

Eggshell Defects and Dietary Essentials

Introduction:

Much information has been learned about eggshell quality during the past 30-40 years. During this period of time, the genetics of the chicken, diets, house design and management practices have changed dramatically. In future, it is very likely that additional changes will have to be made by the commercial egg industry. No matter what changes occur, the eggshell needs to be as strong as possible to maximize the number of eggs reaching the end user.

Many factors influence eggshell quality. Eggshell breakage is directly related to the quality of the shell. It is impossible, even with current knowledge, to correct all eggshell quality problems. We can, however, make significant reductions in the number of eggs lost due to poor shell quality. This can be accomplished if one realizes that no single factor is usually responsible for egg shell quality. Many factors are known to be related to eggshell quality. These include adequacy of nutrition, flock health problems, management practices, environmental conditions, and breeding etc.

In the following review a brief account of each factor is provided. Numerous studies have estimated that the losses due to poor shell quality leads to great economic loss i.e. about 5-7% of eggs produced are not able to reach the end user out of which is about a maximum of 2-3% damage due to the inherent problem while laying and the remaining during the process after laying. In the year 2021, India has produced 122 billion eggs. If the loss due to egg shell defects is considered as 2% then there is a huge economic loss of 976 crores (@ Rs. 4.00 per egg). In a commercial poultry farm having 1 lakh capacity the estimated loss is around 24 lakhs per annum.

The Eggshell

Most good quality eggshells from commercial layers contain approximately 2.2 grams of calcium in the form of calcium carbonate. About 95% of the dry eggshell is calcium carbonate weighing 5.5 grams (10-11% of egg weight). The average eggshell contains about 94-97%

calcium carbonate, 0.3% phosphorus and 0.3% magnesium and traces of sodium, potassium, zinc, manganese, iron and copper.

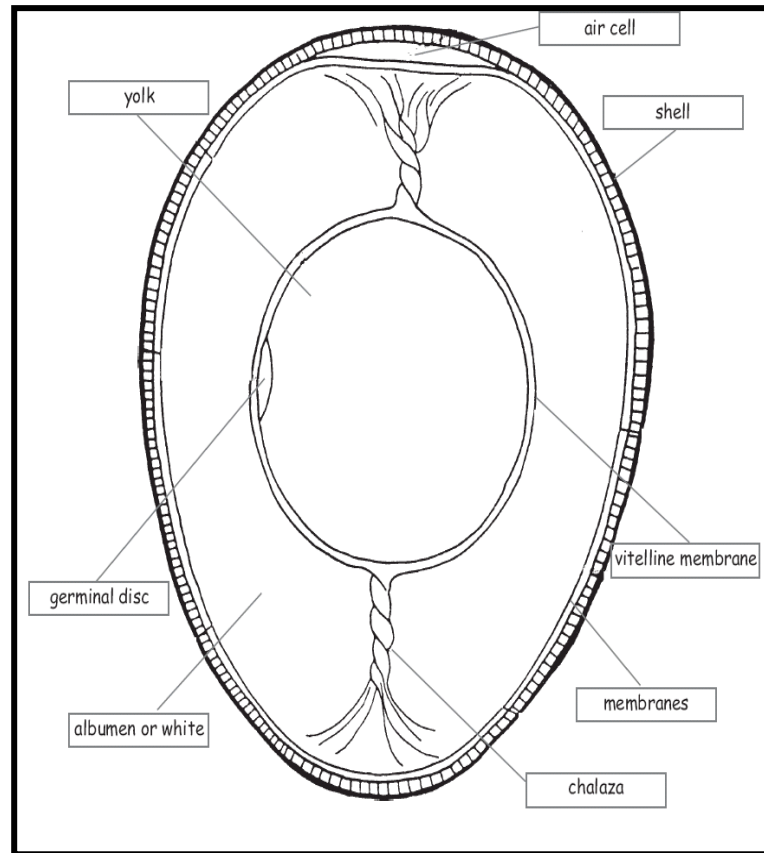
An eggshell that is smooth is desirable as rough shelled eggs fracture more easily. Large sized eggs will usually break more easily than small ones. The main reason for this is that the hen is genetically capable of placing only a finite amount of calcium in the shell.

The poor eggshell problem

Numerous factors affect the general functional quality of the egg shell. These factors affect the quality of the shell mostly prior to when the egg is laid. The thickness of an egg shell is determined by the amount of time it spends in the shell gland (uterus) and the rate of calcium deposition during egg shell formation. If the egg spends a short period of time in the shell gland, then shell thickness will be less. Also, the time of day when the egg is laid will also determine the thickness of the shell. In general, during the earlier part in the day or light portion of the photoperiod, the thicker the shell will be. The amount or rate of calcium deposition will also affect the thickness of the shell.

Why egg shell breaks?

How the egg shell defect appears, from a quote it should be understood that, ***“An egg shell cracks if the strength of the shell is less than the strength of the ‘environmental insult’ to which it is exposed”.*** ***“Crack incidence does not depend on shell strength alone, but on both shell strength and the strength of the insult”.*** Practically all eggs can be protected if enough attention is given to the issue; the amount of breakage experienced can be kept within reasonable limits.



Types of Shell Defects

There are various types of defects existing in the commercial farms and it can vary even very rare or 0.5 % to 5-6% of total production. The different types of defects are gross cracks, hairline cracks, star cracks, misshapen eggs, pimples, sandpaper, pinhole, leathery and glossy eggs.



Factors responsible for poor eggshell quality

✓ Poor nutrition

Nutrition of the laying hen plays a major role in maintaining the shell quality. Not only poor nutrition alone, but conditions associated with age of the bird, salinity of the water, diseases like Infectious Bronchitis, Newcastle disease, environmental temperature etc., plays major role in egg shell quality. Always this is the consideration for the nutritionists to formulate the ration by keeping the above said factors in mind. Nutrients such as Vitamin D, calcium, phosphorus, manganese, copper and zinc play a major role in maintaining the integrity of the shell quality. The imbalance of any one of these nutrient may leads to shell quality associated issues. For example, excess or reduced concentration of phosphorus, chlorine or mycotoxin contamination affects the availability of calcium and vitamin D.

✓ Ageing

Early onset of production or older age is associated with physiological calcium deficiency as associated by increase in kidney 1-hydroxylase and duodenal calbindin (Calcium Binding Protein) in early and late layers as compared with other stages. Early layers exhibit a more severe reduction in shell quality, when compared with late layers, as a result of calcium deficiency. After 40-45 weeks of age the absorption capacity in laying hens especially minerals decreases by 40-50 %.

✓ Saline water

Water quality has a bigger role to play in shell formation. The maximum permissible level of NaCl in poultry drinking water is 250 ppm. Increase in salt intake through the drinking water or the food is also known to reduce shell thickness by minimizing the calcium absorption.

Sodium chloride given in the drinking water reduces shell quality and increasing plasma calcium and phosphorus more than when sodium chloride given in the food.

✓ Diseases

Not all diseases affecting chickens cause a decline in eggshell quality though there may be reduction in production. An example of a disease that can affect the number of eggs and not necessarily the quality is infectious laryngotracheitis. Other common viral diseases, such as egg drop syndrome (EDS), avian influenza (AI), Newcastle disease (ND) and infectious bronchitis (IB) may produce severe effects on external and internal quality of egg. Many times the total number of eggs is not influenced, even though the egg records indicate a drop in total collectable eggs.

✓ Environment

Usually, eggshell quality is not as much of a problem in cooler environments as it is in hot environments. One of the contributing factors causing poorer eggshell quality in hot weather is hens not consuming adequate feed. When environmental temperature becomes excessively hot, feed intake decreases, and energy becomes the first limiting factor to the hen.

Inadequate consumption of amino acids, calcium, phosphorus, and other nutrients can usually be corrected by adjusting the nutrient density of the diet.

For layers, the main consequences of heat stress are a reduction in feed intake, a decrease in intestinal blood flow and ionised calcium levels in blood, a reduction in partial pressure of carbon dioxide and interference in gonadotrophin releasing hormone action, the hypothalamic hormone that regulates the release of leuteinising hormone.

Eggshell thickness decreases markedly during heat stress. There is calcium and phosphorus loss due to acid base imbalance and alkalosis of the blood due to loss of excessive amounts of carbon dioxide by panting (Respiratory alkalosis). Egg weight falls by about 0.4% per °C between 23 and 20°C above 27°C the decrease is about 0.8% per °C rise in environmental temperature. Growth at point of lay is reduced above 24°C, and is extremely low above 28°C. Rate of lay is generally only affected above 30°C. Feed conversion ratio is optimal at a temperature of about 28°C. Above 28°C FCR deteriorates, because of the failure in production.

In such situations, maximum egg mass along with maximum eggshell quality are difficult to achieve with any age bird without balancing the additional nutrients to the bird.

✓ **Other Factors**

Apart from the above discussed causes the following may play a minor role in maintaining the shell quality and profitability. They are mechanical damage by the birds which is due to poor shell strength, rough handling and infrequent egg collection. Though there are so many factors to consider, even a single cause is sufficient enough to disturb the sequence.

Role of minerals in eggshell quality

Generally nutritionists recommend the additional supplementation of either calcium through DCP or shell grit by top dressing or vitamin D supplementation to minimize the losses through poor egg shell during specific periods.

The importance of calcium and vitamin D3

The multi-factor mechanism of transfer of calcium ions to the egg shell consists of a vitamin D dependent absorption of calcium ions that is calbindin (calcium binding protein) mediated. Calbindin acts as a cytosolic facilitator of calcium ion diffusion from the brush border membrane to the basolateral membrane.

The induction of calbindin gene expression in the egg shell gland (ESG) is predominantly calcium dependent. In addition to the induction of calbindin-D synthesis, vit-D₃ (1, 25(OH)₂D₃) exerts other effects on the intestinal epithelium that can have consequences on the calcium absorptive process.

There is more chance for defect in vitamin D metabolism or calbindin gene expression in old hens responsible for thin-shells. Aged hens absorb calcium with a lower efficiency due to lesser synthesis of 1, 25-hydroxycholecalciferol (1, 25(OH)₂D₃), a defect in the hen's ability to alter calbindin synthesis in response to calcium needs and less duodenal and eggshell gland (ESG) calbindin than normal laying hens leading to formation of light uncalcified shells.

✓ Calcium and the egg shell

It is obvious that in order to maintain good egg shell quality it is necessary to assure adequate calcium nutrition. Hens producing approximately 300-320 eggs per year must deposit 24 times more calcium into egg shells than the amount contained in their bones. For this reason, the requirement for calcium supply in the diet *is* enormous. During the 20 hr period in which the egg shell is formed, the hen must deposit 25 mg of calcium on the egg surface every 15 minutes.

As the hen can only obtain 30-50% of total dietary calcium (depending on its source, size of particles, health condition of birds, etc.), the amount of dietary calcium that must be supplied daily ranges from 3.2 to 4.5 g per bird per day (depending on production level, daily feed intake, environmental temperature and other factors).

✓ **Sodium bicarbonate and the eggshell**

During the summer or when the housed temperature goes beyond 32⁰C additional supplementation of NaHCO₃ improves the shell quality by supplying carbonate ions for the process of calcium carbonate formation. Not only in summer but also additional supplementation of sodium bicarbonate at critical situations will improve the quality of shell.

✓ **Zinc and the egg shell**

Along with calcium, carbonate ions are needed in formation of calcium carbonate. However, they are usually neglected as a potential cause of problems associated with egg shell quality. Carbon dioxide, which is present in the oviduct as a common product of cell metabolism or as a gaseous compound in blood, is the main source of carbonate ions. The carbonic anhydrase enzyme requires the presence of zinc and catalyses formation of carbonic acid from water and carbon dioxide.

Organic zinc was associated with higher activity of carbonic anhydrase and in turn with improved shell quality. The fact that zinc is a co-factor of this enzyme makes both activity and proper function of this enzyme potentially sensitive to trace elements, their interactions and availability.

✓ **Manganese and the egg shell**

Presence of manganese (Mn) has an activating effect on alkaline phosphatase; explaining the importance of this element in proper formation of bone tissue and egg shell. In various experiments carried out worldwide, no effects of increased amounts of manganese in the diet on production and weight of eggs were observed. However, egg shell thickness increased significantly. Manganese deficiency decreases egg shell weight; which may support the hypothesis regarding the importance of manganese as a enzyme co-factor in controlling synthesis of mucopolysaccharides. The organic matter in eggshell is polysaccharide which serves as source for the deposition of calcium carbonate.

✓ **Copper and the egg shell**

Copper also plays an important role in a number of enzyme functions in the bird. Copper is closely associated with iron metabolism as it is a part of ceruloplasmin which is an enzyme that plays an important role in the oxidation of ferrous to ferric iron, controlling the movement of iron from the reticuloendothelium to liver and then plasma, affecting red blood cell formation. Another important enzyme dependent on copper is lysyl oxidase which is an integral enzyme in elastin and collagen formation in birds. A deficiency of copper can cause bone abnormalities due to abnormal collagen synthesis, calcium depletion and leads to shell abnormalities. The trace element Copper can keep up the enzymes highly functional to avoid such losses.

The intensive deposition of calcium occurs during the last part of the day and during the night. **Calcification is completed for 80% of the birds two to three hours after lights on. The higher the feed intake and the calcium intake in the afternoon, the higher the calcium deposition and, therefore, the stronger the egg shell. Moreover the absorption of calcium is high when the shell gland is active (70-75%) rather than other times (40-50%).** An adapted feeding timetable based on this knowledge will reduce the mobilization of the calcium from the medullary bone. The introduction of a period of light in the middle of the night improves the shell quality by allowing the hen to replenish her calcium reserves at a key time. Eggshell quality depends to a large extent on the quantity of calcium remaining in the gizzard at the end of the calcification process and, therefore, towards the end of the night.



Conclusion:

It could be concluded that there is no single factor affecting the egg shell quality. But, alteration in one particular cause can have a desynchronizing effect on shell quality. Nutritionists should always have a check list of Vitamin D, Calcium, Phosphorus and other trace minerals like Mn, Cu and Zn. It is to be suggested that, whenever the factors are dominating over the birds' physiological rhythm and causing the severe economic losses by disturbing the egg shell quality, we should have a note on additional supplementation of key nutrients, management, cage arrangement pattern and egg collection pattern to minimize the shell losses. And it can improve the farm profit too.
