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Effect of the Date of Egg-laying on the Biological Value of Eggs and Reproductive Traits in Pheasants (*Phasianus colchicus* L.)

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Pheasant eggs evaluated in the first period of egg-laying did not differ significantly in their weight and shape index and the values of both traits were, respectively, 30.7 to 32.2 g and 76.1 to 78.1%. Over the laying season the thickness of the shell decreased and its capacity for deformation and crush strength were greatest at the end of the laying season. The share of yolk in the egg was highest at the beginning of the laying season (35.3%), however over the peak of egg-laying and its final period the content of the albumen in the egg and the quality of eggs, expressed in Haugh units, increased. The best egg fertility and the results of chick hatch were observed from eggs collected at the beginning of the laying season (respectively, 92.5 and 81.6%) and about the fifth week of production (respectively, 94.4% and 73.9%). Chicks hatched from eggs collected at the early laying season were heaviest (21.5 g) and showed the highest share in egg weight (66.8%).

Key words: Pheasant, egg quality, hatch, laying season.

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Pheasant eggs are used mainly for reproduction, and the hatch results depend on their biological value. The hatch results are most considerably affected by egg weight, shape index, shell thickness and its porosity and the share of the yolk, albumen and shell in the egg. Out of all the morphological traits of the egg, the albumen is of greatest importance, constituting protection for the yolk and the embryo from pathogenic microorganisms and provides water, protein and other nutrients indispensable for appropriate growth and development (BENTON & BRAKE 1996; NARUSHIN & ROMANOV 2002).

Besides genetic factors, the hatchability results depend on the bird age, an adequate mating sex ratio in reproductive flock and bird feeding over the reproduction period, pre-incubation egg storage and incubation technique (DOBRZAŃSKI & BEDNARCZYK 1988; JETHON & MAZURKIEWICZ 1982; MEIJERHOF 1992).

The aim of the present paper was to evaluate reproductive traits in pheasants, especially the traits of egg structure in successive weeks of the laying season, as well as the results of chick hatch over reproduction period.

Material and Methods

The research material consisted of pheasant eggs obtained from a one-year-old bird flock, collected in February 2003 at the mating sex ratio of 1 ♂ : 7 ♀. The research covered the egg laying control, evaluation of egg quality and hatchability results. The reproduction flock was maintained in a partially-roofed aviary and fed with a full-ration granulated mixture (R-304), where 1 kg contained 18% of protein and 2800 kcal (11.7 MJ) of metabolizable energy.

The egg quality was evaluated every two weeks from the 3rd to the 13th week of the egg-laying season in pheasants. Each time 30 eggs were investigated, 24 hours after egg-laying. The egg weight (g) was determined using RADWAG WPS 360 C scales, while the ratio of the width to the length constituted the egg index (%). The egg surface

The studies were carried out in accordance with the Ethical Committee in Bydgoszcz (No. 8/2004).

area (cm^2) was calculated with the following formula (PAGANELLI *et al*. 1974):

$P_S = 4.835 \times W^{0.662}$, where W = egg weight.

Thîe egg density (g/cm^3) was determined with the solid and liquid density set using the WPS 360 C balance software. Shell deformation ($\mu m/cm^2$) was determined using a Marius apparatus, and the shell strength (kg) with the Crusher EGC 20 SW by VEIT Electronics. The shell colour was also defined (% of white) using a Shell Colour Reflectometer QCR-P by Technical Services and Supplies (TSS). The shells were weighed once they had dried at 105°C over three hours and then their thickness was measured (mm) with an electronic micrometric screw. Also the shell porosity was determined following the method described by MAZANOWSKI & ADAMSKI (2002).

The egg content traits were evaluated with a QCD apparatus by TSS. The ratio of the yolk height to its diameter expressed as a percentage constituted the yolk index. The yolk colour was evaluated based on the 15-point La Roche scale. The height of the thick albumen (H) and the egg weight (W) facilitated the calculation of Haugh units (HU) with the following formula (WILLIAMS 1992):

$HU = 100 \lg (H + 7.7 - 1.7 W^{0.37})$

The pheasant eggs used to evaluate the hatchability results were obtained every two weeks from the 3rd to the 11th week of the laying season. A total of 2087 eggs were destined for hatching in five sets. Chick hatching took place in a Bios Midi incubator at the Department of Poultry Breeding, the University of Technology and Agriculture in Bydgoszcz. The setting compartment temperature was maintained at 38°C and the relative humidity to 55 to 60%, while the hatcher – at 38°C and 60 to 75%, respectively. In all sets the percentage of fertilized eggs, dead embryos, crippled and weak chicks and the unhatched chicks as well as healthy chicks hatched from fertilized eggs were counted. Also individual percentage weight losses were calculated from set to the 21st day of incubation, and after hatching was completed the chicks were weighed and their percentage in the weight of eggs before set was calculated.

Using STATISTICA PL (2002) software, the mean values (x) and variation coefficients (v) of egg structure traits were calculated; shell and content with variance analysis and the evaluation of significant differences with the Scheffç test.

Results

The evaluation of reproductive traits in pheasants showed that the average number of eggs per laying hen over the 103-day laying season was 49. Pheasant hens in the first week reached about 7% of their egg laying ability and its peak coincided with the 6th week and accounted for 90.48% (Fig. 1).

Pheasant eggs evaluated in successive weeks of the laying season did not differ significantly in their weight and shape index; the values of both traits ranged, respectively, from 30.7 to 32.2 g and from 76.1 to 78.7% (Table 1). The egg shell deformation was the lowest at the beginning and the highest at the end of the laying season. The egg shell showed the lowest crush strength (0.7 kg) in the 3rd week of the laying season, and the highest crush strength – between the 9th and the 13th week (1.1 to 1.2 kg).

The shell weight was similar until the 11th week of the laying season and ranged from 3.0 to 3.3 g

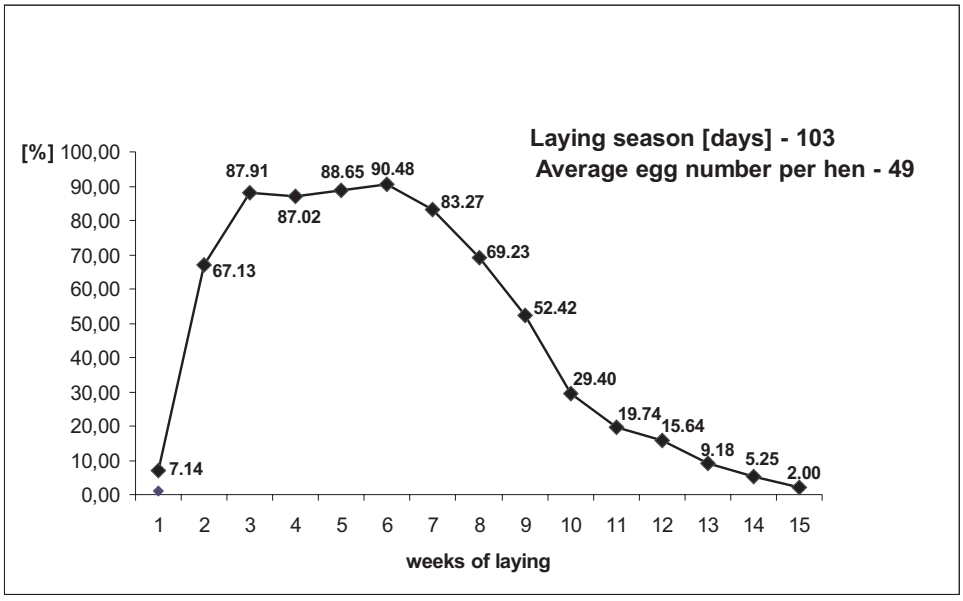

Fig 1. Curves of egg production (%) in pheasants.

Table 1

Mean values (x) and variation coefficients (v) of egg structure and eggshell traits in pheasants in successive weeks of the laying season

Trait		Week of laying						
		3	5	7	9	11	13	3-13
Egg weight (g)	x	32.2	31.4	31.0	31.0	31.8	30.7	31.3
	v	9.6	6.3	6.7	7.7	6.0	7.2	7.3
Egg shape index (%)	x	77.9	78.7	78.3	78.4	76.1	78.4	78.0
	v	4.4	3.0	3.8	4.1	6.0	4.3	4.3
Egg area surface (cm^2)	x	48.1 ^{b}	51.4 ^{a}	46.9 ^{b}	46.9 ^{b}	47.7 ^{b}	46.7 ^{b}	48.0
	v	6.4	1.5	4.5	5.3	3.98	4.7	5.6
Egg density (g/cm^3)	x	1.055 ^{c}	1.081 ^{a}	1.081 ^{a}	1.074 ^{b}	1.078 ^{ab}	1.075 ^{ab}	1.074
	v	1.1	0.5	0.5	0.8	0.5	0.5	1.1
Egg shell deformation ($\mu m/cm^2$)	x	24.5 ^{b}	26.6 ^{ab}	27.1 ^{ab}	26.7 ^{ab}	26.5 ^{ab}	28.6 ^{a}	26.6
	v	17.9	10.9	10.7	13.1	12.1	10.5	13.2
Egg shell resistance (kg)	x	0.7 ^{c}	1.0 ^{ab}	0.8 ^{bc}	1.2 ^{a}	1.1 ^{ab}	1.1 ^{ab}	1.0
	v	42.9	40.0	37.5	25.0	27.3	27.3	27.3
Egg shell weight (g)	x	3.3 ^{a}	3.1 ^{a}	3.1 ^{a}	3.1 ^{a}	3.0 ^{ab}	2.8 ^{b}	3.0
	v	12.1	9.7	9.7	12.9	6.7	10.7	13.3
Egg shell proportion (%)	x	10.2 ^{a}	9.9 ^{ab}	9.9 ^{ab}	10.0 ^{ab}	9.4 ^{bc}	9.0 ^{c}	9.7
	v	7.8	7.1	8.1	10.0	6.4	7.8	9.3
Egg shell thickness (mm)	x	0.304 ^{a}	0.303 ^{a}	0.293 ^{ab}	0.295 ^{ab}	0.283 ^{ab}	0.275 ^{b}	0.292
	v	9.9	8.9	78	10.5	8.1	8.7	9.6
Egg shell density (g/cm^3)	x	2.003	1.973	2.060	1.998	1.995	2.000	2.005
	v	6.1	7.6	6.3	5.8	9.6	5.1	6.9
Egg shell colour (% of white)	x	27.6 ^{c}	32.9 ^{bc}	1.9 ^{bc}	35.8 ^{ab}	36.3 ^{ab}	39.0 ^{a}	33.9
	v	14.8	19.4	16.6	18.7	17.9	17.9	20.9
Pore number on the whole eggshell area surface	x	4811 ^{ab}	4988 ^{a}	4465 ^{c}	4551 ^{bc}	4511 ^{bc}	4514 ^{bc}]	4643
	v	10.4	3.7	9.5	7.9	8.5	8.5	9.2

a, b, c – mean values of traits in columns with different letters differ significantly ($P \leq 0.05$).

(Table 1), and a significant decrease was recorded at the end of the laying season (2.8 g). Eggs obtained at the beginning of the laying season showed the greatest share of the shell (10.2%), and at the end – the lowest (9.0%). The thickest shell was noted in eggs at the beginning and at the peak of the laying season (0.304 and 0.303 mm), and the thinnest – at the end (0.292 mm). In successive weeks of the laying season the egg shell was lighter in colour (from 27.6 to 39.0% of white). The number of pores throughout the egg shell surface was significantly highest in the 5th week of production. The variation coefficients of the analyzed traits of the structure of egg and shell were low or average, and the greatest variation was recorded for shell strength and colour.

The weight and share of the yolk in pheasant eggs were significantly highest at the beginning of the laying season and accounted for, respectively, 11.4 g and 35.3%, and on the other dates of the evaluation, they were similar in value (Table 2). The intensity of yolk colour had increased by the 9th week of the laying season from 5.3 to 7.4 points on the La Roche scale, and at the end of production (in the 11th and the 13th week), – it was similar. The weight of the albumen did not differ significantly in successive weeks of the laying season and ranged from 17.6 to 18.8 g, while the percentage of albumen in the egg was the lowest in the 3rd and the 5th week of the laying season, and significantly higher – in successive weeks of the evaluation. The egg quality expressed in the number of Haugh units was significantly lowest at the beginning of the laying season (77.2), and the highest (86.3) – in the 11th week of production.

An egg weight loss up to the 21st day of hatching ranged from 14.1% in eggs collected in the 3rd week of the laying season to 16.9% in the 7th week of egg production (Table 3). The heaviest chicks (21.5 g) and the greatest percentage of chicks in the egg weight (66.8%) were observed from eggs collected at the beginning of the laying season. The values of these traits showed significant differences when compared with the values recorded af-

Tabele 2

Mean values (x) and variation coefficients (v) of egg content traits in pheasants in successive weeks of the laying season

Trait		Week of laying						
		3	5	7	9	11	13	3-13
Yolk								
weight (g)	x	11.4 ^{a}	10.0 ^{b}	9.7 ^{b}	9.8 ^{b}	10.0 ^{b}	9.9 ^{b}	10.1
	v	12.3	6.0	6.2	10.2	9.0	6.1	9.9
proportion (%)	x	35.3 ^{a}	35.3 ^{a}	31.4 ^{b}	31.7 ^{b}	31.5 ^{b}	32.3 ^{b}	32.4
	v	8.8	8.8	5.7	7.2	7.0	6.2	8.0
index (%)	x	47.3 ^{ab}	45.0 ^{bc}	44.1 ^{bc}	42.1 ^{c}	49.6 ^{a}	44.2 ^{bc}	45.3
	v	6.3	10.6	6.8	9.3	7.7	9.5	9.9
colour by La Roche scale (points)	x	5.3 ^{c}	6.1 ^{bc}	6.9 ^{ab}	7.4 ^{a}	7.0 ^{ab}	6.9 ^{ab}	6.6
	v	18.9	18.0	15.9	10.8	21.4	21.7	21.2
pH	x	6.22 ^{bc}	6.15 ^{c}	6.28 ^{b}	6.19 ^{bc}	6.80 ^{a}	6.20 ^{bc}	6.30
	v	1.1	0.8	2.1	1.0	2.8	1.1	3.8
Albumen								
weight (g)	x	17.6	17.6	18.2	18.1	18.8	18.0	18.0
	v	11.4	11.4	9.3	9.4	8.0	9.4	10.0
proportion (%)	x	54.5^{b}	56.4 ^{ab}	58.7 ^{a}	58.3 ^{a}	59.1 ^{a}	58.6 ^{a}	57.6
	v	6.0	13.6	3.7	4.6	3.7	3.2	7.3
height (mm)	x	4.5 ^{b}	5.4 ^{ab}	5.6 ^{a}	4.5 ^{b}	5.9 ^{a}	5.1 ^{ab}	5.2
	v	17.8	22.2	19.6	24.4	16.9	21.6	23.1
pH	x	8.94 ^{ab}	8.66 ^{cd}	8.74 ^{cd}	9.00 ^{a}	8.60 ^{d}	8.80 ^{bc}	8.79
	v	1.9	1.8	1.2	1.8	2.3	3.1	2.6
Haugh units	x	77.2 ^{b}	83.5 ^{ab}	84.7 ^{a}	77.8 ^{b}	86.3 ^{a}	82.0 ^{ab}	81.8
	v	8.2	9.9	7.9	10.3	7.2	9.1	9.6

For explanation see Table 1.

Tabele 3

Hatchability results of pheasants in successive weeks of the laying season

Trait		Week of laying					
		3	5	7	9	11	3-11
Egg weight before set (g)	x	32.2	31.8	31.5	32.0	31.3	31.7
	v	6.8	6.1	7.5	5.7	5.4	6.5
Egg weight loss from 0 to 21 day of hatch (%)	x	14.1 ^{c}	14.4 ^{bc}	16.9 ^{a}	15.3 ^{bc}	15.8 ^{ab}	15.3
	v	14.0	12.1	17.8	10.5	21.2	18.0
Fertility eggs (%)	x	92.5	94.4	91.8	81.7	74.8	88.3
Proportion to fertility eggs (%):							
dead embryos	x	8.7	9.9	7.4	15.8	18.5	11.1
unhatched chicks	x	6.2	10.1	12.6	17.1	18.2	11.4
cripple and weak chicks	x	3.5	6.1	6.5	5.9	4.9	5.2
healthy chicks	x	81.6	73.9	73.5	61.2	58.3	72.2
Day-old chick body weight (g)	x	21.5 ^{a}	20.7 ^{ab}	20.2 ^{b}	20.3 ^{b}	20.4 ^{b}	20.7
	v	8.3	7.3	10.0	8.4	7.4	8.7
Day-old chick proportion in egg weight (%)	x	66.8 ^{a}	65.3 ^{ab}	64.0 ^{b}	63.4 ^{b}	65.2 ^{b}	65.2
	v	4.5	4.3	5.2	5.8	5.1	5.2

For explanation see Table 1.

ter the laying peak. As for the other dates of the evaluation, the values of the traits analyzed were similar.

Eggs obtained in the 5th week of production showed the greatest fertility (94.4%); however, it decreased along the egg-laying season to 74.8% in the 11th week (Table 3). Despite a slightly inferior fertility of eggs collected at the beginning of the laying season (92.5%), the proportion of healthy chick hatch index value was higher (81.6%), as compared with the results obtained in the 5th week of the laying season (73.9%). The embryonic mortality was lowest for the eggs from the 7th week of the laying season and accounted for 7.4%. Throughout the laying season, the chick hatch decreased from 81.6 to 58.3%. A reverse trend was recorded for the percentage of unhatched chicks, which increased from 6.2 to 18.2%.

Discussion

The egg laying season in pheasants kept in aviaries has a duration of 70 to 100 – 120 days and is a factor determining the number of eggs per laying hen (TORGOWSKI *et al*. 1990). A similar number to the number of eggs per laying hen (49.5 to 50.4) over the 10-week control was reported by TORGOWSKI and KONTECKA (1998). Other research which involved 90 or 74 control days, concerning the effect of various feed additives (JAMROZ *et al.* 1985; MAZURKIEWICZ *et al*. 1991 b), as well as the system of bird mating and keeping (TORGOWSKI & POTKAŃSKI 1994 a) on pheasant laying production, noted a lower number of eggs per laying hen.

The present average pheasant egg weight ranged from 30.7 to 32.2 g, and the differences in evaluation of that trait for successive dates were non-significant. KRUPKA *et al*. (1984) noted that the weight of eggs laid by pheasant hens over the laying season increased, and mean values for that trait were similar to the results obtained in the present research. A lower egg weight, 29.2 and 27.9 g, respectively, was noted by AR *et al*. (1979) and SPEAKE *et al.* (1996), while a greater weight – by PAGANELLI *et al.* (1974). Similarly MRÓZ and PUDYSZAK (2000) noted a greater egg weight in the first laying season, as well as a more spherical egg shape (from 79.81 to 80.17%) than in the present experiment.

Throughout the laying season the mean values of shell deformation and its crush strength were, respectively, 26.6 μm/cm^2 and 1.0 kg. In other studies the pheasant egg shell showed a greater deformation capacity, however a similar or greater strength (KRYSTIANIAK & KONTECKA 2002; KUŹNIACKA *et al.* 2004 a; NOWACZEWSKI & KONTECKA 2002).

The shell weight over the pheasant laying season decreased from 3.3 to 2.8 g, and its thickness – from 0.304 to 0.275 mm, which must have been due to a inferior use of feed minerals, especially calcium, by intensively laying and aging birds. A decrease in shell thickness over the laying season was also noted by DEEMING and WADLAND (2002). A thinner egg shell than in the present study, was recorded by MRÓZ and PUDYSZAK (2000), and a thicker shell (308 μm) by AR *et al*. (1979).

The eggs of the beginning of the pheasant laying season showed a greater percentage of yolk and a lower percentage of albumen than at the production peak and at its end. A greater share of yolk in eggs at the laying peak (from 36 to 43%) was reported by CAREY *et al.* (1980) and by MRÓZ and PUDYSZAK (2000), while the share of albumen, according to the reports of these authors, was similar to the present results. NOWACZEWSKI and KONTECKA (2002) demonstrated a similar yolk weight in the eggs of pheasants fed without vitamin C or with 100 mg of vitamin C added. In the same research a lower albumen weight was observed than here.

Over the evaluated season, the mean value of the yolk colour scored 6.6 and was similar to that reported by KUŹNIACKA *et al.* (2004 a). Throughout the reproduction period the pheasants were fed with the same feed mixture, and so the increased yolk colour intensity must have been affected by green forage which was accessible during the production period.

Throughout the laying season, the egg quality was enhanced, which is confirmed by Haugh unit values (Table 2). Lower values of Haugh units recorded at the beginning of reproduction were connected with a greater egg weight and a lower percentage, and mainly a low height of the thick egg albumen over that period.

The egg weight losses up to the 21st day of hatch were lowest at the initial pheasant laying period (14.1 and 14.4%), while the chick weight over that period was greatest, which could have been due to a slightly greater weight of eggs over that period. In another experiment (KUŹNIACKA *et al.* 2004 b) involving an analysis of pheasant egg weight losses during hatching, the lowest percentage weight losses in eggs obtained at the beginning of the laying season were also recorded, and the highest – from the eggs from the production peak. MRÓZ *et al.* (2003) noted lower percentage egg weight losses during hatching, at a similar egg weight before set. The average chick weight recorded in the present research was 20.7 g, and its share, as compared with the egg weight – 65.2%. Higher values of both traits, 22.3 g and 71.6%, re-

spectively, were recorded by MRÓZ *et al.* (2003), while the mean chick weight reported by WILSON (1991) was similar (20.9 g), and the percentage of the chicks to the egg weight before set was lower (61.9%).

Inferior results of the chick hatch from the eggs obtained from the end of the laying season in the present research may be due to deteriorated egg shell quality, which is revealed by a lower shell thickness of the egg in that period (Table 1). This is confirmed by DEEMING and WADLAND (2002), who recorded deteriorated pheasant egg shell quality during the laying season, and, as a result, a lower percentage of egg fertility and chick hatch. In yet another experiment the same authors (DEEMING and WADLAND 2001) also demonstrated a greater mortality of pheasant embryos during the laying season, however it was non-significant.

KOUBEK (1989) showed percentages of egg fertility similar to those recorded in the present research (89.8 to 90.4%) and a lower or similar percentage of chick hatch from fertilized eggs (67.0 to 75.2%). TORGOWSKI and KONTECKA (1998) also noted a similar percentage of egg fertility, yet a lower percentage of crippled and weak chicks, as compared with those evaluated in the present research. MAZURKIEWICZ *et al.* (1991), investigating reproductive traits in pheasants fed differently, showed a wide range of the egg fertility results (79.0 to 92.1%) and chick hatch from fertile eggs (from 63.8 to 78.9%).

To sum up, pheasant eggs did not differ significantly in their weight and shape throughout the laying season. Over the laying season the shell thickness decreased, while its capacity for deformation and the crush strength were greatest at the end of the laying season. The share of yolk in the egg was the greatest at the beginning of the laying season in pheasants, while at the laying peak and at the end of the laying season the content of albumen in the egg and the egg quality increased, expressed in Haugh units. The best chick hatch results were recorded for the eggs collected at the initiation of the laying season and about the 5th week of production.

References

AR A., RAHN H., PAGANELLI C. V. 1979. The avian egg: mass and strength. The Condor **81**: 331-337.

BENTON JR. C. E., BRAKE J. 1996. The effect of broiler breeder flock age and length of egg storage on egg albumen during early incubation. Poult. Sci. **9**: 1069-1075.

CAREY C., RAHN H., PARISI P. 1980. Calories, water, lipid and yolk in avian eggs. The Condor **82**: 335-343.

DEEMING D. C., WADLAND D. 2001. Observations on the patterns of embryonic mortality over laying season of pheasants. Br. Poult. Sci. **42**: 569-573.

DEEMING D. C., WADLAND D. 2002. Influence of mating sex ratio in commercial pheasant flocks on bird health and the production, fertility, and hatchability of eggs. Br. Poult. Sci. **43**: 16-23.

DOBRZAŃSKI Z., BEDNARCZYK M. 1988. A radiation temperature and changes in turkey egg weight during hatching. Med. Wet. **44**: 693-696. (In Polish).

JAMROZ D., GIEBEL O., MAZURKIEWICZ M. 1985. Egg production in pheasants fed pheasant feeds composed of native components enriched with Ca, P and NaCl. Med. Wet. **41**: 504-506. (In Polish).

JETHON W., MAZURKIEWICZ M. 1982. Zootechnic and veterinary aspects of hatch efficiency in pheasant chickens. Med. Wet. **38**: 186-188. (In Polish).

KOUBEK P. 1989. Occupation and depredation of artificial pheasant nests. Folia zool. **38**: 109-118.

KRUPKA J., DZIEDZIC R., DROZD L. 1984. The weight of pheasant eggs during egg production. Proc. 5th Poultry Symp. Zootechnic & Veterinary Aspects Pheasants, Pigeons, Quails and Others Game Birds Breeding Wrocław 1984: 79-83. (In Polish).

KRYSTIANIAK S., KONTECKA H. 2002. Eggshell quality depending on its colour and laying period of pheasants. Nauk. Zoot. (Suppl.) **16**: 131-135. (In Polish).

KUŹNIACKA J., ADAMSKI M., BERNACKI Z. 2004 a. Comparison of morphological composition and physical traits of eggs in different bird species. Prace Wydz. Nauk Przyrod. BTN, ser. B, **53**: 139-144. (In Polish).

KUŹNIACKA J., BERNACKI Z., ADAMSKI M. 2004 b. Hatchability of common pheasant and partridge eggs according to the term of laying season. Zesz. Nauk. PTZ Prz. Hod. **72**: 57-67. (In Polish).

MAZANOWASKI A., ADAMSKI M. 2002. Evaluation of reproductive traits and egg quality in Astra G geese during the first reproductive period. Ann. Anim. Sci. **2**: 67-78.

MAZURKIEWICZ M., JAMROZ D., BARTCZAK R., GAWEŁ A., NICPOŃ J. 1991. The influence of livex on healthy state and productivity of pheasants. Med. Wet. **47**: 493-496. (In Polish).

MEIJERHOF R. 1992. Pre-incubation holding of hatching eggs. World's Poult. Sci. J. **48**: 57-68.

MRÓZ E., PUDYSZAK K. 2000. Pheasant egg shell colour and its effect on hatchability. Zesz. Nauk. PTZ Prz. Hod. **49**: 459-466. (In Polish).

MRÓZ E., MICHALAK K., PUDYSZAK K. 2003. Effect of genotype of pheasants and colour of egg shells on hatchability. Zesz. Nauk. PTZ Prz. Hod. **68**: 39-44. (In Polish).

NARUSHIN V. G., ROMANOV M. N. 2002. Egg physical characteristics and hatchability. World's Poult. Sci. J. **58**: 297-303.

NOWACZEWSKI S., KONTECKA H. 2002. The effect of vitamin C supplementation on some characteristics of hatching eggs of pheasants. Rocz. Nauk. Zoot. Suppl. **16**: 257-261. (In Polish).

PAGANELLI C. V., OLSZOWKA A., AR A. 1974. The avian egg: surface area, volume, and density. The Condor **76**: 319-325.

SPEAKE B. K., MCCARTNEY R. J., FEAST M., MALDJIAN A., NOBLE R. C. 1996. The relationship between the fatty acid profiles of the yolk and the embryonic tissue lipids: a comparison between the lesser black backed gull (*Larus fuscus*) and the pheasant (*Phasianus colchicus*). Comp. Biochem. Physiol. B **115**: 493-499.

STATISTICA PL. USER'S GUIDE. 2002. Version 6, series 1101.

TORGOWSKI J., POTKAŃSKI A., MUSIAŁ K. 1990. Effect of different management condition of pheasant reproductive flock on production results. Rocz. AR Poznań, Zoot. **214**: 91-97. (In Polish).

TORGOWSKI J., KONTECKA H. 1998. Effect of the addition of vitamin C and Iron to pheasant (*Phasianus colchicus*) diets on their production and haematological indices. Rocz. AR Poznań, Zoot. **302**: 235-242. (In Polish).

WILLIAMS K. C. 1992. Some factors affecting albumen quality with particular reference to Haugh unit score. World's Poult. Sci. J. **48**: 5-16.

WILSON H. R. 1991. Interrelationships of egg size, chick size, posthatching growth and hatchability. World's Poult. Sci. J. **47**: 5-20.