avitech technical bulletin

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MAINTAINING EGG SHELL QUALITY

Poor egg shell quality is a huge hidden cost to the egg producer. Estimates are that more than 10% of eggs produced in the hen house are uncollectible or break before intended use. The first 2-5 percent is lost simply, due to form which may be shell less, cracked or broken to the extent that they are not suitable for collection. Another 3-8 percent is lost during collection, moving through the belts, cleaning, packing and transportation to the end user. Because the first 2-5% loss is due to uncollectible eggs, most egg producers often estimate their egg loss due to poor shell quality at only this percentage, which is most likely an underestimation. At Rs.1.50/ egg, even a 5 percent loss could be as much as Rs. 2.7 million/year for 100 thousand layer house. The economic losses for the breeders will be even more due to reduced hatchability and chick livability. Therefore, every effort must be directed towards improving shell quality and reducing egg breakage.

Egg: The fertile egg is highly complexed reproductive cell and is a tiny center of life, where initial development of embryo takes place. Most of the commercial eggs are infertile. The yolk is surrounded by albumen, having high water content, elasticity and shock absorbing capacity. This entire mass is surrounded by two membranes and an external covering called egg shell. The shell provides a proper shape to the egg and is meant for conserving the valuable nutrients within the egg.

Hen egg contains approximately 76% water, 12% protein, 10% lipids and rest vitamins, minerals and carbohydrates. Egg is a major source of human dietary protein with high biological value and excellent protein efficiency ratio.

Egg Shell: The outer cover of the egg, the shell comprises 10-11% of total egg weight. On an average the eggshell weighs 5-6g, with remarkable mechanical properties of breaking strength (>30N) and is 300-350 micrometer thick. This structure plays a crucial role in protecting the contents of the egg from the microbial and physical environment and in controlling the exchange of water and gases. The calcium content of the eggshell is approximately 1.7-2.5g. An average eggshell contains:

Calcium carbonate	: 94-97%
Phosphorus	: 0.3%
Magnesium	: 0.2%
Sodium, Potassium, Manganese, Iron and Copper	: traces
Organic matter	: < 2%

The small amount of organic matter mostly consists of matrix proteins (mixture of proteins and polysaccharides rich in sulphated molecules) and shell pigment. The matrix proteins are critically important in determining the egg shell structure and serves as foundation for the deposition of calcium carbonate.

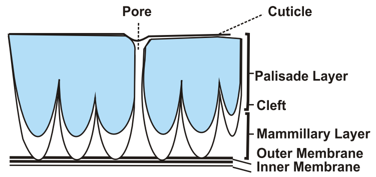


Fig. 1: Structure of the egg shell

There are about 8000 microscopic pores on the shell. The outer surface of the shell itself consists of a mucous coating (cuticle) which is deposited on the egg just prior to the lay. This proteinous covering helps to protect the interior content of the egg from bacterial penetration through the shell.

Shell Quality: The aesthetic quality of the egg shell relates to the quality factors which one can observe; such as soundness of the shell, shape of the shell and colour of the shell. However, for commercial layer and breeder operations, shell quality means increased shell thickness and shell breaking strength to reduce number of cracked eggs, an increased number of saleable/ hatching eggs and a higher number of viable day old chicks.

Methods to Measure Shell Quality: On farm methods and sophisticated equipments are available for accessing shell quality parameters. The egg shell strength is the main, but not the only factor that determines shell quality. Egg shell quality can be measured as:

- Egg size and visual shell defects
- Specific gravity
- Shell colour
- Shell breaking strength
- Percentage shell (Shell weight X 100/Egg weight)
- Shell thickness (mm)
- Ultrastructure of the shell

The specific gravity of an object equals the weight of its volume relative to the weight of an equal volume of water, when both are at the same temperature. The specific gravity of an egg is equal to the egg's density relative to water. The specific gravity of all four parts of the egg is different (shell: 2.325, Yolk: 1.032, albumen: 1.038, shell membranes: 1.075). Since the specific gravity of shell is more than two times higher than the other parts of the egg, the percentage of the shell has major influence on the specific gravity of whole egg. As the amount of shell increases, the specific gravity of the egg increases. Egg specific gravity, therefore, is a good indicator of percentage shell and shell quality.

The incidence of breakage is above normal, if the specific gravity of a flock averages less than 1.080.

Shell breaking strength can be measured through shell force gauge (static compressor) and is expressed in dynes/cm^2(N).

Maintaining egg size, proper and routine candling and measurement of specific gravity can be easily practiced at farm level.

Shell Quality Defects: These defects are obvious from direct external observation/ candling and are important for evaluation for the producer and consumer. It is also the main criteria for selecting hatching eggs. These may be as :

a) **Misshaped Eggs:** If albumen quality is very poor and there is no sound foundation upon, which to build the true shell; The result can be the distinctive 'crinkled' shell typical of certain viral diseases. Misshaped eggs can also arise for other reasons. *i.e*, the shell may break in the shell gland during

the formation process; The damage can be partly repaired but a bulge forms around the centre of the egg (an equatorial bulge). Any factor which causes disturbance to the birds 10-14 hours before the egg is laid is likely to increase the incidence of this fault.

b) **Coated Shells:** Additional calcium may be deposited onto

some eggs causing calcium splashing or a pink coloured egg. Typically these faults are caused by the egg remaining in the shell gland for an extended period. Often young flocks just coming into production are very susceptible to this defect. Any stresses or disturbances at the time when the egg is due to be laid will encourage the bird to retain the egg.

c) **Rough Shelled Eggs:** In some cases, two eggs may be in the shell gland at the same time which can cause a form of rough shelled egg often

referred to as a 'target' or 'thumb-print' type. This problem can also result in 'slab-sided' eggs. There are other types of rough shelled eggs, including those with pimples or a sandpaper-type texture. Bird

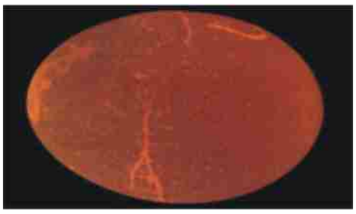
health and age often affect the incidence of this problem.

d) **Soft and Weak Shelled Eggs:** Soft and weak shelled eggs can be common in older birds, especially those which are nearing the end of the laying period, having produced a high output of eggs. Whenever they are seen in younger flocks, they can be associated with coated or rough shells. If an egg is retained in the shell gland for too long, the next ovulation takes place at the usual time but before the previous egg is laid. The second egg may spend less time than normal in the shell gland and the result is a soft or shell-less egg. In such cases, a hen may not lay an egg on one day, but may lay both a coated and a soft-shelled egg on the next.

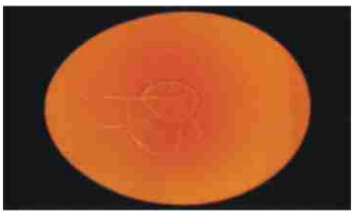
As a general point, it should be noted that a single stress or disturbance to a flock of laying hens can be enough to desynchronize the processes of egg formation for several days. This can cause a prolonged effect upon egg quality and during this time, a number of different egg quality faults may be seen.

e) Cracked Eggs: Egg shells can easily be damaged after the egg is laid and cracking is one of the most common reasons for downgrading. It may be due either to an inadequate egg shell being laid or to poor handling which may occur during collection, grading or transportation. Three main types of cracks are identified:

i) **Hairline cracks** are the most difficult to identify, particularly in very fresh eggs. Skilled candling is needed together with ideal working conditions. Hairline cracks are often caused by an egg colliding with an inflexible surface.

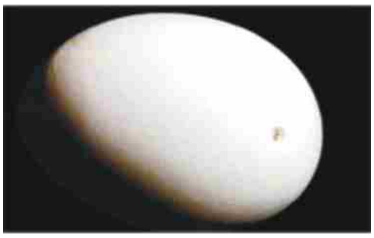


ii) **Star cracks** may often be visible under normal light although they are more easily



seen during candling. A central point of impact may be seen and star cracks are often due to collisions between eggs.

iii) **Pinhole and toe-hole cracks** can be caused either by the birds themselves or by any sharp protrusions which may



come into contact with the egg. There is evidence that a fault which appears similar may occur before the egg is laid.

f) Dirty and Glazed Shells: After the egg is laid, it can become affected with numerous contaminants including faecal material, dust, mud, litter (in non-cage systems), blood and the contents of other eggs. The latter is often referred to as glazing or varnishing. All of these lead to eggs being downgraded. High standards of hygiene and management, coupled with appropriate diet formulation and pest control must be maintained to overcome this defect.

g) Body Checks: Sometimes during the egg formation, the egg is cracked while it is still in the body of the hen. These eggs which are commonly referred as **"body checks"** are repaired by an additional deposit of shell over the cracked area, resulting in a ridge having shells with thin areas and are weaker than normal eggs. With table eggs, it creates an increased risk of breakage en route to the consumer and lowers the utility value of the egg. With hatching egg, it is major factor contributing to cracks during

storage and results in lower hatchability.

Factors Influencing Shell Quality:

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

i) **Strain:** Some strains of the birds may be able to deposit calcium for the egg shell at a faster rate than others, resulting in better deposition. It is observed that darker brown eggs have a higher shell quality than lighter brown eggs.

ii) **Diseases:** Diseases like infectious bronchitis (IB), Newcastle disease (ND), avian influenza (AI) and egg drop syndrome (EDS) affect the shell quality. IB virus causes soft/rough shelled eggs, discolouration and wrinkling of the shell. EDS virus affects only the shell gland but with ND or IB, every portion of the reproductive tract can be affected.

iii) **Management:** Poor housing, high ambient temperature, rough handling of the eggs will affect the eggshell quality. Since large eggs are more prone to cracks, the egg size must be managed through proper nutritional and lighting management.

Eggs from hens in the 3L:1D (3 days light : 1 day dark) regimen had a significantly greater shell breaking strength than eggs from hens in the 16L: 8D (16 hours light : 8 hours dark) regimen.

iv) **Moulting:** The management practice of "forced" or "induced" moulting has shown to improve shell quality in all ageing flock. Following the moult, egg specific gravity, shell weight, shell thickness and percentage shell were either the same as they had been prior to the moult, or had improved, for all strains. Egg shell breaking strength improved in all strains as the result of the induced moulting.

v) **Age of Bird:** As the hen ages, the thickness of the shell usually declines. Older flocks lay larger eggs, which break easily. The hen is genetically capable of placing only a finite amount of calcium in the shell. Secondly, hen looses some of her ability to mobilize calcium from the bone, and is less able to produce the needed calcium carbonate. The absorption and mobilization of calcium decreases to less than 50% of normal after 40 weeks of age.

vi) **Drugs:** For example, sulfa drugs affect the eggshell quality whereas tetracyclines have some beneficial effects.

vii) **Water Quality:** Many studies showed that saline drinking water, including tap water containing sodium chloride supplied to mature laying hens at concentrations similar to those found in underground bore water, has an adverse effect on eggshell quality while having little effect on feed intake, egg production or egg weight. In contrast some reports indicate that there were no visible shell defects and specific gravity was also not adversely affected.

viii) **Stress:** While a genetic predisposition for egg and eggshell quality exists, good genes can be upset by environmental stresses. The shell is formed by the activity of cells lying the oviduct and uterus. Under stress the secretions of these cells become acidic and the cells can be damaged or destroyed. In extreme cases, stress induced effects can result in eggshells that have excess deposits of calcium – a sort of powdery "bloom" on the surface and result in misshapen eggs.

Relocation stress is known to have effects on the visual appearance of eggs produced; increasing the incidence of calcium coated and checked (misshapen) eggs. Major types of relocations, such as movement from one type of housing to a completely new housing environment, can produce severe visual defects of the egg.

ix) **Environmental Temperature:** One of the factors contributing to poorer eggshell quality in hot weather is inadequate feed intake. Eggshell quality is somewhat compromised during summer months. During exposure to warm environmental temperature, the hen reacts by increasing its rate of breathing (panting) in order to cool itself. This causes the lowering of CO_2 in the blood and produces a condition termed "respiratory alkalosis". The pH of the blood becomes alkaline and the availability of calcium for the eggshell is reduced. This disturbance in acid-base balance causes an increase in soft-shelled eggs during summer.

Temporary thinning of the egg shell may occur during periods of high ambient temperature (above 25°C) since feed intake is reduced. The shells quickly regain normal thickness when temperatures are reduced and feed intake increases.

Respiratory alkalosis also causes increased carbonate loss through the kidney resulting in competition between kidney and uterus for carbonate ion, consequently resulting in poor eggshell thickness. During heat stress calcium intake is reduced as a direct consequence of reduced feed intake and this stimulate bone resorption resulting in hyperphosphatemia. This inhibits the formation of calcium carbonate in the shell gland. Also heat stress reduces carbonic anhydrase (Zinc dependent enzyme) activity in the uterus. Under heat stress more blood is shunted to the peripheral tissues with concomitant reduction in flow of blood to the oviduct resulting in poor shell quality. Lastly the ability of layers to convert vitamin D_3 to its active form is reduced during heat stress.

x) **Nutrition:** There is a complex relationship between calcium, phosphorus, vitamin D_3 and the hormonal system of the layer in calcium metabolism during lay. Calcium and phosphorus balance is critical for proper egg production and eggshell quality. Layer ration should be formulated with correct amount of calcium and phosphorus (usually 3.5 – 4.0% calcium, 0.35-0.40% phosphorus)

a) **Calcium:** Both excess and deficiency of calcium will negatively affect the shell quality. An egg contains almost 2 grams calcium; hence an average of 4 grams of calcium intake per day is required by a layer to maintain good shell quality since only 50 – 60% of dietary calcium is actually used in shell formation.

Calcium requirement of a laying hen is 4 – 6 times that of a non-laying hen. The egg enters the shell-gland region of the oviduct – the uterus – 19 hours prior to oviposition, and the shell does not store calcium ions to attach on protein matrix.

During the last 15 hours of shell formation, calcium movement across the shell gland reaches a rate of 100–150 mg/hr. This process draws calcium from two sources: diet and bone. Normal blood calcium level is about 20 – 30 mg/dl with a normal layer ration of 3.56% calcium or higher, while layers on a 2% calcium diet, 30– 40% of the calcium is derived from bone. It is therefore important to have pullets, prior to lay, on a high level of calcium to store it on body.

Intestinal absorption of calcium in the diet is about 40% when the shell gland is inactive, but reaches 72% when active. This time closely coincides with late afternoon or the dark hours for the layer. Having higher calcium levels in the gut during this time is important to ensure calcium is being taken from the diet and not bone. Large particle sizes of calcium sources allow calcium to be metered throughout this time.

In growers, most importantly, high calcium levels during the growth period will interfere with the proper development of the parathyroid gland by increasing gut pH, which will decrease absorption. The damage to the parathyroid would be permanent and would affect the bird's laying cycle afterwards.

b) **Phosphorus:** The phosphorus content of the eggshell is small i.e. 20mg, compared with 120mg in the egg contents. There is also uneven distribution of the phosphorus in the inner and outer layers of the shell. Phosphate ions have an inhibitory effect on the $CaCO_3$ and bring the shell formation to an end.

High levels of phosphorus in the blood will inhibit the mobilization of calcium from bone. The absorption of calcium and phosphorus are interrelated and can be influenced by:

Source and form of calcium and phosphorus: Calcium source and particle size plays a role in calcium level in the gut when needed. Phosphorus must be in a form that is available and usable by the layer.

Intestinal pH: Phosphorus absorption is optimal at pH 5.5-6.0. When the pH is higher than 6.5, absorption of phosphorus markedly decreases. Excess free fatty acids in the diet can cause the pH to decrease and therefore, interfere with calcium and phosphorus absorption.

Calcium and phosphorus ratio: High calcium or phosphorus levels in the intestine reduce the absorption of both. High calcium increase the pH in the gut and phosphorus absorption is decreased along with zinc and manganese absorption. High plasma phosphorus decreases calcium absorption from the gut and calcium mobilization from the bone. Phosphorus is an integral part of the acid-base balance in the body. The proper ratio of calcium to phosphorus (Ca: P ratio) for growing birds is 1.5–2.0 Ca: 1.0 P.

Vitamin D_3: Vitamin D_3 metabolite is essential in absorption of the Calcium.

c) **Vitamin D_3:** Vitamin D_3 is vital for absorption and mobilization of calcium during shell synthesis. The importance of adequate vitamin D_3 intake by the hen is obvious and it is essential for proper calcium and phosphorus utilization. However, excess vitamin D_3 and its metabolites have not shown to benefit eggshell quality when normal hens are already consuming adequate vitamin D_3.Vitamin D_3 is the major control element in stimulating calcium absorption from the intestine. This effect is facilitated by the synthesis of calcium-binding protein (CBP).

Vitamin D_3 intake must be adequate. The function of vitamin D_3 is related to its metabolite 1,25 dihydroxy D_3 that is formed in the bird's liver and kidneys. Any problem that affects the integrity of these organs or the parathyroid gland will have an adverse effect on the action of vitamin D_3 and thereby calcium absorption and metabolism.

d) **Diet formulation:** Shell breaking strength was greater for the sorghum diet than wheat or barley based diet and less for maize-soya diet. High levels of calcium and phytate in the diet of laying hen reduce the availability of trace minerals, especially manganese and zinc. Addition of non starch polysaccharides breaking and phytase enzymes to the feed tends to improve eggshell quality.

No deleterious effects on egg and eggshell quality were observed when levels of chloride and magnesium were upto three times higher than recommended levels. Excess dietary chlorine, however, decreases blood bicarbonate concentration, which plays a pivotal role in eggshell calcification. Low dietary cationic-anionic balance, presence of non starch polysaccharides, mycotoxins and contaminants results in poor shell quality.

How to Improve Shell Quality:

a) **Vitamin C (Ascorbic acid):** Ascorbic acid is essential for synthesis of organic matrix (tropocollagen) of eggshell. Ascorbic acid alleviates the ill effects of heat stress by reducing the plasma cortisone level in the bird. Ascorbic acid is a cofactor in the conversion of vitamin D to the active hormonal metabolite "Calcitriol" (1,25 $(OH)_2D_3$), which stimulates intestinal absorption of calcium and thus elevates plasma calcium to a level that supports normal mineralization of bones.

A dietary level of 250 mg ascorbic acid/kg diet of moulted hen improves the egg production and eggshell quality by enhancing intestinal calcium absorption or by resorption of bone Ca mediated through 1,25 $(OH)_2D_3$ production.

b) **Sodium bicarbonate ($NaHCO_3$):** Hens aged 30 weeks fed with 1% dietary $NaHCO_3$ and housed at 32° C either in conventional or intermittent lighting programme had improved eggshell breaking strength. The improvement in eggshell quality was more in the group with intermittent lighting programme. Supplementation of $NaHCO_3$ to laying hens at high temperatures is a means of improving eggshell quality as hens consume the additional bicarbonate during the period of active shell formation.

The addition of sodium bicarbonate or purified sodium sesquicarbonate, has shown to elevate the dietary electrolyte balance, improved acid-base balance and has a positive effect on eggshell quality.

c) **Aluminosilicates:** Results indicate as much as 40% improvement in egg specific gravity and 2.2% improvement in feed conversion by the addition of 0.75% sodium aluminosilicate to layer diets. Shell quality increased in summer but not in winter. However, care must be undertaken while selecting composition and ion exchange capacity of silicates.

d) **Minerals:** Zinc, Manganese and copper are compounds involved in the metabolic process of eggshell formation. These trace minerals work as co-factors of enzymes involved with shell matrix formation. Carbonic anhydrase, which is zinc dependant, stimulates calcium carbonate deposition for eggshell formation. Polymerase enzyme, which is dependent on manganese, forms the shell glycoprotein matrix or foundation.

Supplementing the diet with highly bioavailable minerals like mineral-amino acid complexes increases the eggshell weight and eggshell thickness. Copper affects the synthesis of shell membrane by activity of copper containing enzyme lysyl oxidase.

Dietary supplementation of zinc methionine improved the shell breaking strength. There was no improvement in shell quality where zinc sulphate was supplemented to approximate zinc concentration of zinc methionine.

e) **Calcium:** Provide extra calcium to the older hens @1g/bird in the form of oyster shell over and above normal requirement in summer months. Maintain the desired particle size of calcium source at the time of shell formation. The minimum size of calcium source to improve gizzard retention is about 1 mm. Solubility and absorption of calcium source must be major criteria. Magnesium content of calcium source must be as low as possible. Organic calcium is also a good option.

f) **Chemicals:** Injection of Indomethacin 4hr or 16hr post-entrance of egg into uterus delays oviposition and prevents premature expulsion of some soft shelled and shell less eggs. Chemotherapeutic agents like salicylic acid, aspirin reduce body temperature of laying hens during heat stress thereby alleviates its ill effects.

g) **Management:** Reducing egg breakage at farms requires constant attention to management details and proper equipment maintenance. Some methods to reduce the percentage of broken eggs are:

i) Provide cushioning of some type at the front of egg collection area of the cages. This will soften the impact of eggs rolling on to the collection wires and reduce the incidences of hairline cracks. Be sure that cushioning is positioned correctly to receive the eggs from the cages.

ii) Collect the eggs at least twice a day and more often if possible. Eggs rolling down the cage floor have an increased chance of being broken if there are several eggs already in the collection area.

iii) Maintain egg collection wires/trays in good condition. Examine them regularly for sharp edges, any foreign objects and for excessive wear and tear of the wire mesh/trays.

iv) Ensure that eggs do not pile up; dead birds protruding from the cage often block the egg flow to the collection area and causes spilling of the egg on the floor.

v) Routinely check the quality and condition of the egg trays in which the eggs are collected from the cages.

vi) Train egg collection workers for carefully picking the eggs from the cage area and gently placing them in the collection trays without slowing down the collection process.

vii) Be sure that ventilation is well maintained and fans, if any are working properly during hot weathers. Try to provide constant ambient temperature as far as possible.

viii) Reduce sound, activity and movement of workers inside the layer houses as much as possible to reduce disturbances to the birds.

ix) Procure good quality feed ingredients devoid of contaminants, adulterants and mycotoxins and provide wholesome water at all times to the birds.

x) Reduce flies, and rats causing annoyance to the birds.

xi) Check size, specific gravity, shell thickness routinely and if any change is observed, try to correct it by various means.

Conclusion :

Though precise statistics are not available, the economic loss due to poor eggshell quality is estimated to be Rs. 6 billion being at very conservative (assuming 150 million commercial layers and each bird losing @ Rs. 40/bird/ year due to cracked eggs). The above amount excludes the hatching eggs by breeding birds. These eggs have already been paid for the cost of production, so any successful effort to market a higher percentage means more net returns for the egg producer. The future of egg industry will go together with producer to innovate and supply quality eggs at reasonable cost.

Maintaining eggshell quality is a complex activity. 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 realises that no single factor is usually responsible for egg breakage. Many factors are known to be related with eggshell quality including, flock health problems, management practices, environmental conditions, breeding and adequacy of nutrition.

Dr. Lokesh Gupta is working as Regional Technical Manager in Avitech since 2004. He has a Master's degree in Animal Nutrition.

AVITECH
ANIMAL HEALTH PVT. LTD.
(An ISO 9001:2000 Company)
GP - 51, Udyog Vihar, Sector - 18, Gurgaon - 122001, Haryana, India
Phone : + 91 - 124 - 4011147, 4278511-12, Fax : +91 - 124 - 4013620
E-mail : info@avitechnutrition.com, Website : www.avitechnutrition.com