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SHELL QUALITY – EVERLASTING PROBLEM IN THE TODAY POULTRY SCIENCE

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Review paper

Abstract: Shell breakage (6-20%) is of major concern for its economic consequences and safety of egg consumption. A great deal of effort in the fields of nutrition, genetics and enviromental conditions have been carried out to improve eggshell quality but understanding the formation of the eggshell fabric and the origin of shell defects is perhaps the key to solving eggshell problems. The aim of this review is to summarise new information on eggshell problems. The aim of this review is to summarise new infotmation on eggshell formation and update the nutritional unfavourable enviromental conditions.

Keywords: Egg production, shell quality, problem, possible solutions

Introduction

The quality of the egg shell is still a major concern of many participants in the poultry production chain, producers of table eggs and hatching egg producers. The successful development of a chicken embryo depends on the quality of the egg shell, i.e. its robustness for the purpose of protection, protection from infection and water loss from the egg, and most importantly, it is a source of calcium for the formation of the skeleton of the embryo (*Lavelin et al., 2000*). On the other hand, in the commercial production and marketing, table eggs are exposed to many shocks affecting percentage of broken and cracked eggs and thus directly affecting the economic losses of the producer. In addition, there is growing concern about the safety (hygiene compliance) of eggs, as the egg shell is the first barrier against bacterial penetration of the egg and therefore must be free of defects. Ban on cage system of housing hens in the EU, also increases the risk of infection from

Salmonella, etc., so in that sense, the eggshell quality is very important (*Nys, 2001*).

Shell breakage is still a major concern of egg producers, because 80 to 90% of the eggs deficiencies relates to eggshell. Defects include eggs without shell that are rarely observed and not counted in the number of fresh laid eggs, and the eggs that acquired defects in body before oviposition which may be partially and completely removed. The defective eggs include eggs irregular shape, eggs with partially thin shell and eggs with a rugged shell (*Bell, 1998*). Shell eggs differ depending on the chicken breed or hybrid, flock age, season, oviposition and between chickens in the same flock.

Egg shell is a highly organized mineral structure built of spherical calcite crystals deposited on the outer surface of the membrane around egg white. Crystals of calcium carbonate (in the form of calcite) are formed by crystallization from supersaturated solution of secretion from the distal fallopian tube - uterus. Layers take about 20 hours to form a shell, which shows the huge requirements for continuous supply of required quantities of calcium. Every interruption in calcium supply to uterus leads to a decline in the quality of the shell and further economic losses.

Harms et al. (1996) report that approximately 6-8% of the total egg production is not usable/markatable due to poor quality of shells, and *Roland (1988)* points out that 12-13% of eggs are lost on the way from the producer to the consumer for the same reasons. The ability of eggshell to withstand the impact of the external force is the strength of the shell *(Hamilton, 1982*). Many factors influence the quality of the shell, and its strength, such as genetic basis, layer hen age, nutrition, environmental conditions, disease, etc. (*Washbourne, 1982; Vitorović et al., 1995, Roberts and Nolan, 1997; Daghir 2004, Zhang et al., 2005, Pavlovski et al., 2012*). Eggs of better quality of egg shell are laid in the afternoon period compared to the morning (*Pavlovski and Vitorović, 1996; Škrbić et al., 1998; Tumova et al., 2007*). The main source of calcium in the hens diet is the finely ground limestone, chalk. Shell formation takes place during the night and then layers consume less or not at all food and calcium needs are not adequately met. The problem of the quality of the egg shell over last 30 years, and it is still current, is subject of numerous studies since broken egg shell depends not only on the strength of the shell, but also on shell thickness and strength of "attack" on it.

In this paper, we focus on the formation of the egg shell, shell quality problems and possible solutions for improving the quality of the shell.

Forming of the eggshell

Eggshell is formed in the uterus, expanded section of fallopian tubes called the shell gland. After fertilization of the egg in the infundibulum and secretion of egg white in the magnum, the egg enters the isthmus (narrowing of the tubes) 2 to 3 h after ovulation. In the isthmus, granular cells secrete various components of the shell membranes such as type X collagen. In utero, from the supersaturated solution of calcium carbonate (about 5 to 6 g) the crystals are formated that are deposited in layers on the surface of the thin outer membrane protein. The quality of the shell formed to a large extent depends on the size and shape of crystals on the one hand and on the other on the interaction of calcium carbonate and organic matrix.

A large number of matrix macromolecules have only recently been discovered and identified. In the uterine fluid and organic shell secretions three types of proteins have been discovered: egg white proteins (lysozyme, ovotransferrin, ovalbumin), osteopontin, which was first identified in bone and uterine proteins that are unique to the process of forming of shell: ovocleidin 17, 116; ovocalyxin 32 *(Nys et al., 2000*). Egg white proteins are located in the membranes of the egg. They can participate in the fight against microorganisms because of their microbial activity, and lysozyme and ovotransferrin can affect the size and morphology of calcite crystals when the crystals grow *in vitro* in the presence of these proteins. It is assumed that greater protein participation in the eggshell affects the morphology of the shell and the quality. It is known that the shell quality in older hens is worse and shell breakage increased. The decline in shell thickness with the age of the hens is related to the inability to reduce shell weight. Preliminary research indicates that in the egg shell from older hens there are more matrix proteins. Further research in this area should confirm the hypothesis that matrix proteins play a role in the formation of the shell. Feeding hens remains of utmost importance, because it is the only supplier of inorganic substances necessary for the formation of the shell.

Eggshell defects

Common defects (deficiencies) of eggshell that may result in the economic loss in the production of eggs (Egg Quality A Practical Approach, Roche) are: *large cracks, thin line fissures, rough cracks, eggs of deformed shape, equilateral egg, eggs covered with cracks, pimply shells.*

Measuring of the quality

Research literature abounds with research on the effects of nutrition, light regime, population density, genetic bases and similar on the quality of the shell, but what is the quality of the shell and how is it measured?

Of the physical properties of the eggshell the following traits are measured in order to improve the quality of the shell:

EGGSHELL WEIGHT, SHELL DEFORMATION, BREAKING FORCE
EGG LENGTH / WIDTH = EGG SHAPE INDEX
TOTAL SHELL THICKNESS
THICKNESS OF THE MAMMILARY LAYER
EFFECTIVE THICKNESS
FRACTURE TOUGHNESS
SPECIFIC WEIGHT

The right choice of the measure brings us to the real conclusion of the factors influencing the quality of the eggshell and other aspects of the quality of the product.

Possible solutions

Control of egg mass (shell). Egg mass is still of paramount importance for the maintenance of good eggshell quality. Egg masses can be reduced by a lower total amount of protein in the diet (19/15mg/day) or methionine levels (500/200 mg / day), but it can adversely affect the level of production. Supplementing 0.25 or 0.5% of amido ethyl-sulfonic acid in powder form for laying hens decreases the egg mass and has no effect on production traits, but there is no information whether there is any effect on the share of eggshell. The energy level can not be manipulated, but there is abundant information in the literature describing the influence of the fat on the egg mass. Adding 4% of fat affects the egg mass at the start of production (*Grobas, 1999*), but at the end of production, adding fat should be avoided, so the mass of the eggs would not be increased. Vegetable oils are rich in unsaturated fatty acids and 0.81% linoleic acid (*Harms et al., 2000*) positively affect egg mass. Using more saturated fatty acids (palm oil) and adding linoleic acid in quantities that meet the daily needs of normal hens physiological function (0.8%), are alternatives with which to control the increase in weight with age of laying hens, especially when egg mass reduction does not reflect the change in mass of the eggshell.

Calcium in the diet of chickens. In rearing chickens (8-16 weeks of age) the calcium requirements range from 0.9 to 1,1%. Excessive doses of calcium in food for longer period is not recommended because it can cause depression in the growth of hens and kidney damage and increased mortality (*Hamilton and Cipera, 1981)*. The most important period in the rearing is when the young hens become laying hens. Calcium levels need to be increased two weeks before the laying starts to facilitate the development of medullary bone, and more importantly to avoid that hen lays the first egg without the addition of calcium in the diet that could result in negative calcium balance that is difficult to correct later. Delays in the introduction of a greater share of calcium has a negative effect on the quality of the egg shell of the first laid egg and throughout the laying period has a negative impact on the quality of the shell (*Roland, 2000*). Today, hens mature sexually much earlier and therefore produce their first egg before they move into a facility for hens which should coincide with the introduction of a meal for layers. Therefore, it is recommended to add 2.5 to 3.5% calcium in the diet prior to beginning of laying, that is, from 14 to 16 weeks of age of young hens.

Daily consumption of calcium by layers of is 2.2 g hence, the calcium requirements are 4g. If the level of calcium in the diet is below 3%, it increases the mortality and reduces the production of eggs, which has been confirmed in their research by *Keshavarz (1998 a, b)* and *Chandramoni et al. (1998).* Optimal quality of eggshell was determined in eggs from hens fed with a diet containing more than 3.5% calcium in layers of brown shell eggs (*Vitorović et al., 1995; Safaa et al, 2008)* and 4 to 4.5 g per day (*Scott et al., 1999*). Selection of hens for large number of eggs is associated with a daily production of eggs, where more eggs are laid in the morning or before the light is turned on (80% of the new-laid eggs 11 hours subsequent to turning off of the lights, i.e. 3h after lights are turned on). Thus, eating in the morning can not ensure a normal supply of calcium to form a shell that is over 1.5 h before oviposition. Introducing the midnight feeding of hens improves synchronization between calcium intake and the formation of shells and shell quality, especially when you introduce the intermittent light (2 h) at night and only when the line for feeding of hens is on.

The particle size of calcium. The main source of calcium in laying hens feed is the finely ground limestone, chalk. Eggshell formation takes place mainly at night, when hens consume less or do not consume food at all, and calcium needs were not being met sufficiently. On of the main factors influencing the quality of the eggshell is particle size of calcium and this problem has been present in the last 30 years, and is the subject of numerous studies. In order to overcome it, replacement of a part of chalk in the mixture is recommended, with marble of larger particles (*Guinot and Nys 1991; Roberts and Nolan, 1997; Pavlovski et al., 2000; Pavlovski et al., 2006; Amer et al., 2007; Pavlovski et al., 2008*). Larger marble particles slowly dissolve is in the digestive tract and calcium becomes available during the evening and night periods. In contrast, finely ground limestone dissolves rapidly and is used in few hours.

Phosphorus. Numerous studies show that in the rearing period, different levels (0.2 to 0.3%) do not affect the quality of the first egg or bone mineralization. Shell quality decreases with increased level of accessible phosphorus in the diet. In the warm period of the year, the need for phosphorus in layers increases and if it is below 0.25% mortality of hens and shell breakage increase. Recommended quantity is 350 mg/day/hen to maintain skeleton of hens. The low level of phosphorus in feed reduces the need for calcium leading to bone problems and poor quality of eggshell. This can be partially improved by adding large particles of marble (*Nys 1995*).

Magnesium. Magnesium deficiency (less than 0.21%) influence number of laid eggs and the shell quality. Food for laying hens should contain 0.16%, which is four times more than the needs of laying hens (0.4%) (*Vogt et al., 1984*). In fact, there is no set amount of magnesium, which is added to the diet because plant nutrients such as bran, sunflower, rapeseed, contain enough Mg and therefore there is no information whether, by adding of these to food, the quality of the eggshell can be improved or worsen, except levels greater than 0.77% (*Enginering, Arttech and Leeson, 1983*). In any case, the excess Mg in the diet (greater than 0.6%) affects the increased consumption of water, which can lead to an increase in the number of dirty eggs.

Microelements. The main trace elements to form eggshell are manganese and copper. The lack of Cu in the diet affects negatively the biochemical and mechanical properties of the eggshell membrane and thus leads to deformation of egg shape (*Chowdury, 1990*). Mn deficit in the diet for laying hens (below 7mg) causes thinner shell, partly due to the deterioration of see-through spots due to worsening of the ultra shell structure in the mammalian layer and reduction of the concentration of the polysaccharides which are precursors of matrix proteins. In the literature there are no data that the Zn deficit in food affects the formation of the shell, but it is known that the amount of Zn below 10mg/kg reduces the number of fresh laid eggs. The Zn deficit in the same amount decreases the weight of hens, egg production, the number of newly hatched chicks, hens plumage forming, but there is no negative impact on the quality of the eggshell.

Food for laying hens containing 30mg/kg Zn, 20mg/kg Mn and 6mg/kg Cu is not sufficient to meet the needs of hens, therefore other sources mentioned of microelements must be provided (*Zamani et al., 2005*), including Fe and Co. The deficit of these elements affects the reduction of shell mass. *Abdllah et al. (1994)* consider this to be due to Mn deficiency. The amount of Mn 70-100mg/kg provides good quality eggshell strength and thickness (*Faria et al., 1999*).

The content of Cu in the amount of 70-140 mg/kg reduces the eggshell thickness. Attempts to improve the quality of the shell by adding boron (100 mg / kg), vanadium (20 mg/kg) or fluoride (6-20 mg/kg) did not provide convincing results. The metals such as nickel (100-500mg/kg) , chromium (500-2000mg/kg) or lead (20-100mg/kg) reduce the mass of eggshell (*Meluzzi et al., 1996*).

Selenium supplementation to the diets of hens up to 0.8 mg/kg in order to produce functional foods has no negative effect on the quality of the eggshell *(Pavlović et al., 2010)*.

It can be said that of all the trace elements, Mn has the leading role in improving the strength of the shell. If it is added to hen feed in the amount of 60-60-10 mg / kg, Mn, Zn and Cu the breaking force is increased, but not deformation and the eggshell mass (*Mabe et al., 2003*).

Electrolytes. The Na (less than 0.1%) and chloride deficit (less than 0.11%) in the diet for hens adversely affect egg production and shell quality, and on the other hand any excess chloride in food (0.75 to 0.8%) has a detrimental effect on the quality of the shell (*Gezen et al., 2005*). The presence of NaCl in water supply for hens (2 g/l) affects the reduction in eggshell quality (*Chen and Balnave, 2001*). In regard to the new system of housing of hens in accordance with EU regulations, hens are able to get directly in touch with the waste which increases the number of dirty eggs. In this case, if the food contains 1.6 to 5.5 g / kg of Na and 2.3 to 7.5 g / kg K, it results in increased water consumption and large amounts of waste and as a consequence more dirty eggs.

Other nutrients. It is known that aluminosilicates, vitamins C and E improve eggshell quality. Vitamin D3 in the amount of 400 IU increases the number of eggs and improves shell quality (*Whitehead, 1996*). *Seven (2008)* reported the positive effects of added vitamin C on the mass and egg shell thickness in heat stress conditions, contrary to the results of research *Supić et al. (1997).*

Numerous studies concerne the use of zeoilite in poultry nutrition. Sodium aluminosilicate (zeolite, 0.75 or 1.5%) improves egg specific mass, and this was confirmed in 77% of the 35 papers presented (*Nys, 2001*), especially when the Ca level in the diet was 2.75%. There is definitely a positive effect on the quality of the shell, and yet there are still concerns about its use in poultry nutrition and a positive effect on the quality of eggshell. Absorption of 10 to 25% aluminum and 40% silicon in the intestines of hens originating from the sodium zeolite limits the use of this additives (*Roland et al., 1993*).

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Ljuska – aktuelni problem u živinarstvu

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Rezime

Lom ljuske (6-20%) problem je od velikog značaja sa stanovišta ekonomskih posledica i bezbednosti jaja u ishrani. U oblasti ishrane, genetike i uslova životne sredine se čine veliki napori kako bi se poboljšao kvalitet ljuske jajeta, ali razumevanje procesa nastanka ljuske i porekla defekata ljuske predstavlja

ključ za razumevanje ovog problema. Cilj ovog preglednog rada je da se rezimiraju nova saznanja i informacije o pitanjima ljuske jajet, kao i ažuriraju novi nepovoljni prehrambeni i uslovi životne sredine.

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