laying period and during the period of observation, and the frequency of double-yolk eggs was positive (r_P = 0.00 to r_P = 0.21) and mostly statistically highly significant (P < 0.01). On the other hand, statistically highly significant negative correlations (P < 0.01) were found between the number of eggs laid during the period of observation and the frequency of cracked eggs, where the correlations in the individual lines ranged between r_P = –0.04 and r_P = –0.23. Positive correlations, mostly statistically highly significant (P < 0.01), were found between the number of eggs laid during the period of observation and the frequency of shell-less eggs (r_P = 0.00 to r_P = 0.15). With the increasing weight of eggs the frequency of abnormal eggs also increased, in particular of double-yolk eggs (r_P = 0.08 to r_p= 0.32), for the most part statistically highly significantly (P < 0.01). The correlations between the individual types of abnormal eggs were positive. Statistically highly significant correlations (P < 0.01) were discovered between the frequency of double-yolk eggs and cracked eggs (r_P = –0.02 to r_p= 0.22) on the one hand and, between double-yolk eggs and shell-less eggs (r_P = 0.16 to r_P = 0.24) on the other.

Keywords: hens; cracked eggs; double-yolk eggs; shell-less eggs; egg yield; egg weight; body weight

The frequency of defective eggs, which include cracked eggs, double-yolk eggs and shell-less eggs, differs in dependence on the line or breed. For instance Abrahamsson and Tauson (1993) reported a different frequency of cracked eggs in two lines of White Leghorn hens. Patterson *et al*. (2001), however, did not observe a marked difference in the percent of cracked eggs between the white-egg and brown-egg hybrids (5.7 and 5.4%, respectively). In terms of the genetic determination of the frequency of cracked eggs Brah *et al*. (1992) calculated coefficients of heritability for the frequency of cracks in two White Leghorn lines, i.e. 0.59 and 0.36, respectively.

On the basis of the calculated correlations Grunder *et al*. (1991) reported that high egg production was associated with low shell quality. They also reported that the heavy body weight of hens at 365 days was statistically significantly associated with high shell weight. Phenotypic correlations were estimated within generations and pooled in two brown-egg type lines (Merat *et al*., 1992). Among the significant correlations there was a positive relation between the percent of cracked eggs and the body weight of adult hens. Renema *et al*. (2001) reported a higher frequency of double-yolk eggs from heavier hens than from lighter ones.

Abdallah *et al*. (1993) reported highly negative correlations between the percentage of cracked eggs and the percentage of the shell, shell weight per unit surface area, specific gravity, and shell

Supported by the Grant of Ministry of Education, Youth and Sports of the Czech Republic (Project No. MSM 432100001).

weight. However, a positive correlation was found between the percentage of cracked eggs and egg weight. Harms and Abdallah (1995) discovered that double-yolk eggs had a lower percentage of the shell.

The frequency of cracked eggs is also influenced by the technology. Abrahamsson *et al*. (1995) pointed out that the type of cage technology had an effect on the frequency of cracked eggs. The frequency of cracked eggs was the lowest in hens kept in conventional cages, as compared to get-away cages, conventional plastic cages and modified and enriched cages. Few differences between the systems were registered regarding the interior egg quality. Appleby *et al*. (1993) compared the frequency of cracked eggs between conventional and experimental cages. They discovered that the proportion of cracked eggs was slightly (but not significantly) higher in the experimental cages. The temperature in the laying house and the length of the applied light cycle also influenced the frequency of cracked eggs. Ugurlu *et al*. (2002) found a positive correlation between the increasing temperature (from 21.4°C to 27.6°C) and the proportion of cracks. Spies *et al*. (2000) observed that the hens laid more double-yolk eggs (i.e. 0.9% of the total egg production) under a 24-hour cycle than under a 28-hour one (0.3%).

The frequency of abnormal eggs during the laying period is of multi-factorial nature and influences not only the production of table eggs from the final hybrids but also the production of eggs from the original lines, suitable for incubation.

MATERIAL AND METHODS

We investigated 3 985 hens of original laying lines from the stock of the brown-egg laying hybrids Moravia: in a total of five lines of two breeds – three Rhode Island Red lines (RIR A, RIR B and RIR C) and two Bar Plymouth Rock lines (BPR A and BPR B). At the age of 16 weeks all the pullets were individually placed simultaneously into one laying house with cages (700 cm^2 per hen). All the pullets, later hens, were placed in the same cages, fed the same ration *ad libitum* (17% crude protein, 11.5% metabolisable energy, Ca 3.5%), watered with nipple drinkers and subjected to the same light regime (12 hours from 125 days of age to 140 days of age, increasing ½ hour/week from 141 days of age to 170 days of age, 15 hours after 171 days of age).

During production checks that were carried out between 125 and 240 days of age, the number of eggs laid before the age of 150 days, the number of laid eggs at the age of 151 to 165 days and the total number of eggs laid in the whole period by the age of 240 days was recorded. The eggs laid by hens between the age of 180 and 190 days were weighed individually on automatic scales. The average egg weight was calculated from all the eggs laid in this period. The body weight was determined in each line by weighing the first 30 hens from the successive cages at the age of 210 days. During production checks, the number of abnormal eggs from all hens, i.e. the number of cracked eggs, number of two-yolk eggs and the number of shell-less eggs, were monitored every day. The percentage of the respective abnormal eggs was calculated on the basis of the number of total laid eggs, cracked eggs, double-yolk eggs and shell-less eggs.

The egg mass was determined as the product of the average number of laid eggs for the period of observation (by 240 days of age) and average weight of eggs for the period between 180 and 190 days of age.

The measured parameters (cracked eggs, double-yolk eggs, shell-less eggs and production parameters) were statistically analysed and the differences between the lines were tested by the *t*-test. The correlations were defined by the calculated phenotypic correlations.

RESULTS AND DISCUSSION

Table 1 gives the average number of cracked eggs, double-yolk eggs and shell-less eggs for the period of observation, the number of eggs laid by the age of 150 days, the number of eggs laid at the age from 151 to 165 days, and the total number of eggs laid over the period of observation, i.e. by the age of 240 days, the average weight of eggs at the age from 180 to 190 days and the body weight at the age of 210 days in hens of five lines. Figure 1 shows the percentage of all abnormal eggs laid by hens of the respective lines by the age of 240 days.

The average body weight of the hens of the respective lines at the age of 210 days ranged between 2.01 ± 0.17 kg (line BPR B) and 2.38 ± 0.17 kg (line RIR A). The average total number of eggs before 150 days of age differed in the individual lines but this difference was not statistically significant, the lowest average number of laid eggs was 2.92 ± 2.25 eggs and the highest 7.03 ± 4.53 eggs. The hens of BPR B line, which laid the lowest number of eggs before

Table 1. Average values of body weight, egg yield, frequency of abnormal eggs, egg weight and egg mass from hens of five original laying lines

Line		n	Body weight (kg)	n	Number of eggs laid by 150th day of age	Number of eggs laid by 165th day of age	Number of eggs laid by 240th day of age	Number of cracks	Number of double-yolk eggs	Number of shell-less eggs	Egg weight (g)	Egg mass (kg)
RIR A	$\bar{x}$	30	2.38	236	5.62	9.39	88.94	3.37	2.18	2.05	51.87	4.63
	$s_{\bar{x}}$		0.17		3.81	3.85	10.66	3.71	1.65	1.69	3.50	0.54
BPR A	$\bar{x}$	30	2.33	1 036	4.16	7.51	82.63	2.49	2.48	1.64	51.72	4.10
	$s_{\bar{x}}$		0.15		2.45	3.86	13.34	2.76	2.01	0.98	3.98	0.65
BPR B	$\bar{x}$	30	2.01	963	2.92	5.66	72.32	2.92	2.16	1.95	49.35	3.80
	$s_{\bar{x}}$		0.17		2.25	3.68	11.59	3.47	1.67	1.48	3.50	0.60
RIR B	$\bar{x}$	30	2.17	854	4.78	7.67	82.97	3.64	1.99	1.99	51.93	4.33
	$s_{\bar{x}}$		0.17		3.45	3.99	11.16	4.36	1.47	1.69	3.51	0.62
RIR C	$\bar{x}$	30	2.22	896	7.03	9.69	91.12	2.31	2.00	2.02	53.38	4.94
	$s_{\bar{x}}$		0.20		4.53	4.48	14.64	2.63	1.66	1.99	3.76	0.80

the age of 150 days (5.66 ± 3.68 eggs), also laid the lowest number of eggs in the period of observation by 240 days of age (72.32 ± 11.59 eggs). The hens of RIR C line laid the highest number of eggs before 150 days of age (7.03 ± 4.53 eggs), and also laid the highest number of eggs over the period of observation – by 240 days of age (91.12 ± 14.64 eggs). Egg yields at the age from 151 to 165 days of age ranged between 5.66 ± 3.68 eggs (hens of BPR B line) and 9.69 ± 4.48 eggs (hens of RIR C line).

The proportion of abnormal eggs out of the eggs laid by the age of 240 days was the lowest in eggs in the hens of RIR C line and the highest in eggs laid by the hens of BPR B line, i.e. 7.0% and 9.7%, respectively (Figure 1). The RIR C hens laid the highest number of eggs, and at the same time the lowest number of abnormal eggs. The average number of cracked eggs laid by line RIR C and line RIR B by the age of 240 days ranged between 2.31 ± 2.63 and 3.64 ± 4.36 eggs, respectively. The RIR C hens laid the lowest amount of cracked eggs and the RIR B hens the highest (2.5% and 4.4%, respectively) (Figure 2). The percentage of cracked eggs in the original lines was found to be lower than the number reported by Patterson *et al.* (2001) in the hens of brown-egg and white-egg hybrids. The

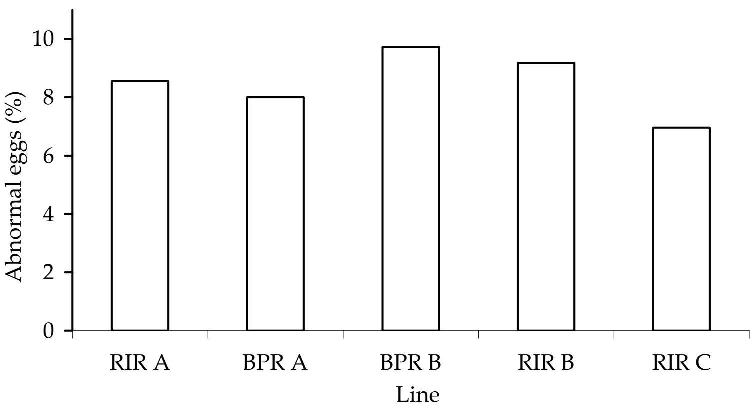

Figure 1. Frequency of abnormal eggs laid by hens of original laying lines by 240 days of age

different frequency of cracked eggs in the respective lines is in accordance with the observations of Abrahamsson and Tauson (1993), who determined a different frequency of cracked eggs in the two lines of hens. At the age of 250 days the average number of double-yolk eggs ranged between 1.99 ± 1.47 eggs (line RIR B) and 2.48 ± 2.01 eggs (line BPR A). The percentage of double-yolk eggs was the lowest in eggs laid by the hens of RIR C line (2.2%) and the highest by both BPR lines (3.0%). In hens of the original lines the percentage of double-yolk eggs was higher than what was presented, for instance, by Spies *et al*. (2000). In this connection we must draw attention to the fact that the frequency of double-yolk eggs is higher at the beginning of the laying period.

The average number of shell-less eggs laid by hens by 240 days of age ranged between 1.64 ± 2.00 eggs (line BPR A) and 2.05 ± 2.3 eggs (line RIR A). The lowest percentage of shell-less eggs was laid by the hens of BPR A line (2.0%) and the highest by the hens of BPR B line (2.7%).

The eggs of the hens of BPR B line had the lowest average egg weight (49.35 ± 3.50 g) and also the lowest amount of produced egg mass before the age of 240 days (3.80 ± 0.60 kg). The highest average egg weight (53.38 ± 3.76 g) as well as the highest amount of egg mass by the age of 240 days (4.94 ± 0.80 kg) was determined in the hens of RIR C line. No statistically significant differences were observed between the average values of the respective lines due to the high variability within the lines.

Table 2 gives the calculated phenotypic correlations between the individual defects of laid eggs and the body weight at the age of 210 days, number of eggs laid at the age of 150 days, number of eggs laid between 151 and 165 days of age, egg yield at 240 days of age, egg weight at the age from 180 to 190 days and production of egg mass in hens of seven lines. Phenotypic correlations between the body weight of hens and the frequency of cracks, double-yolk eggs and shell-less eggs were calculated within the range of r_P = –0.56 and r_P = 0.53, and between the body weight of hens and the frequency of cracks in the range between r_P = –0.30 and r_P = 0.13. The argument of Merat *et al*. (1992) that there is a positive correlation between the body weight of the hen and the frequency of cracked eggs was not confirmed. Although the correlation r_P = 0.53 ($P < 0.01$) between the body weight and the frequency of double-yolk eggs in the hens of BPR A line was statistically highly significant, we cannot confirm the findings of Renema *et al*. (2001), who reported that the proportion of double-yolk eggs laid by heavier hens was higher than by lighter hens. The correlations found in the present study ranged between r_P = –0.32 and r_P = 0.53. The correlations between the body weight of the hen and the frequency of shell-less eggs ranged between r_P = –0.56 and r_P = 0.54; the values of r_P = –0.56 and 0.54 reported in the RIR A and the BPR A lines were statistically highly significant ($P < 0.01$).

Negative phenotypic correlations ranging between r_P = –0.23 and r_P = 0.13 were determined between the number of eggs laid by the age of 150 days, the number of eggs laid between days 151 and 165 and eggs laid over the period of observation by 240 days of age, and the frequency of cracks. Negative phenotypic correlations ranging between r_P = –0.04 and r_P = –0.23 were calculated between the number of

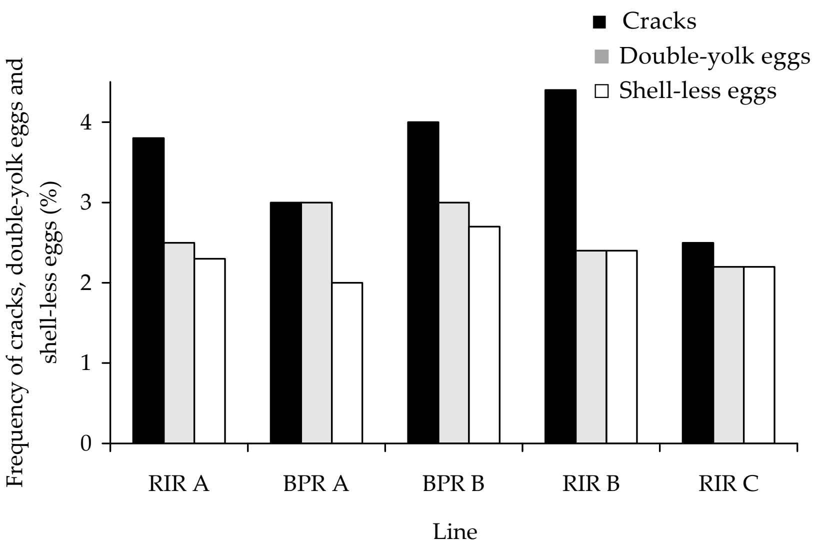

Figure 2. Frequency of cracks, double-yolk eggs and shell-less eggs by 240 days of age

Table 2. Correlation coefficients between the frequency of abnormal eggs, body weight, egg yield, egg weight and egg mass

Line	n	Body weight	n	Eggs laid by 150th day of age	Eggs laid by 165th day of age	Eggs laid by 240th day of age	Double-yolk eggs	Egg weight	Egg mass
Cracks									
RIR A	30	–0.09	236	–0.12	–0.21^{++}	–0.23^{++}	0.09	0.26^{++}	–0.04
BPR A	30	–0.12	1036	0.07^{+}	–0.03	–0.13^{++}	–0.02	0.07^{+}	–0.07^{+}
BPR B	30	0.13	963	–0.09^{++}	–0.13^{++}	–0.04	0.22^{++}	0.07^{+}	0.04
RIR B	30	–0.30	854	–0.02	0.01	–0.11^{++}	0.11^{++}	–0.01	–0.09^{++}
RIR C	30	0.00	896	0.13^{++}	–0.01	–0.10^{++}	0.07^{+}	–0.03	–0.07^{+}
Double-yolk eggs									
RIR A	30	–0.32	236	0.01	0.03	0.07	–	0.18^{++}	0.13^{+}
BPR A	30	0.53^{++}	1036	0.03	0.09^{++}	0.07^{+}	–	0.15^{++}	0.16^{++}
BPR B	30	–0.05	963	0.14^{++}	0.21^{++}	0.00	–	0.32^{++}	0.18^{++}
RIR B	30	0.19	854	0.00	0.12^{++}	0.00	–	0.08^{+}	0.03
RIR C	30	–0.19	896	0.14^{++}	0.11^{++}	0.14^{++}	–	0.17^{++}	0.19^{++}
Shell-less eggs									
RIR A	30	–0.56^{++}	236	–0.05	–0.04	–0.04	0.17^{++}	0.07	0.08
BPR A	30	0.54^{++}	1036	0.18^{++}	0.08^{++}	–0.11^{++}	0.24^{++}	0.02	–0.10^{++}
BPR B	30	–0.05	963	–0.04	–0.03	–0.12^{++}	0.23^{++}	0.15^{++}	–0.02
RIR B	30	0.07	854	0.14^{++}	0.00	–0.15^{++}	0.16^{++}	0.06	–0.09^{++}
RIR C	30	0.00	896	0.12^{++}	0.00	0.00	0.17^{++}	0.11^{++}	–0.07

$^{+}P < 0.05$, $^{++}P < 0.01$

eggs laid over the period of observation by the age of 240 days and the occurrence of cracks. The correlations r_P = –0.10, –0.11, –0.13 and –0.23 discovered in the RIR C, RIR B, BPR A and RIR A lines were statistically highly significant ($P < 0.01$) and did not confirm the conclusions of Grunder *et al.* (1991), who reported that, on the basis of the calculated correlations, high egg production was associated with low shell quality.

The phenotypic correlations between the number of eggs laid before 150 days of age, the number of eggs laid between days 151 and 165 of age and eggs laid over the period of observation by 240 days of age, and the frequency of double-yolk eggs were not negative and ranged between r_P = 0.00 and r_P = 0.21. The correlations r_P = 0.09, 0.11, 0.12, 0.14 and 0.21 discovered in the BPR A, RIR C, RIR B, and BPR B lines were statistically highly significant ($P < 0.01$). Only the correlation r_P = 0.07 between the number of eggs laid over the period of observation by 240 days of age and the frequency of double-yolk eggs was significant ($P < 0.05$) in the hens of BPR A line.

The phenotypic correlations between the number of eggs laid before the age of 150 days, the number of eggs laid from days 151 to 165 and over the period of observation by 240 days of age, and the frequency of shell-less eggs ranged between r_P = –0.15 and r_P = 0.18. The correlations between the number of eggs laid over the period of observation by 240 days of age and the frequency of shell-less eggs were zero and negative, and ranged between r_P = –0.15 and r_P = 0.00. The correlations r_P = –0.11, –0.12, –0.15 found in the BPR A, BPR B and RIR B lines were statistically highly significant ($P < 0.01$).

The phenotypic correlations based on the quantification of the correlation of the frequency of double-yolk eggs and cracks were mostly positive and ranged between r_P = –0.02 and r_P = 0.22; r_P = 0.11 and 0.22 found in the RIR B and BPR B lines were statistically highly significant (P < 0.01). The positive correlation r_P = 0.07 in the RIR C line was statistically significant (P < 0.05). The correlations between the frequency of double-yolk eggs and shell-less eggs were also positive (r_P = 0.16 to r_P = 0.24). The correlations found in all the lines were statistically highly significant (P < 0.01).

The correlations between the weight of eggs at the age of 180–190 days and the frequency of cracks were mostly positive and ranged between r_P = –0.03 and r_P = 0.26. The value 0.26 of the RIR A line was statistically highly significant (P < 0.01), the value r_P = 0.07 in the BPR A and BPR B lines was statistically significant (P < 0.05). This finding is in accordance with the conclusions of Abdallah *et al*. (1993). The correlations between the weight of eggs from hens of the age from 180 to 190 days and the frequency of double-yolk eggs (r_P = 0.08 to r_P = 0.32) were statistically significant and positive in all the lines. The correlation of r_P = 0.08 observed in the RIR B line was statistically significant (P < 0.05), the correlation coefficients of the other four lines were statistically highly significant (P < 0.01). The correlation between the weight of eggs from hens of the age of 180–190 days and the frequency of shell-less eggs was positive in all the five lines and ranged between r_P = 0.02 and r_P = 0.15. The correlation coefficients in line RIR C (r_P = 0.11) and BPR B (r_P = 0.15) were highly significant (P < 0.01).

The correlation between the amount of egg mass and frequency of abnormal eggs was quantified by coefficients ranging between r_P = –0.10 and r_P = 0.19. The correlation between the amount of egg mass and frequency of double-yolk eggs was positive in all the lines and ranged between r_P = 0.03 and r_P = 0.19. The values of r_P = 0.16, 0.18 a 0.19, calculated in lines BPR A, BPR B and RIR C, respectively, were statistically highly significant (P < 0.01), the correlation r_P = 0.13 calculated in line RIR A was statistically significant (P < 0.05).

The results indicate the there exist differences between the lines in the frequency of cracked eggs, double-yolk eggs and shell-less eggs during the egg laying period by the age of 240 days, but they are not statistically significant. The correlation between the number of laid eggs, both at the beginning of the laying period and in the period of observation, and the frequency of double-yolk eggs was statistically highly significant (r_P = 0.00 to r_P = 0.21). On the other hand, the correlations between the number of eggs laid over the period of observation and the frequency of cracked eggs (r_P = –0.04 to r_P = –0.23) and between the number of eggs laid over the period of observation and the frequency of shell-less eggs (r_P = 0.00 to r_P = 0.15) were negative and statistically highly significant. The frequency of abnormal eggs increased with increasing egg weight, in particular of double-yolk eggs (r_P = 0.08 to r_P = 0.32). The correlations between the individual types of abnormal eggs were positive. Statistically highly significant correlations were discovered between the frequency of double-yolk eggs and cracked eggs (r_P = –0.02 to r_P = 0.22) as well as between double-yolk eggs and shell-less eggs (r_P = 0.16 to r_P = 0.24). These statistically significant correlations make it possible to apply them in selection within the original lines of laying hens.

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Received: 03–04–14
Accepted after corrections: 04–01–09

ABSTRAKT

Defektní vejce a jejich vztah ke snášce, hmotnosti vajec a těla u slepic pěti výchozích snáškových linií

Sledování probíhalo u 3 985 individuálně ustájených slepic pěti výchozích snáškových linií dvou plemen RIR a BPR. Zastoupení abnormálních vajec z vajec snesených do věku 240 dnů se pohybovalo u jednotlivých linií od 7,0 % do 9,7 %. Průměrný počet vajec křapů se pohyboval u linií v rozpětí od 2,5 % do 4,4 %, dvoužloutkových vajec od 2,2 % do 3,0 % a vajec bez skořápky od 2,0 % do 2,7 %. Mezi počtem snesených vajec na počátku snášky a v celém sledovaném období a frekvencí výskytu dvoužloutkových vajec byla zjištěna kladná závislost (r_P = 0,00 až r_P= 0,21), většinou statisticky vysoce průkazná (P < 0,01). Naopak negativní závislosti, statisticky vysoce průkazné (P < 0,01), byly vypočteny mezi počtem snesených vajec za celé sledované období a frekvencí výskytu vajec křapů, kde se vypočtené korelace u jednotlivých linií pohybovaly v rozpětí r_P = –0,04 až r_P = –0,23. Kladné korelace, většinou statisticky vysoce průkazné (P < 0,01), byly zjištěny mezi počtem snesených vajec za celé sledované období a frekvencí výskytu vajec bez skořápky (r_P = 0,00 až r_P = 0,15). Se vzrůstající hmotností vajec se také zvyšovala frekvence výskytu sledovaných druhů abnormálních vajec, především dvoužloutkových vajec (r_P = 0,08 až r_P= 0,32), většinou statisticky vysoce průkazně (P < 0,01). Mezi jednotlivými druhy abnormálních vajec byly vypočteny kladné korelace. Statisticky vysoce průkazné kladné korelace (P < 0,01) byly zjištěny jak mezi výskytem dvoužloutkových vajec a křapy (r_P = –0,02 až r_P = 0,22), tak i mezi výskytem dvoužloutkových vajec a vajec bez skořápky (r_P = 0,16 až r_P = 0,24).

Klíčová slova: slepice; křapy; dvoužloutková vejce; vejce bez skořápky; snáška; hmotnost vajec; hmotnost těla

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