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REVIEW ARTICLE

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EVALUATION OF EGGS IN TERMS OF HATCHING CAPABILITY

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ABSTRACT

Hatching results depend on the biological value of the eggs and on factors affecting the development of the embryo during incubation, as well as the conditions in which the eggs are kept between being laid and being placed in the incubator. Numerous studies conducted in Poland and other countries indicate that the suitability of eggs for hatching and their biological value are determined by genetic factors (mainly the origin of the birds) as well as environmental factors. Hatching eggs are primarily subject to assessment of external characteristics. The most important characteristics determining whether eggs are suitable for incubation are their weight, shape, structure and eggshell condition, as proper structure is a fundamental condition of satisfactory hatching results. Egg weight is highly dependent on genetic factors, as evidenced by the high heritability coefficients of this trait. Assessment of the hatching eggs weight is important because the weight of the hatchling is positively correlated with the egg weight. Works clearly confirm the effect of genotype on the physicochemical features of eggs, including the weight of the egg, yolk and eggshell. The eggshell plays an extremely important role in eggs used for reproduction. Eggshell quality traits are determined by both genotype and non-genetic factors, including the layer hen age and the diet, particularly the amount, form and availability of calcium. An important factor affecting the hatching process and quality of chicks is egg storage.

Key words: structure, egg quality, hatching, genetic factors

INTRODUCTION

Eggs intended for hatching are obtained from poultry breeding flocks, and the requirements for these eggs are much higher than for table eggs. Hatching results depend on the biological value of the eggs and on factors affecting the development of the embryo during incubation, as well as the conditions in which the eggs are kept between being laid and being placed in the incubator. Numerous studies conducted in Poland and other countries indicate that the suitability of eggs for hatching and their biological value are determined by genetic factors (mainly the origin of the birds) as well as environmental factors [Spiller et al. 2003, Boruta and Pijarska 2004, Gierzilov 2004, Tilki and Inal 2004, Malec 2005, Biesiada-Drzazga 2009]. Embryonic development and hatching results depend on both the external and internal characteristics of hatching eggs. The physical characteristics of eggs and the value of individual features of their structure are adapted to the fundamental biological function of the egg, i.e. proper development of the embryo in specific environmental conditions [Węsierska 2006, Onagbesan et al. 2007]. Hatching eggs are primarily subject to assessment of external characteristics. The most important characteristics determining whether eggs are suitable for incubation are their weight, egg shape, structure and eggshell condition, as proper structure is a fundamental condition of satisfactory hatching results.

EGG WEIGHT

As early as the 1980s and 1990s, research was carried out on the effect of the egg weight and egg shape index on hatching rates [e.g. Szczerbińska 1997, Christensen et al. 2001, Biesiada-Drzazga and Janocha 2009]. In addition, Pijarska [2005], Rachwał [2008, 2011] and Reijrink et al. [2008] studied the effect of egg weight on the weight of hatchlings, showing a significant impact of this trait on hatching of healthy chicks. The generally accepted measure of egg size is their weight. Egg weight is highly de-

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pendent on genetic factors, as evidenced by the high heritability coefficients of this trait (h^2 = 0.4–0.6) for various populations of chickens [Zhang et al. 2005].

Nys [2000] emphasizes that egg weight depends on genetic (h^2 = 0.4–0.6) and environmental factors, mainly temperature and diet. The egg size is affected by the age and weight of the hen. Egg weight is primarily determined by the weight of the albumen, and to a lesser extent by the yolk and eggshell [Bednarczyk 1991]. Many studies have shown that the best hatching results are obtained from medium-weight eggs. Eggs of inappropriate weight usually have an abnormal yolk-to-white ratio. Water can also evaporate more easily from small eggs, leading to excessive density of their contents and impeding nutrient absorption by the embryo.

Assessment of the weight of hatching eggs is important because the weight of the hatchling is positively correlated with the egg weight. The effect of egg weight on hatchling weight has been demonstrated in other experiments [Yannakopoulos and Tserveni-Gousi 1987, Pijarska 2005].

Yolk weight is a crucial factor affecting hatchability. In heavier eggs, the share of yolk may be smaller than in eggs of low or medium weight, which can negatively affect embryonic development [Huse and Kuźniacka 2015]. Any change in the proportions of the morphological components of the egg (eggshell, white and yolk) can reduce hatching rates [Michalak and Mróz 2003].

The egg weight is determined more by the body weight of the bird than by its laying capacity. The relationship between egg weight and the body weight of the layer is primarily a function of the secretory capacity of the oviduct magnum, which in turn depends on the surface area of the oviduct [Bednarczyk 1991]. Another feature affecting egg weight is the laying rate, which determines the time the egg is in the oviduct. Increased egg weight and size are associated with the ongoing growth of the bird and development of its reproductive system, and mainly with the increased rate of oocyte growth and albumen secretion in the magnum [Adamski 2008]. Laid eggs may be very small, below 48 g, or very large, above 73 g. Very small eggs may appear when the birds first begin laying, indicating that the flock is not sufficiently mature. Large eggs weighing over 73 g may have two yolks. Double-yolk eggs are formed when two ovarian follicles burst simultaneously in the ovary and two yolks fall into the oviduct. They are then surrounded by a common albumen layer and eggshell. Sokołowicz and Krawczyk [2004] have shown that one of the factors influencing egg weight is the laying rate. A lower laying rate allows birds to store more of the material needed to build and increase egg weight. Calik [2002], analysing the relationship between egg weight and body weight of hens from strains H33, M55 and V44, confirmed the close relationship between body weight and egg weight, as reduced weight of layers was accompanied by a decrease in egg weight, and conversely, heavier hens usually laid heavier eggs.

EGG SHAPE

The shape of hatching eggs, defined by the egg shape index, is significant, as proper egg shape is a condition for normal development of embryos and chicks during incubation. Better hatching rates are widely believed to be obtained from round eggs. Research by Pakulska et al. [2003] showed better fertilization and hatching rates from more rounded goose eggs.

According to Szczerbińska [1997], the egg shape affects hatching rates because it determines the positioning of the embryo. Deterioration in hatching occurs when the egg shape index significantly deviates from the average for the species. The author states that elongated, flattened or spherical eggs pose a problem when they are placed on the incubator tray. In the case of spherical eggs it can be difficult to determine which is the blunt end, so they may be placed in the incubator with the air cell facing downward, thus reducing the chance of hatching. In elongated eggs, on the other hand, the embryo may be incorrectly positioned when it shifts from a horizontal to a vertical position.

MORPHOLOGY AND GENETICS

In addition to the weight and shape of eggs, hatching rates also depend largely on the quality characteristics of eggs, including their morphological composition [Kuchida et al. 1999]. The egg of all species consists of the same basic components, in a characteristic layered arrangement [Huse and Kuźniacka 2015]. Studies of the morphological components and physical characteristics of eggs are relatively numerous [Silversides and Scott 2001, Suk and Park 2001, Abanikannda and Leigh 2007, Abanikannda et al. 2007]. Works by Silversides and Budgell [2004] and by Czaja and Gornowicz [2006] clearly confirm the effect of genotype on the physicochemical features of eggs, including the weight of the egg, yolk and eggshell. Narushin and Romanov [2002], Hocking et al. [2003], Basmacioglu and Ergul [2005], Czaja and Gornowicz [2006], Krawczyk [2009], have also shown that genotype influences egg quality.

THE ROLE OF THE EGGSHELL

The shell plays an extremely important role in eggs used for reproduction. Eggshell quality traits are determined by both genotype and non-genetic factors, including the age of the layer and the diet, particularly the amount, form and availability of calcium [Scott and Silversides 2000, Silversides and Scott 2001]. Calik [2011], in an as-

sessment of the quality of eggs of six strains of laying hens, also found that the origin and age of hens affected the quality features of eggs and their shells. Hocking et al. [2003], Roberts [2004], Biesiada-Drzazga and Janocha [2009], and Krawczyk [2009] have emphasized that the feature most correlated with the hen's genotype is the eggshell colour, whose intensity depends on age.

The eggshell performs a fundamental function in gas exchange, protecting the developing embryo, and supplying it with calcium to build the skeleton. The eggshell protects the contents of the egg against both penetration by harmful microorganisms from the outside and evaporation of water from the inside. From the moment the egg is laid, physicochemical changes referred to as ageing lead to a loss of the natural protective capacity of the eggshell and the movement of water and gases, both within the contents of the egg and between its internal environment and the surrounding environment . The amount of water that evaporates from the inside of the egg is determined by physiological factors, such as the permeability of the shell, the diameter of the eggshell pores, and the rate at which the cuticle dries out and cracks. Small eggs, with a greater surface area in relation to their volume, have been shown to lose water faster [Calik et al. 2003].

The path to the inside of the egg leads through the eggshell pores, which number from 7000 to 17,000, with a diameter from 13 microns at the blunt end to 6 microns at the pointed end [Węsierska 2006]. Shell quality is also determined by its ultrastructure. Studies on the ultrastructure of the eggshell and eggshell membranes have been conducted by Carnarius et al. [1995] in chicken eggs, by Puchajda et al. [1997] in turkey eggs and by Puchajda et al. [2000] in goose eggs. According to these researchers, hatching of chicks is more influenced by the ultrastructure of the shell than by its thickness. Hatching results are also affected by the structure of the pores of the eggshell [Meir and Ar 1987, Tullet 1990].

According to some authors, the thickness of the chicken eggshell ranges from 0.25 to 0.45 mm and varies over the surface of the shell. It is thickest at the pointed end of the egg, intermediate at the blunt end, and thinnest at the equator. According to other researchers [Malec et al. 1999], eggshell thickness is genetically determined, but can be influenced by environmental factors. This opinion is supported by the research of numerous authors [Shafey 2002, Nowak and Sobczak 2005, Biesiada-Drzazga and Janocha 2009]. In a study by Puchajda et al. [2000], the average eggshell thickness of two-year-old White Koluda geese was 0.530 mm at the pointed end of the egg, 0.515 mm at the blunt end, and 0.547 mm in the middle. Dohnal et al. [1990] indicated a relationship between the hatching rate and the thickness and strength of the eggshell. The eggshell thickness was found to be inversely proportional to the ability of water vapour to pass through it.

The weight, density and elastic deformation of the shell affect the quality of the incubation and hatching processes [Gornowicz et al. 2013]. Fragile shells, which are subject to microcracks, allow bacteria and fungi abundant in the henhouse environment to penetrate the egg [Mertens et al. 2006]. Results reported by Premavalli and Viswanagthan [2004] indicate a positive relationship between the strength, thickness, and density of the eggshell. The authors found that the age of hens affects the frequency of internal cracks in the eggshell and that egg weight is negatively correlated with eggshell thickness. On the other hand, according to Pantheleux et al. [1999], a thicker eggshell is only partially responsible for greater strength. Hunton [2005] emphasizes that the mechanical properties of the eggshell are primarily influenced by its structure and the concentration of matrix proteins, and the changes in the mechanical properties of the eggshell that take place with age are associated with a reduction in the hen's absorption of calcium and phosphorus from feed and slower mineralization.

THE YOLK AND THE ALBUMEN

The yolk is the largest known biological cell. It is a concentrate of essential vitamins, minerals, and fatty acids with valuable biological properties. Research by Kontecka et al. [2012] indicates an increase in yolk weight in successive weeks of laying in Cobb 500 flocks, accompanied by deterioration in its quality.

The albumen plays an extremely important role in the hatching egg. Egg albumen consists mainly of colloidal proteins, with a small amount of sugars and mineral salts. Studies have shown that an increased proportion of albumen in the egg negatively affects hatching results. According to Huse and Kuźniacka [2015], in chicken eggs with 63% albumen the hatching rate from fertilized eggs (89.5%) is higher than for eggs with 53% albumen, in which the hatching rate from fertilized eggs is only 66.1%. The time eggs are stored before being placed in the incubator also has a major impact on deterioration of albumen quality. Storage of eggs lowers the pH of the albumen, adversely affecting its quality and loosening its structure [Michalak and Mróz 2003].

FERTILIZATION

In egg production by breeding flocks of chickens, while the number of eggs obtained from the layer is of course important, the primary task is to obtain eggs that can be used for hatching. Cocks are widely believed to be responsible for egg fertilization, although some influence of the hens should be considered as well. Poor fertilization rates can result from overweight cocks and their associated low sexual activity, from damage to their feet and the skin on the soles due to poor litter quality, or from

an inadequate male-to-female ratio in the flock [Rachwał 2011]. Fertilization results depend on semen quality, the reproductive behaviour of females, the mating system, diet, and environmental conditions, including day length. The substantial impact of environmental factors is due to the low heritability of this trait. Research by Goncalves et al. [2015] confirms that reproduction results depend to a very great extent on cocks. Therefore, males should not be selected for the breeding flock solely on the basis of body weight and conformation traits; an assessment of semen quality is necessary as well. It should be emphasized that studies on reproduction are particularly justified in meat hens. Breeding birds of this type often attain high body weight, which makes it difficult to obtain high fertilization rates in natural mating, especially in the second half of the reproductive period [Gumułka et al. 2003]. Artificial insemination is currently used on a large scale in meat chickens with the dwarfism gene (*dw*). In breeding practice, however, it may become a necessity in all meat hens.

A characteristic feature of reproduction in birds is the ability of females to store sperm in the oviduct, which enables the use of economically beneficial natural mating of several females with one male in poultry farming, as well as artificial insemination. The likelihood that consecutively laid eggs will be fertilized, taking into account polyspermy in birds, depends in part on the number of sperm present in the infundibulum. It can be roughly estimated based on the sperm population retained in the perivitelline layer in laid eggs. Gumułka and Kapkowska [2002], in a study conducted on eggs obtained from Arbor Acres meat hens, showed a marked decrease in the number of sperm stored in old hens (62 weeks old compared to 36 weeks old).

PRE-INCUBATION STORAGE CONDITIONS

An important factor affecting the hatching process and quality of chicks is egg storage. Studies on the eggs of laying hens and meat hens have investigated the impact of egg storage time on their quality [Silversides and Scott 2001, Suk and Park 2001] and incubation conditions [Barbosa et al. 2013, Bergoug et al. 2013]. According to Pijarska and Malec [2006], eggs are not suitable for incubation immediately after they are laid. The best results are obtained from eggs stored for 3–4 days before being placed in the incubator. This is the time required for stabilization of egg structures, primarily the albumen and chalaza, for the loose fibres of the inner eggshell membrane to become compact, and for completion of eggshell calcification [Pijarska and Malec 2006]. On the other hand, a number of changes occur when eggs are stored for too long, such as cracking of the cuticle, an increase in the pH of the egg contents, water evaporation, air cell enlargement, thinning of the yolk, weakening of the vitelline membrane, protein breakdown, loss of vitamins and lysozyme, and accumulation of toxins due to embryo development. Chicks from such eggs have a lower body weight and may have poorer health and survival rates.

According to Rachwał [2008, 2008a, 2008b], egg storage conditions should ensure that the embryos are not damaged or weakened, which reduces hatching results. Incubation of chicken eggs that have been stored too long prolongs the incubation period, due to delayed embryo development and slower growth in the first days of incubation. According to the author, in chickens the negative impact of prolonged egg storage time on hatching results depends on the age of the flock and the origin of the birds. The research showed that only eggs from younger flocks can be stored for more than one week. In eggs from one line of Lohmann Brown hens stored up to nine days, hatchability of over 85% was obtained, while in the case of another Lohmann Brown line it fell to below 80% after seven days of storage. In addition, the study reported the highest hatchability not from completely fresh eggs, but from eggs that had been stored for 3–4 days.

With regard to storage conditions for hatching eggs, it should be noted that the egg itself has a number of defense mechanisms that protect it against adverse environmental conditions, mainly penetration by microorganisms. These include the following:

- The egg contents, especially the albumen, contain substances that protect the future embryo against infection: lysozyme, avidin, conalbumin, cystatin and ovomucoid.
- The viscosity of the thick albumen prevents bacteria from moving towards the yolk, while the chalaziferous layer forms a mechanical barrier.
- The vitelline membrane of the yolk contains as much as 30% lysozyme in its dry matter [Trziszka and Kopeć 1997].

According to Węsierska [2006], the egg is particularly vulnerable to penetration by microbes during laying and the formation of an oxygen reservoir for the developing embryo. The natural protection of eggs by the inner and outer eggshell membrane lasts 14 days or more, but only in optimal microclimate conditions [Chowdhury 1990] .

The main factors inhibiting microbial proliferation in eggs are widely believed to be the lack of available nutrients in the albumen and its highly alkaline pH [Węsierska 2006]. An important role is played by ovotransferrin, also called conalbumin, which has the ability to bind iron, copper or aluminium ions, owing to which it exhibits its bacteriostatic activity. Another substance with a major role is lysozyme, which has high enzymatic activity (e.g. hydrolysis of the cell walls of Gram-positive bacteria) and forms a complex with ovomucin, responsible for the gelatinous structure of egg white. Cystatin and

avidin present in egg white are also highly bactericidal, with the ability to bind biotin, which is necessary for the growth and development of many microorganisms [Que and Reed 2000, Węsierska et al. 2005, Węsierska 2006].

SUMMARY

Numerous studies conducted in Poland and other countries indicate that the suitability of eggs for hatching and their biological value are determined by genetic factors (mainly the origin of the birds) as well as environmental Hatching eggs are primarily subject to assessment of external characteristics. The most important characteristics determining whether eggs are suitable for incubation are their weight, shape, structure and eggshell condition, as proper structure is a fundamental condition of satisfactory hatching.

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OCENA JAJ PO WZGLĘDEM ICH PRZYDATNOŚCI DO WYLĘGU

STRESZCZENIE

Wyniki lęgów zależą od wartości biologicznej jaj oraz od czynników mających wpływ na rozwój zarodka w okresie inkubacji, a także od warunków, w jakich znajdowały się jaja od momentu zniesienia do momentu umieszczenia ich w aparacie wylęgowym. Liczne badania krajowe i zagraniczne wskazują, że o przydatności jaj do wylęgu i ich wartości biologicznej decydują czynniki genetyczne (głównie pochodzenie ptaków) i szeroko pojęte czynniki. Jaja wylęgowe podlegają przede wszystkim ocenie cech zewnętrznych. Najważniejszymi cechami jaj, na podstawie których kwalifikuje się je do inkubacji, są: masa, kształt, budowa i stan skorupy jaj. Masa jaja w znacznym stopniu zależy od czynników genetycznych. Ocena masy jaja wylęgowego jest istotna z tego powodu, że masa piskląt jest dodatnio skorelowana z masą jaja wylęgowego. W wielu badaniach udowodniono, iż najlepsze rezultaty wylęgowości uzyskuje się z jaj o średniej masie. Istotne znaczenie dla jaj wylęgowych ma ich kształt, określany za pomocą indeksu. Prawidłowy kształt jaja warunkuje bowiem właściwy rozwój zarodków i piskląt w okresie inkubacji. Wylęgowość jaj w dużym stopniu zależy nie tylko od masy i kształtu jaj, ale również od cech jakościowych jaj, w tym składu morfologicznego. Prace badawcze jednoznacznie potwierdzają wpływ genotypu ptaków na cechy fizykochemiczne jaj, w tym na masę jaja, żółtka i skorupy. Niezmiernie ważną rolę w jajach przeznaczonych do reprodukcji odgrywa skorupa. Cechy jakości skorup są determinowane zarówno genotypem, jak i czynnikami niegenetycznymi, do których należy zaliczyć wiek nioski i żywienie, a w szczególności jego ilość, formę oraz dostępność. Każda zmiana proporcji składników morfologicznych jaja (skorupa, białko, żółtko) może obniżać i zakłócać wskaźniki lęgów. Ważnym zagadnieniem wpływającym na prawidłowy proces klucia i jakość piskląt jest etap przechowywania jaj.

Słowa kluczowe: struktura, jakość jaj, wylęgowość, czynniki genetyczne

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