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Embryo mortality and poult quality depend on the shell structure of turkey hatching eggs

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An investigation was conducted between 7 and 12 weeks of the laying season, on hatching eggs of heavy-type turkeys, differing in shell surface characteristics (eggs with good quality shells, rough-shelled eggs and eggs without shell surface pigmentation). Six incubation series were carried out. The percentage of eggs containing dead embryos was determined on consecutive days of incubation and the percentage of eggs containing living unhatched embryos was determined on day 28 of incubation. Moreover, peaks of embryo mortality and periods of increased embryo mortality rates, as well as the hatching rate of fertilized eggs were also established. The weight and body conformation of poults were determined after incubation, on an individual basis.

Peaks of embryo mortality were observed on day 3 in the group of eggs with rough shells and on day 24 in the group of eggs with shells of normal quality. Increased embryo mortality rates were recorded in all groups of eggs between day 2 and 5 and between day 23 and 25 of incubation, as well as on day 8 in the group of eggs without shell surface pigmentation. After 2 and 3 weeks of incubation, embryo mortality rates in the groups of eggs with rough shells and eggs without shell pigmentation were higher by 7.5 and 18.5%, respectively, in comparison to the group of eggs with normal quality shells (8.0%) The highest hatching rate (92.54%) was noted in the group of eggs with shells of good quality. Differences in egg weight had a significant effect ($P \leq 0.01$) on poult weight, which ranged from 62.6 g in the groups of eggs with normal quality and rough shells to 60.8 g in the group of eggs without shell surface pigmentation. Poults that hatched from eggs with shells of good quality had lower relative body weight (68.30 *vs*. 68.67 and 69.45%, $P \leq 0.01$). The most poults ($P \leq 0.01$) with anatomical abnormalities hatched from eggs without shell surface pigmentation while the fewest – from eggs with good quality shells (71.65 *vs* 45.25%). Poults with anatomical abnormalities of the umbilicus and plumage dominated among birds with physical defects. The relationship between eggshell structure characteristics and physical defects of poults was not confirmed statistically.

KEY WORDS: eggshell / embryo mortality / poult quality / turkey

The reasons for embryo mortality during incubation are complex. In most cases, they are related to inadequate incubation technologies rather than to poor egg quality. However, in order to increase overall incubation results, an improvement in incubation technologies must be accompanied by an improvement in the quality of hatching eggs [Taylor 1999, Malec *et al*. 2002].

The correlation between eggshell surface and egg hatchability in turkeys is generally known. Thickened areas of shell mass and the lack of shell pigmentation are quite common in turkeys. However, despite their lower hatchability, such eggs are not eliminated prior to incubation [Mróz 1998, Mróz and Faruga 2000, Mróz *et al*. 2007]. Another problem is the egg weight increase during the laying season. More poults are hatched from eggs with lower weight and of a lower albumen content [Faruga et al. 1996, Mróz et al. 2002]. Similar relationships have also been reported for chickens [Mauldin *et al*. 1996, Malec 1999, Niedziółka *et al*. 2001, Malec *et al*. 2002].

Embryo mortality is high or increased at some stages of incubation, whereas at other stages it remains at a low level. In turkeys the first peak of embryo mortality is observed between the incubation day 3 and 6, and the second between day 26 and 28. At the beginning of incubation the number of dead embryos is affected primarily by egg quality [Borzemska 1978, Mróz 1998, Christensen 2001, Mróz *et al*. 2007]. Increased embryo mortality rates between day 7 and 25 indicate poor sanitary conditions prior to or during incubation [Borzemska 1978, Malec *et al*. 1999, Malec *et al*. 2002]. Late embryo mortality in the hatching unit increases by 3.0 to 5.6% along with an increase in egg weight and egg quality deterioration [Christensen *et al*. 1996, Mróz *et al*. 2007].

The yolk content of an egg, its energy value and water percentage determine poult quality [Tazawa and Whittow 2000]. The structure and chemical composition of all egg parts undergo changes during the laying season [Applegate and Lilburn 1996, Faruga *et al*. 1996]. An increase in egg weight over this period results in an increase in the birth weight of poults, which limits their mobility and contributes to the occurrence of umbilical and leg defects [Orłowska and Mróz 2006]. The shape, structure and pigmentation of eggshells affect the weight and body conformation of day-old chickens [Decuypere *et al*. 2001, Tona *et al*. 2003]. In turkeys, this relationship has not been confirmed experimentally. No data on the physiological phenomena taking place in the uterus during the formation of shells with areas of thickened mass and without pigmentation are available, either.

Studies on the body conformation of poults, conducted in Poland to date, have focused on their posture, liveability and body weight, the structure of head, neck, backbone, umbilicus, yolk sac, legs and plumage [Dziaczkowska 1980], as well as on the most common physical defects, including anatomical abnormalities of the umbilicus, plumage and legs [Mróz *et al*. 2004]. Generally, the quality of artificially hatched poults and chicks is not satisfactory. No physical defects are usually found in 31.5 to 57.9% of poults and in 48 to 62% of chicks [Tona *et al*. 2003, Mróz *et al*. 2004, Orłowska and Mróz 2006]. Certain anomalies do not eliminate birds from farming, but decrease their value [Mauldin *et al*. 1996, Tona *et al*. 2003].

The aim of the present study was to determine embryo mortality rates and the quality of poults that hatched from eggs differing in shell structure.

Material and methods

The material comprised hatching eggs of heavy-type turkeys, laid between 7 and 12 weeks of the laying season. Eggs differed in shell surface characteristics and represented three groups, *i.e*. eggs with good quality shells, rough-shelled eggs and eggs without shell surface pigmentation. Eggs were collected randomly at one-week intervals (Tab. 1, Photo 1). Each egg was weighed individually, accurate to 0.1 g. Six

Table 1. Characteristics of turkey egg groups [Mróz 1998]

Eggshell characteristics	Eggshell structure		
	normal-quality shell	rough shell	shell without pigmentation
Surface	cream, smooth, shiny	light-cream, thickened areas of shell mass of various size and shape	white, smooth, shiny
Pigmentation	brown, round, oval or elongated spots over the entire surface area	brown or gray, in the form of circles around the thickened areas, as well as round, oval or elongated spots; no pigmentation over some parts of the eggshell surface	invisible over the entire surface area

incubation series were carried out in PETERSIME incubators (6 series × 3 groups × 126 eggs = 2268 eggs). Eggs containing dead embryos were eliminated during incubation, and those containing living unhatched embryos were eliminated at the end of incubation. The total numbers of eggs referred to as incubation losses were 468, including 73 in the group of eggs with normal quality shells, 135 in the group of rough-shelled eggs and 260 in eggs without shell surface pigmentation. The day of embryo death was determined using the key proposed by Dziaczkowska and Faruga [1983]. The percentage of embryos that died on consecutive days of incubation and the percentage of unhatched eggs were calculated in relation to total incubation losses. Peaks of embryo mortality and periods of increased embryo mortality rates were assumed to be > 10 and 5-10%, respectively. The hatching rate of fertilized eggs was calculated at the completion of incubation. Within 2 hours after hatching, each bird was weighed (accurate to 0.1 g). The relative body weights of poults were determined using a universally accepted formula:

$$\text{relative body weight of a poult (\%)} = \frac{\text{individual body weight (g)}}{\text{mean egg weight in the analysed group (g)}} 100\%$$

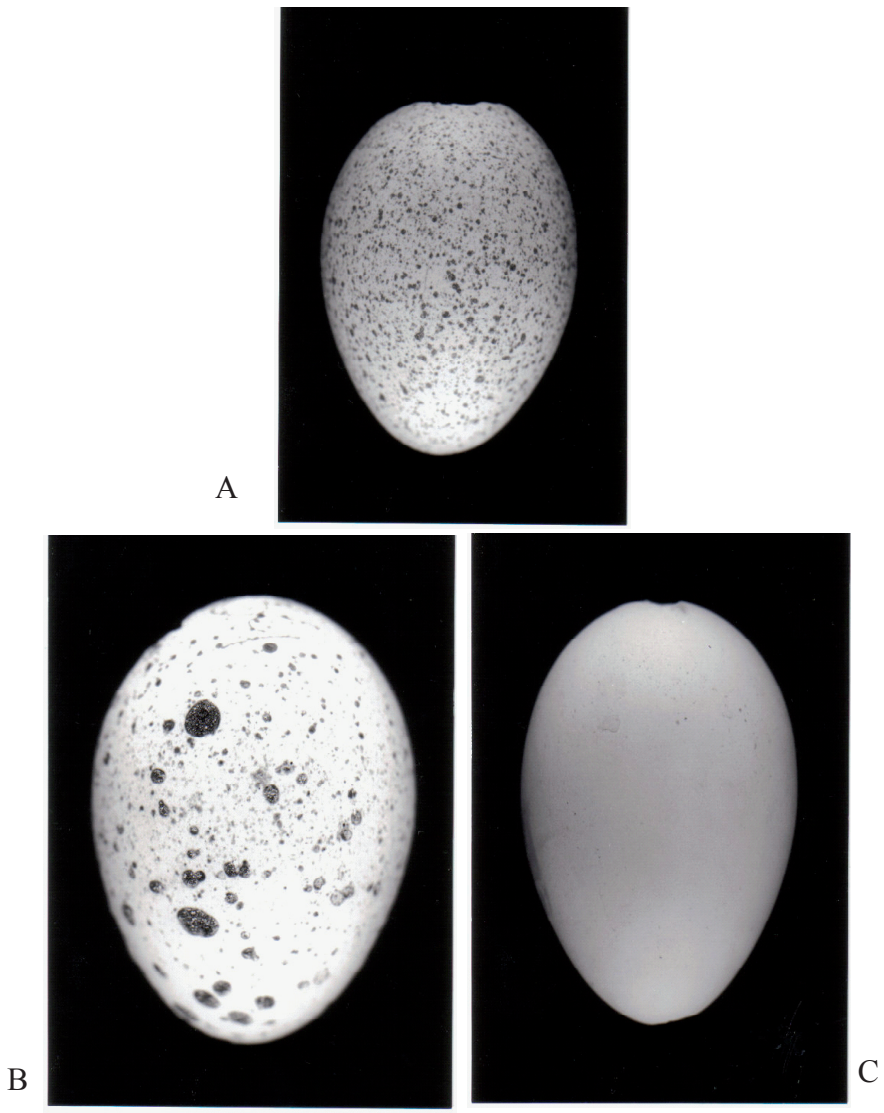

Photo 1. A – regular shell, B – granulation shell, C – shell without pigmentation.

The body conformation of hatchlings was estimated by previously verified methods (Tab. 2). The percentages of poults with and without physical defects were calculated. Some birds had several defects, so the percentages exceeded 100. The numerical data on egg weight, body weights of poults, hatchability and body conformation of newly-

Table 2. Criteria for evaluation of the body conformation of newly-hatched poults [Dziaczkowska 1980]

Specification	Body conformation of newly-hatched poults	
	normal	abnormal
Motor activity	able to walk, wings held tight to the body	drowsy, lethargic, sitting on their haunches, dropped wings
Head, beak	shape typical of turkeys	thickened areas around the eyes and neck, beaks and heads bent to one side
Eyes	shiny, lively, round	closed, narrow, eyelids stuck together
Down	dry, clean, complete plumage	wet, caked with faeces or covered with albumen, thick, incomplete plumage
Umbilicus	body-coloured, healed	black crust, long umbilical cord
Yolk sac	invisible, soft abdomen	swelling in the umbilical region, yolk sac incompletely retracted, wet down in the umbilical region
Legs	skin-coloured, straight shanks and toes, normal posture	twisted legs, swollen feet, congestion, abnormal posture

hatched birds were verified statistically based on means and coefficients of variation, and the significance of differences was determined by Duncan's test.

Results and discussion

The first mortality peak was observed on day 3 in the group of rough-shelled eggs and on day 24 in the group of eggs with normal quality shells. No peaks of embryo mortality were observed in the group of eggs without shell pigmentation (Fig. 1). Increased embryo mortality rates were recorded in all groups of eggs between day 2 and 5 and between day 23 and 25 of incubation, as well as on day 8 in the group of eggs without shell surface pigmentation. Incubation losses due to unhatched eggs were considerable in all groups, reaching the highest level in the group of eggs with normal quality shells. Embryo mortality varied between groups in successive weeks of incubation. After 2 and 3 weeks, higher embryo mortality rates were recorded in groups of eggs with rough shells and eggs without shell pigmentation, compared to the group of eggs with good quality shells, while in the other weeks they were lower in these groups (Tab. 3).

The first peak of embryo mortality confirmed the worse quality of rough-shelled eggs, in comparison with the remaining two groups. Increased embryo mortality

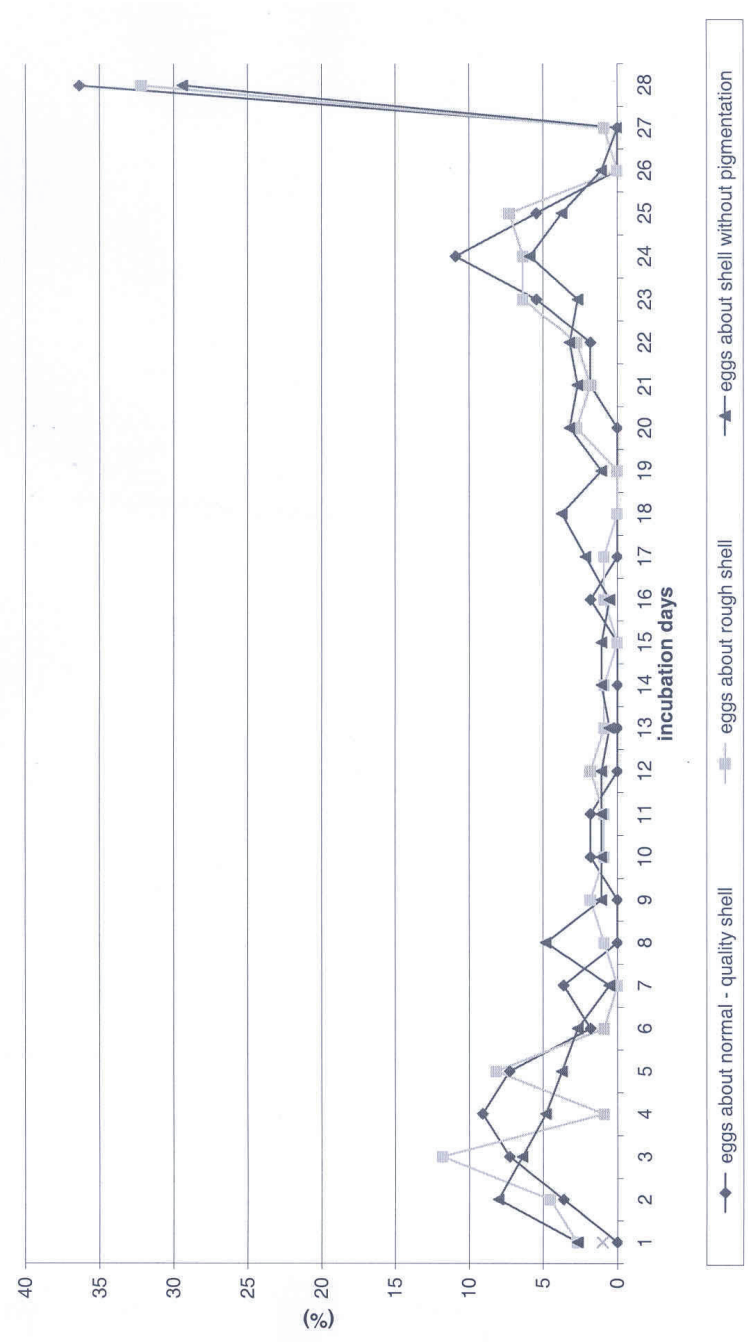

Fig. 1. Embryos mortality and unhatched poults in incubation days 1-28.

Table 3. Dead embryos and unhatched eggs (means)

Item	Eggshell structure		
	normal-quality shell	rough shell	shell without pigmentation
Dead embryos (%)	63.6	67.9	70.3
Including			
week 1 of incubation	31.0	29.0	28.5
week 2 of incubation	4.0	9.0	11.0
week 3 of incubation	4.0	6.5	15.5
week 4 of incubation	24.6	23.4	15.3
Unhatched eggs (%)	36.4	32.1	29.7

% – in relation to total dead embryos and unhatched eggs.

observed over the other periods indicated a lower biological value of eggs without shell pigmentation and rough-shelled eggs, reported previously [Borzemska 1978, Malec *et al*. 1996, Mróz 1998, Niedziółka *et al*. 2001, Mróz *et al*. 2002]. The high percentage of unhatched embryos in all egg groups suggests an extended incubation period, characteristic of heavy-type turkeys [Borzemska 1978, Mróz 1998, Taylor 1999, Mróz *et al*. 2002a, 2002b].

Eggs with shells of good quality were found to be the heaviest. Egg weight affected the body weights of poults. The birds that hatched from eggs with normal quality and rough shells were significantly heavier than those that hatched from eggs with non-pigmented shell surface ($P \leq 0.01$). The relative body weight of poults and variation within this trait were the lowest in the group of eggs with shells of normal quality (Tab. 4).

Turkey farming is dominated by heavy-type birds characterized by high hatching weight, ranging from 61.2 to 69.7 g [Christensen and Donaldson 1992, Applegate and Lilburn 1996, Orłowska and Mróz 2006]. According to Christensen *et al*. [1996], the body weights of newly-hatched poults are lower, ranging from 46.4 to 59.0 g, depending on egg weight and the age of hens. Generally, heavier eggs produce heavier birds (by 5%) – Shanawany [1987], Christensen *et al*. [1996]. The body weight of poults in the current study were comparable to those of poults of the strains BUT, Hybrid and Nicholas, which vary from 60.1 to 63.1 g [Christensen and Donaldson 1992].

The higher relative body weight of poults that hatched from rough-shelled eggs and eggs without shell pigmentation could result from a higher free water content of their bodies. Relative body weight of poults exceeding 70 g was recorded in the case of very big eggs, laid by hens older than 50 weeks [Shanawany 1987, Applegate and Lilburn 1996, Mróz and Pudyszak 1997]. The body weight of a poult may also depend on the exact time that passed from hatching, so it would be difficult to compare the current results with those obtained by other authors.

Table 4. Mean weight of hatching eggs and mean body weight of newly-hatched poults

Item		Eggshell structure		
		normal-quality shell	rough shell	shell without pigmentation
Egg weight before incubation (g)	mean	91.8^{A}	90.3 ^{B}	88.5 ^{C}
	V%	6.37	6.83	8.13
Weight of poults:				
absolute (g)	mean	62.6^{A}	62.6^{A}	60.8^{B}
	V%	7.16	7.52	8.51
relative (%)	mean	68.30^{B}	69.45^{A}	68.67^{A}
	V%	6.59	7.10	7.96

% – in relation to mean egg weight
Mean values in lines followed by different letters differ significantly at P≤0.01.

Table 5. Characteristics of hatchability and conformation of newly hatched poults

Item		Eggshell structure		
		normal-quality shell	rough shell	shell without pigmentation
Hatching rate of fertilized eggs (%)	mean	92.54^{A}	85.08^{A}	72.93^{B}
	V%	4.69	6.47	11.46
Number of examined poults		681	620	505
Poults without physical defects (%)	mean	54.73^{Aa}	40.67^{b}	28.33^{B}
	V%	18.14	27.35	41.46
Poults with physical defects (%)	mean	45.25^{Bb}	59.31^{a}	71.65^{A}
	V%	21.95	18.75	16.40
incl. weak, sluggish birds (%)	mean	3.52	3.87	4.95
	V%	2.34	6.61	6.80
Head and beak defects (%)		0.0	0.0	0.0
Eye defects (%)		0.0	0.0	0.0
Plumage defects (%)	mean	13.11	19.99	26.78
	V%	42.37	47.65	46.95
Umbilical defects (%)	mean	84.25	85.98	82.96
	V%	6.87	8.25	6.98
black crust (%)	mean	68.47	73.93	70.37
	V%	14.94	10.70	15.15
long umbilical cord (%)	mean	15.78	12.05	12.59
	V%	49.96	36.06	54.23
Yolk sac defects (%)	mean	2.52	0.62	2.96
	V%	6.40	7.12	6.50
Leg defects (%)	mean	4.50	4.25	4.16
	V%	31.99	72.82	49.96

Means in lines followed by different letters differ significantly at: small letters – P≤0.05; capitals – P≤0.01.

Photo 2. A – enlargement and wet plumage near umbilicus. B – umbilical defect – black crust; C – leg defect.

The highest hatching rate (P≤0.01) was noted in the group of eggs with good quality shells, while the lowest in the group of eggs without shell pigmentation (Tab. 5). Many poults had anatomical abnormalities, and the fewest birds with physical defects hatched from eggs with good quality shells (P≤0.01; Tab. 5). No head, beak or eye defects were observed in poults. The most poults that showed decreased moving activity hatched from eggs without shell pigmentation. In this group, and in the group of rough-shelled eggs, more poults had wet down, caked with faeces or covered with albumen remains (Photo 2). Anatomical abnormalities of the umbilicus were the most common physical defects of poults. Many of them had a black crust on the umbilicus (Photo 2). Fewer had long umbilical cords. Incompletely retracted yolk sacs and leg defects were observed in a small number of poults (Tab. 5).

Increased embryo mortality rates at 2 and 3 weeks of incubation affected poorer overall incubation results. The quality of hatchlings was unsatisfactory. The present study confirmed previous speculations that eggs with irregular shell structure produce more poults with physical defects than normal quality eggs. A high percentage of poults with umbilical defects was also

recorded previously [Mróz *et al*. 2004, Orłowska and Mróz 2006]. This could be related to metabolic heat production by developing embryos. Heat excess accelerates hatching and causes umbilical cord residuals to be left with blood [Taylor 1999]. According to other authors, this phenomenon – never occurring under natural conditions – is caused by inadequate gas exchange across the eggshell. The percentage of poults with incompletely retracted yolk sacs, similar in all groups, was not related to eggshell quality. Plumage abnormalities, observed primarily in poults that hatched from eggs with irregular shells, resulted from a longer incubation and hatching period. Plumage defects, at a similar level in groups of eggs with regular and irregular shells (approx. 13%), were also recorded earlier by Mróz *et al*. 2004, 2006. The percentage of poults with umbilical defects was higher (88-97%) in the case of eggs stored for a longer time prior to incubation, and lower (47 -52%) in that of eggs stored for no longer than 7 days [Mróz *et al*. 2004, Orłowska and Mróz 2006].

Despite considerable inter-group differences, the present study did not confirm statistically the relationship between eggshell structure characteristics and physical defects of poults. The problem requires further investigation.

It may be concluded that eggs without shell pigmentation as well as rough-shelled eggs have a lower biological (hatching) value compared to eggs with normal quality shells. On day 8 and after 2 and 3 weeks of incubation the latter showed the lower embryo mortality rates. The highest hatching rate (92.54%) was noted in the group of eggs with good quality shells and was by 7.46 and 19.61% higher than in the groups of eggs with rough shells and eggs without shell pigmentation, respectively.

In all groups, considerable losses were caused by poults unhatched until 28 days of incubation. Poults that hatched from eggs without shell surface pigmentation were lighter, had higher relative body weights and more morphological defects, compared to poults that hatched from eggs with normal quality and rough shells. The relationship between eggshell structure characteristics and physical defects of poults was not confirmed statistically.

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Jakość skorupy indyczych jaj wylęgowych a śmiertelność zarodków i jakość wyklutych piskląt

Streszczenie

Badania prowadzono na jajach o skorupie prawidłowej bądź ziarnistej lub pozbawionej pigmentu, zniesionych między 7 a 12 tygodniem nieśności indyków typu ciężkiego.. Przeprowadzono 6 lęgów. Określono procent zarodków zamarłych w kolejnych dniach inkubacji, a w 28 dobie lęgu określono procent indycząt niewyklutych. Ustalono szczyty zamierania zarodków i okresy ich podwyższonej śmiertelności oraz obliczono wylęgowość indycząt z jaj zapłodnionych. Po wylęgu skontrolowano indywidualnie masę i budowę indycząt.

Szczyty śmiertelności zarodków stwierdzono w grupach jaj o skorupie ziarnistej w 3 dobie, a z prawidłową – w 24 dobie inkubacji. Podwyższoną śmiertelnością charakteryzowały się zarodki ze wszystkich grup jaj między 2 a 5 i 23 a 25 dobą, a zarodki z jaj o skorupie pozbawionej pigmentu – dodatkowo w 8 dobie inkubacji. W 2 i 3 tygodniu inkubacji śmiertelność zarodków z jaj ze skorupami ziarnistymi i pozbawionymi pigmentu była większa o 7,5 i 18,5% w porównaniu z jajami o skorupie prawidłowej – 8,0%. Wylęgowość była największa w grupie jaj o skorupie prawidłowej – 92,54%. Zróżnicowana masa badanych grup jaj wpłynęła istotnie (P≤0,01) na masę ciała jednodniowych indycząt, która wahała się od 62,6g w grupach ze skorupą prawidłową i ziarnistą do 60,8g w grupie o skorupie pozbawionej pigmentu. Indyczęta wylężone z jaj o prawidłowej skorupie miały mniejszą względną masę ciała – 68,30% – w porównaniu z indyczętami pozostałych grup – 68,67 i 69,45% (P≤0,01). Najwięcej indycząt (P≤0,01) z wadami budowy pochodziło z jaj o skorupie bez pigmentu – 71,65%, a najmniej z jaj o skorupie prawidłowej – 45,25%. Najczęstszymi wadami budowy indycząt były wady pępka i upierzenia. Związek budowy skorupy z rodzajem wad budowy ciała indycząt nie został potwierdzony statystycznie.