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Factors Affecting Quality and Quantity of Egg Production in Laying Hens: A Review

[1]*Farhad Ahmadi and* [2]*Fariba Rahimi*

[1]Department of Animal Science, [2]Faculty of Nursing and Obstetric,
Islamic Azad University, Sanandaj Branch, Kurdistan, Iran

Abstract: Egg shell quality and egg internal quality are of major importance to the egg industry worldwide. This review covers the formation of the hen's egg and ways of measuring egg shell quality and egg internal quality. Egg shell quality may be measured as egg size, egg specific gravity and shell color, shell breaking strength, shell deformation (destructive or non-destructive), shell weight, percentage shell, shell thickness and shell ultra structure. New methods emerge from time to time. Egg internal quality is measured as yolk color, the integrity of the perivitelline membrane and albumen quality. Factors that affect egg shell quality and egg internal quality are reviewed. The complexity of the process of egg shell formation means that imperfections can arise in a number of places in the oviduct of the hen. Egg shell quality may be affected by the strain and age of hen; induced moult; nutritional factors such as calcium, phosphorus, vitamins, water quality, non-starch polysaccharides, enzymes, contamination of feed; general stress and heat stress; disease, production system, or addition of proprietary products to the diets. Egg internal quality may be affected by storage; hen strain and age; induced moult, nutrition and disease. An understanding of the range of factors that affect egg shell quality and egg internal quality is essential for the production of eggs of high quality.

Key words: Egg quality · Egg quantity · Hough Units · Laying hens

INTRODUCTION

For the egg industry worldwide, the production of eggs which are of good egg shell quality and good internal quality is critical to the economic viability of the industry. Problems with egg quality currently cost the industry many of millions of dollars per year. Therefore, it is of great importance to understand the factors that affect egg shell quality and egg internal quality. The hen's egg consists of the yolk (30-33%), albumen (approximately 60%) and the shell (9-12%) [1]. It is sold commercially as shell egg, egg product or as components derived from eggs (Fig. 1).

Formation of the Hen's Egg: The egg of the laying hen is the end product of a complicated series of processes which are outlined in detail in Solomon [2] and Johnson [3]. The first step is the ovulation of the yolk (with associated ovum) from the left ovary into the left oviduct (Fig. 2). The right ovary and oviduct do not develop in the commercial laying hen. The yolk is captured by the infundibulum where the developing egg remains for about 15 minutes and it is here that the formation of the perivitelline membrane and chalazae occurs.

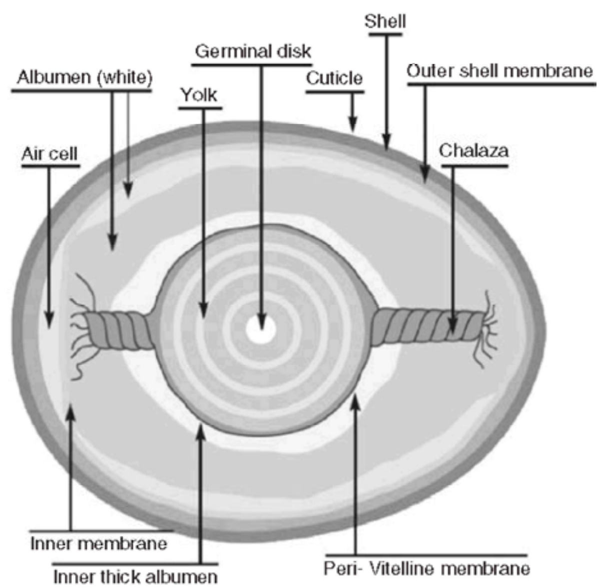

Fig. 1: Sections of internal and external of hen egg [2]

In breeder birds, fertilization also occurs in this region of the oviduct. The egg then moves into the magnum where it remains for about 15 hours while the egg white (albumen) proteins (about 40 in all) are produced.

Corresponding Author: Farhad Ahmadi, Islamic Azad University, Sanandaj Branch, Kurdistan, Iran.
Tel:+98 918 873 4591, E-mail: farhad_ahmadi@iausdj.ac.ir.

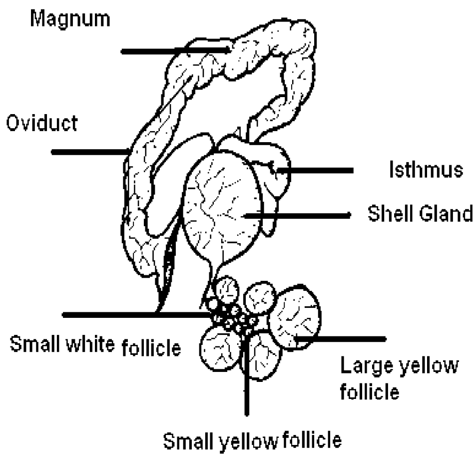

Fig. 2: Reproductive system of hen [2]

The layer of proteins provides mechanical and bacterial protection for the yolk as well as creating a template for the later formation of the shell membranes and shell. Next the developing egg passes into the isthmus which, over one hour, produces the fibres that make up the inner and outer shell membranes. The egg then enters the tubular shell gland where water and electrolytes enter the albumen (a process called "plumping") and the formation of the mammillary cores commences, over a period of approximately 5 hours. The longest time during egg formation is spent in the shell gland pouch (at least 15 hours) and it is here that the egg shell is formed and the process of "plumping" is completed. The organic matrix of the egg shell consists of the shell membranes, the mammillary cores, the shell matrix and the cuticle. The inorganic portion of the egg shell consists of calcium carbonate. The different layers of the egg shell: the mammillary knob layer, palisade layer and surface crystal layer are made up of calcite crystals of different orientations. The fine structure of the avian egg shell is described in Nys *et al.* [4], Roberts and Brackpool [5] and Solomon [2], Recent evidence suggests that it is the formation of the organic matrix that determines the rate of formation of the egg shell and the termination of shell formation [4,6]. Finally, the egg is laid via the vagina and cloaca. The complex nature of the process of formation of the internal components of the egg and the egg shell means that quality problems may arise at any of several stages during the formation of the egg. Also, problems with egg internal quality and egg shell quality may result from a combination of factors, rather than from a single factor. However, research has identified a number of factors that are known to adversely affect egg quality.

Egg Shell Quality

Measurement of Egg Shell Quality: Egg shell quality may be measured in a number of ways. Some of these methods necessitate the destruction of the egg. In addition, some methods are direct whereas others are indirect [6]. Direct methods include measures of shell breaking strength such as impact fracture force, puncture force or quasi-static compresses and shell weight. Direct and indirect measurements of shell strength can also be considered as mechanical and physical properties of the egg, respectively [7]. In commercial operations, eggs are either candled using light to detect cracks and other defects or they pass through an electronic crack detector for detection of cracks. Experimentally, egg shell quality may be measured by a number of ways and there is some equipment available commercially to assist with these measurements, such as the egg quality equipment produced by that is used in the laboratory. The specific gravity of the whole egg may be measured by immersing eggs in salt solutions of different specific gravity to see at what concentration of solution they float. Alternatively, special equipment can be used based on Archimedes principle. However, a number of authors have raised questions for the validity of the use of egg specific gravity as a measure of egg shell quality [8-10, 13, 11]. At best, it is an indirect indicator of the amount of shell present in relation to the size of the egg. Shell color may be monitored by visual comparison with a series of graded standards or it may be measured by shell reflectivity, which is detection of the proportion of incident light that is reflected from the surface of the egg, under controlled conditions. Egg weight is easily measured by a suitable balance. The measurement of shell breaking strength and shell deformation (either destructive or non-destructive) requires the use of special equipment. Shell breaking strength is most commonly measured by quasi-static compression where the egg is compressed under controlled conditions until the shell cracks or breaks. The minimum force required to cause failure of the shell is then recorded. Studies have shown a strong negative correlation between shell breaking strength measured by quasi-static compression and the percentage of cracks. Indirect means include specific gravity, non-destructive deformation, shell thick quasi-static compression and the percentage of cracks [10]. Shell deformation may be non-destructive where the deflection of the shell under a given force is measured, or it may be destructive and measured as the distance the shell is compressed before it fails [12]. The amount and thickness of the egg shell have been found to be related to egg shell strength.

Shell weight may be measured by breaking open an egg, carefully rinsing the pieces of shell, drying them and then measuring shell weight. The shell weight can then be calculated as a proportion of egg weight to give percentage shell. Shell thickness may be measured by a suitable gauge and is usually measured on three pieces of shell taken from around the equator of the egg. In the author's laboratory, a gauge based on a Mitutoyo Model 2109-10 Dial Comparator Gauge, mounted on a frame, is used to measure shell thickness. The strength of an egg shell is determined not just by the amount of shell that is present, but also by the quality of construction of the shell. Studies of the quality of construction are conducted by examining the ultrastructure of the egg shell under the scanning electron microscope, as described by Solomon [2], Roberts and Blackpoll [5] and Nys *et al.* [4]. In circumstances where shell weight, percentage shell and shell thickness are good but shell breaking strength is relatively poor, the explanation probably lies with the shell ultrastructure, or how well the shell has been constructed. New techniques, such as the measurement of dynamic stiffness of the eggshell, are being developed all the time and compared with the more traditional measurements of egg shell strength [11]. These authors point out that the different measures of egg shell strength are measuring slightly different things.

Factors Affecting Egg Shell Quality

Age and Bird Strain: As a result of genetic selection, different strains of laying hen vary significantly in egg shell quality, egg size and production [12] and there are clear differences between modern commercial birds and traditional breeds of laying fowl. Selection for one characteristic such as production or egg weight can affect other characteristics of the hen such as egg shell quality [13]. Genetic selection programs need to monitor a range of characteristics to ensure that improvement of one characteristic is not at the expense of other equally important traits. Older birds tend to lay bigger eggs and have a higher egg output, which impacts on shell strength as described above [15]. Very young birds with immature shell glands may produce shell-less eggs or eggs with very thin shells [16]. A number of studies have shown that egg shell quality decreases as birds grow older [14-17]. Egg size increases with increasing hen age at the same time as shell weight increases or stays the same. Either way, the increase in egg weight is not accompanied by a proportional increase in shell weight so that the ratio of shell weight to egg weight (often referred to aspercentage shell) decreases. There is some evidence that the inability of the hen to produce an increased amount of egg shell is related to the activity of 25-hydroxy-cholecalciferol-1-hydroxylase, an enzyme involved in calcium homeostasis [18, 19]. Dietary manipulations that decrease egg size may improve egg shell quality in older hens [20] and some supplements are effective in improving egg shell quality in aging hens [21].

Egg Shell Integrity: Defects considered under the category of egg shell integrity include gross cracks, hairline cracks, star cracks and thin shelled or shell-less eggs. As cracked eggs cannot be made available for retail sale, high number of cracked eggs will have a negative impact on the profitability of any egg producer. One of the most obvious reasons for egg shell cracks (including gross cracks, hairline cracks and star cracks) is mechanical damage Egg shell strength ultimately affects the soundness of the shell, with weaker shelled eggs more prone to cracks and breakages and subsequently microbial contamination [22, 23]. The effect of aging on egg shell quality can be reversed to some degree by the process of induced moulting Results are variable depending on the nature and severity of the moult and the age of the birds. Roland and Brake [24] reported that the benefits did not last long in older birds and other workers refer to the relatively transient nature of the improvements in shell quality [25,28]. Shell strength can be affected by a wide range of factors including: Nutrition, bird age, egg size, mycotoxicosis and etc.

Nutrition and Water Quality: Each egg shell contains up to 3 grams of calcium. Therefore, the diet of hens must contain adequate calcium in a form that can be utilized efficiently. There is conflicting evidence about the use of particulate calcium although the consensus appears to be that 50-70% of the calcium should be in the form of coarse (2 to 5 mm diameter) particles and the remainder in powder form [4]. The provision of adequate dietary minerals and vitamins is essential for good eggshell quality. Similarly, as water quality varies from country to country and region, the role of drinking water in mineral and trace element supply should not be overlooked. Calcium and phosphorous are essential macro. minerals with calcium forming a significant component of the shell and phosphorous playing an important role in skeletal calcium deposition and subsequent availability of calcium for egg shell formation during the dark period [29,32]. In addition, environmental considerations have resulted in pressure to minimize level of phosphorus in the diets, especially in some densely populated countries. The levels of calcium in feed need to be increased during the rearing period, 7 to 10 days prior to the appearance of the first egg [33]. There is some evidence that provision of additional calcium too soon can result in negative effects on the kidneys if the levels of phosphorus are low [34]. However, more importantly, if additional calcium is not provided early enough, there may be long-term negative effects on calcium metabolism and bone stores of calcium [4, 35].

Vitamins such as Vitamin D are necessary for calcium metabolism and must be included in the diet. The vitamin D metabolite 25-hydroxyvitamin D_3 (which is converted into the biologically active form of vitamin D_3 inside the bird) is now commercially available and may prove valuable under some circumstances. Adequate levels of vitamin C are essential for normal good health and may also help to alleviate the effects of stress [35]. There is also evidence that supplemental vitamin E assists under conditions of heat stress [36]. Low levels of vitamin A may increase the incidence of blood spots, which reduce the internal quality of the egg [37]. Water quality may influence egg shell quality. Water containing high levels of electrolytes (saline drinking water) may have long term negative effects on egg shell quality [38]. However, the imported strains of laying hen do not appear to be as susceptible to this effect as are the Australian-bred strains [39]. The water supplied to birds must also be hygienic to ensure that disease is not transmitted by this route. The temperature of the water provided to laying hens is also important, especially during hot weather. It appears that hens reduce water intake or may even cease to drink, if the water gets too hot. Studies have shown that provision of cool drinking water can improve egg shell quality in heat-stressed hens [40].

Diets containing high levels of non-starch polysaccharides (NSPs) increase gut viscosity, hold a large amount of water and cause watery and sticky droppings. The use of NSP-degrading enzymes has been used for some time in broiler diets, to alleviate these problems [41]. In recent years, feed enzymes have been added to the diets of laying hens, mainly in an attempt to reduce the incidence of wet droppings and the consequent management problems. A study conducted at the University of New England found that addition of commercial enzyme preparations to poultry feed not only improved the moisture content of droppings under some circum stances, but also resulted in improved egg shell quality for wheat-and barley-based diets [42]. However, this study also found that the addition of the enzymes caused some lightening of the colour of the egg shells of brown egg layers and a reduction in Hough Units. These potential negative effects need to be monitored during any use of feed enzymes for laying hens. Phytase is used in poultry diets to release phytate-bound phosphorus and reduce phosphorus levels effluent. Phytase supplementation has been shown to improve egg shell quality and the effects of phytase supplementation are modi?ed by the levels of calcium and nonphytate phosphorus in the diet [34,43,46]. Australian poultry diets typically contain up to 10 % meat meal so that phosphorus is not usually limiting. However, recent evidence of synergistic effects of phytase and xylanase in wheat-based broiler diets [47] warrants consideration of use of phytase in Australian layer diets. In addition, the possibility exists that less meat meal will be used in poultry diets in the future. Contamination of feed with mycotoxins has the potential to reduce production and egg shell quality. However, it is likely that these effects are mediated via a reduction in feed intake of the contaminated feed [48]. Some hens, as the result of possessing an inherited gene, accumulate significant amounts of trimethylamine (TMA) in eggs, resulting in an unacceptable fishy odor. The cause is the inability of the hens to oxidize the TMA contained in feed ingredients such as rapeseed meal and fish meal [37].

Stress

General Stress: A range of types of general stress can affect egg shell quality. High population densities were shown some time ago to increase the production of body-checked eggs [49]. Body-checked eggs are thought to result from contraction of the shell gland while the egg shell is in the early stages of formation. Stress can also induce delays in the timing of oviposition when hens retain their eggs and this can result in an increased incidence of white-banded and slab-sided eggs [50]. The white-banded egg is the one that is retained beyond the normal oviposition time while the slab-sided egg is the one that entered the shell gland while the first egg was still there. The stressors of relocation, or exclusion from nest boxes of birds that normally had access to them, can cause an increase in the incidence of calcium "dusted", white-banded, slab sided and misshapen eggs [50, 51]. Even handling of birds which are not used to handling can increase the incidence of cracked eggs [52]. Many of the deleterious effects of general stress on egg quality can be induced by injections of adrenaline [51, 53].

Heat Stress: The high temperatures (above 25°C) experienced in most parts of Australia and also in other countries during the summer can result in smaller eggs and reduced shell quality via a number of physiological processes occurring within the bird [54]. Heat stress reduces feed intake and limits the availability of blood calcium for egg shell formation. It may also reduce the activity of carbonic anhydrase, an enzyme which results in the formation of bicarbonate which contributes the carbonate to the egg shell [55]. Therefore, sodium bicarbonate supplementation during heat stress may improve egg shell quality [56]. Feeding practices in hot weather should focus on ensuring that birds are receiving adequate levels of essential nutrients [57]. Diets need to be formulated to match feed consumption and it should be recognized that birds will tend to eat most during the cooler times of the day. The addition of fat to the diet during hot weather has beneficial effects, apparently via a number of mechanisms [57]. The form of calcium provided probably affects the ability of the birds to produce good quality egg shells under hot conditions and it appears that the provision of about half the dietary calcium in a coarse particulate form can improve egg shell quality in heat stressed birds. However, there is no evidence to suggest that increasing the calcium level of the diet above that necessary to achieve an adequate intake of calcium has any beneficial effect [58, 59]. It appears that the phosphorus requirement of laying hens increases slightly at hot environmental temperatures. Other dietary remedies that have been tried to alleviate the negative effects of heat stress include addition of sodium bicarbonate to the diet [55] and supplementation of dietary electrolytes and addition of aluminosilicates. However, the results of using these additives have been variable [58]. As already mentioned, the provision of cool drinking water can alleviate the effects of heat stress.

Disease: A number of trematode and *Prosthogonimus* spp. can inflame the oviduct that resulting in the formation of eggs with soft shells or lacking a shell eases have been reported to affect egg shell quality. Any disease that compromises the health of the bird may result in defective eggs and egg shells by indirect ways. Spackman [60] reviews a range of diseases and their effects on egg quality and an excellent summary of avian diseases such as Egg Drop Syndrome (EDS), Infectious Bronchitis (IB), NCD and Infectious Laryngotracheitis (ILT) in contained in Charlton *et al.* [61]. Any pathogenic agent that grows in the tissues of the reproductive tract can cause problems with egg shell formation. Infectious bronchitis has been reported to cause egg shells to be paler in color and sometimes wrinkled in appearance. Egg drop syndrome, as well as causing drops in production may also result in paler colored egg shells and other deformities such as soft-shelled eggs or rough shells. Other diseases that may cause production drops are Newcastle disease, avian influenza, avian encephalomyelitis and *Mycoplasma gallisepticum* (MG) [61].

Housing Systems: The type of production system may influence egg shell quality. However, early problems with cracked eggs in furnished cages have been greatly improved by changes in design of the furnished cages to include egg saver wires and long nest curtains [62]. Direct comparisons among the different types of production system (e.g. cage, barn, free range) have been made difficult by the shortage of experiments in which all other variables have been maintained constant. Some of the problems with egg shell quality reported from free range systems [63] may result from an inability to ensure a balanced diet for the hens. Some studies have found effects of cage density on egg shell quality [64] alternative housing systems on egg quality and functionality. Very little research has compared the effects of alternative housing systems on egg quality and functionality Hidalgo *et al.* [65], have produced the most comprehensive report thus far on egg functionality and hen housing systems. In their work, caged, cage-free, organic and free-range systems were compared. Organic eggs had the greatest whipping capacity and foam consistency along with the lowest Hough unit scores (indicating poorer egg quality). Cage-produced eggs had the lowest whipping capacity, indicating that they were fresher than other eggs. Hidalgo *et al.* [65], attempted to develop a multivariate technique discriminate partial least squares regression to classify the eggs from the different production systems. Successful, consistent discrimination could only distinguish cage from non cage produced eggs. The most powerful discriminates were found to be shell breaking strength, whipping overrun, protein content and shell thickness. Although the method could not discriminate each of the production methods, it is encouraging that it was able to continually distinguish cage- from cage-free-produced eggs.

Proprietary Products: Some of trace minerals are necessary in small quantities. These include zinc and manganese which act as cofactors or activators for enzymes that are involved in egg shell formation. The form in which these trace minerals are ingested influences the efficiency with which they can be utilized by the laying hens [21]. Proprietary products are available that provide the minerals in forms which improve their availability to the birds. Examples of these products are Egg Shell 49 (Alltech), Iron Egg (All Farm Animal Health, Australia) and Egg Booster (Pro Poultry Australia-distributor for Zinpro Animal Nutrition). It would be expected that trace minerals provided in such a form would result in improved egg shell quality. However, it is not always possible to demonstrate improvements [66, 67], so the additional costs of such products require careful consideration in relation to the potential benefits.

Internal Quality

Measurement of Egg Internal Quality: The interior of the hen's egg consists of the yolk and the white or albumen. A good quality egg should be free from internal blemishes such as blood spots, pigment spots and meat spots. Some commercial grading machinery allows for detection of these defects. Yolk quality is also a component of the internal quality of the egg. There is two components for yolk quality, the colour of the yolk and the strength of the perivitelline membrane which surrounds the yolk. If the perivitelline membrane is weak, the yolk will break more easily [68]. Yolk color preference varies considerably depending on the part of the world and pigments of either natural or synthetic origin may be added to achieve a desired yolk color. In Australia, the preferred yolk color is about 11 on the Roche scale. However, other countries prefer darker or lighter yolk color. The quality of the albumen is usually measured from the height of the albumen at a distance of1 cm from the edge of the yolk. Albumen height is usually converted into Hough Units, based on the following calculation of Hough [69]: However, the validity of the Hough Unit has been questioned [69-71] because it is influenced by the age and strain of bird and is affected by storage.

Hough Unit Equation [69].

$$HU = 100 \log (H-1.7w^{0.37} + 7.6)$$

Where;
HU=Hough unit
H =height of the albumen (mm)
W = Weight of egg (g)

Little is known about the way in which the components of albumen interact, although interactions between ovomucin and lysozyme have been suggested. The changes that occur when albumen becomes less viscous are still poorly understood but ovomucin appears to play a major role and ovalbumin is probably also involved [72]. Leeson and Caston [74] speculate that low viscosity thin albumen may result from eggs spending longer than normal in the shell gland (i.e. by egg retention) and therefore taking up more water, although this correlation has not been demonstrated. Many factors are reported to affect Hough Units:

- Storage time
- Temperature
- Hen age
- Strain of bird
- Nutrition (dietary balance to meet protein and amino acid such as: Lysine, methionine, feed enzymes, grain type and protein source)
- Disease
- Supplements (ascorbic acid, vitamin E)
- Artificial exposure to ammonia,
- Induced moult
- Medication (e.g. Sevin). It is likely that these factors interact in affecting albumen height and Hough units. There is some evidence that the mechanisms by which albumen quality deteriorates are different between changes occurring during egg storage and changes resulting from other factors [75, 76].

Albumin quality: Albumen height and Haugh Units measure the viscosity of the thick albumen. However, current problems in Australia with internal quality often involve a very low viscosity of the thin albumen. Egg albumen has about 12% protein of which the main ones are ovalbumin (54%), ovo transferrin (13%), ovomucoid (11%), α and β ovomucin (1.5-3%) and lysozyme (3.5%) [3]. All except lysozyme are glycoproteins. It is known that there are many minor proteins in albumen but few of these have been identified. Robinson [73] and Li-Chan and Nakai [72] provide a comprehensive review of the components of egg albumen and changes that occur during storage. Furthermore, some of others internal and external quality traits of the egg were estimated using following formulae on the basis of the aforementioned measures [70, 72].

S = $3.9782 W^{0.75056}$
S = Egg surface area (cm^2)
W = Egg weight (mg)

Unit surface shell weight (mg/cm) = Egg weight (mg) / Egg surface area (cm)
Shape index (%) = [Width (cm) / Height (cm)] x 100
Shell ratio (%) = (Shell weight / Egg Weight) x 100
Albumen index (%) = Albumen height (mm)/[(Albumen length (mm) + Albumen width (mm)]/2) x 100
Albumen ratio (%) = (Albumen weight / Egg weight) x 100 Yolk index (%) = (Yolk height / Yolk diameter) x 100
Yolk ratio (%) = (Yolk weight / Egg weight) x 100
Albumen weight (g) = Egg weight - (Yolk weight + Shell weight)

Age and Storage of the Egg: As the egg ages and carbon dioxide (CO_2) is lost through the shell, the contents of the egg become more alkaline, causing the albumin to become transparent and increasingly watery [77]. At higher temperatures, loss of CO_2 is faster and the albumin quality deteriorates faster. Decreasing shed temperatures in the hotter months, combined with regular collection of eggs will help to reduce deterioration of the albumin before collection. Eggs stored at ambient temperatures and humidity lower than 70% will lose 10-15 HU in a few days from point oflay. By 35 days, these eggs will lose up to 30 HU [78]. Storage of eggs at temperatures of 7-13°C and a humidity of 50-60% (as discussed under mottling), will reduce the rate of degeneration of thick albumen proteins and, consequently, egg albumin quality will be maintained for longer [79]. Oiling of eggs can also help to reduce CO_2 losses and thus help maintain internal egg quality but is not a substitute for cool storage [77, 80].

Age of the Hen: HU will decrease with increasing bird age value, with HU decreasing by around 1.5 to 2 units [82] for each month in lay. Doyon *et al.* [83] stated that HU decreases at a fairly constant rate of 0.0458 units day" of lay as the hen ages. Doyon *et al.* [83] also noted that in an ideal situation, HU should be on average 102 at 20 weeks of age, falling to an average of 74 HU by 78 weeks of age.

Consistency: Albumin quality is measured in terms of Haugh Units (HU) calculated from the height of the albumin and the weight of the egg. A minimum measurement in HU for eggs reaching the consumer is 60. However most eggs leaving the farm should be between 75 and 85 HU [84]. Albumin consistency is influenced by:

Nutrition: A number of nutritional factors have been reported to affect albumen quality although Williams [85] concluded that albumen quality is not greatly influenced by bird nutrition. Nevertheless, there are reports of albumen quality decreasing with increasing dietary protein and amino acid content [86], increasing with increased dietary lysine concentration [87], decreasing with the dietary addition of neem kernel meal [88], increasing with ascorbic acid supplementation [89] and increasing with vitamin E supplementation, especially at high ambient temperatures [68, 90]. Different types or cultivars of grains such as pearl millet [91] or wheat [81] can also affect albumen quality.

Contaminants: Ingestion of crude oil resulted in lower Hough Units in poultry [92]. Vanadium has also been shown to reduce albumen quality by reducing the amount of crude ovomucin per millilitre of thick egg albumen [76]. The ovomucin content of the thin albumen was not affected by vanadium supplementation of the diet.

Disease: The main disease of laying hens that has been reported to affect albumen quality is infectious bronchitis virus which may cause a decrease in quality and more variable albumen quality [60]. There is evidence that infectious bronchitis impairs the synthesis of albumen proteins in the magnum of the oviduct [93] and is associated with histological changes in the epithelium of the magnum [94].

Yolk quality

Yolk Colour: Yolk quality is determined by the colour, texture, firmness and smell of the yolk. Although, yolk colour is a key factor in any consumer survey relating to egg quality [77], consumer preferences for yolk colour are highly subjective and vary widely from country to country. The primary determinant of yolk colour is the xanthophyll (plant pigment) content of the diet consumed [95]. It is possible to manipulate the yolk colour of eggs by the addition of natural or synthetic xanthophylls to layer hen feeds. This ability to readily manipulate egg yolk colour can be an advantage in meeting market demands. However, the ease with which yolk colour can be manipulated can lead to unwanted colour changes.

For example, the inclusion of higher than recommended levels or incorrect ratios of pigments can lead to orange-red yolks [95]. Similarly, diphenyl-para-phenylenediamine (DPPD), an antioxidant, has been reported to cause excessive deposition of pigments in the egg yolk. Pale yolks can result from any factor which alters or prevents the absorption of pigments from the diet or the deposition of these pigments in the yolk. These factors could include:1. Any factor which inhibits liver function, subsequent lipids metabolism and deposition of pigment in the yolk. For example, mycotoxicosis caused by aflatoxin Bl [96]. 2.Coccidiosis, although this is rare in adult hens.

Motted Yolk: This case (with many pale spots and blotches which vary in colour, size and shape), occur when the contents of the albumen and yolk mix as a result of degeneration and increase permeability of the vitelline membrane [97]. Dietary factors which may cause mottled yolks include:

The presence some of anticoccidal agent (nicarbazin) in the feed has shown by numerous authors to cause mottling [98].

- Worming drugs such as Piperazine [97].
- Gossypol from cotton seed meal [99].
- Certain antioxidants such as gallic acid (from grapes, tea and oak bark) and tannic acid, or tannins from grains such as sorghum [99].

Handling and Storage Temprature: Storage time and temperature has also been shown to affect the degree of egg yolk mottling [80]. Okeudo *et al.* [70] stated that as the internal temperature of the egg increases above 7°C, the protein structures of the thick albumen and vitelline membrane breakdown faster. As the membrane degenerates during storage, water enters the yolk causing mottling and after prolonged storage, albumen proteins also enter the yolk increasing the severity of mottling.

Yolk Firmness: The yolk of a freshly laid egg is round and firm [80]. However, as the egg ages and the vitelline membrane degenerates, water from the albumen moves into the yolk and gives the yolk a flattened shape.

Yolk Texture: Rubbery yolks may be caused by severe chilling or freezing of intact eggs, the consumption of crude cottonseed oil or the seeds of some weeds [23].

Internal spot

Blood and Meat Spots: Blood spots may vary from indistinguishable spots on the surface of the yolk to heavy contamination throughout the yolk. Although, blood spots are normally closely associated with the yolk and occasionally blood may be diffused through the albumin. Blood spots occur when small blood vessels in the ovary rupture when the yolk is released. Vitamin K plays an important role in blood clotting. Vitamin K deficiency can result in an increased occurrence of blood spots [100]. Some strains of birds appear to be predisposed to blood spots although the incidence is low [15]. Avian encephalomyelitis has been reported as a cause of blood spots [101]. Jones [99] reported an increase in blood spots from essentially 0 to 3% in birds affected with T-2 toxicosis. Mycotoxicosis may reduce vitamin K absorption and this may explain the elevated incidence of blood spots in hens affected by T-2 toxicosis. Meat spots these are usually associated with the albumin rather than the yolk and often consist of small pieces of body tissue. However, some may consist of partially broken down blood spots or pigments. The occurrence of blood spots varies with strain of bird, increases with age of bird and is reported to be higher in brown egg layers [101, 102].

CONCLUSION

As mentioned above, many factors can affect egg shell quality and egg internal quality. An awareness of this range of factors allows an egg producer to monitor eggs and optimize egg quality. However, on the basis of above information to arrive the best management, best practice, highest performance and optimum feed efficiency proposed the following factors:

- Proper housing is essential for efficient egg production. Birds that are comfortable are healthier than birds kept under improper conditions and production costs are lower. Environmental temperature and air circulation are critical, with the optimum temperature being between 57 and 79°F (13.9 and 26.1°C).
- Production system, at present time over 90 percent of all eggs produced in the world are from caged layers. Eggs produced in cages cost less to produce than those in floor systems due to much more intensive labor and floor space requirements with

the latter. Most new operations are environmentally controlled multiple-level cage systems that are completely automated with mechanical feeding and watering equipment and conveyor belts that carry the eggs out of the laying house. Environmental housing also provides a method of controlling temperature, light and humidity. Additionally, controlled housing provides protection from predators and disease-carrying rodents and pests.

- Eggs top quality related to have a high percentage of thick albumen. A lack of this factor can be attributed to breeding and disease of the birds and to improper care of the egg after production. Low quality whites can also be attributed to high levels of ammonia gas in the laying house due to improper optimum ventilation of system.
- Nutrition management, the breaking strength of an egg shell is affected by feed, breeding, age, free from disease and heat stress. The average commercial feed supplemented with "grit" (calcium carbonate) usually has sufficient calcium, phosphorus, manganese and vitamin D to produce sound shells.
- Control of management related to careful egg collection, handling and processing of transportation, immediately after it is laid, an egg begins to lose quality, even if it is removed from the nest, cooled, packed and marketed promptly. Keeping temperature and humidity conditions at an optimum level retards this loss in quality to a large degree. Although most eggs are produced by large in-line integrated operations, some are still produced from off-line production facilities. At off-line sites, certain steps are necessary to maintain egg quality at the highest level. Some of these steps are: Gather eggs frequently (at least 3 times a day); Handle the eggs carefully to prevent breakage; Cool the eggs promptly and store them under the optimum temperature and humidity; Pack the eggs in clean, cool packing materials; and Pack clean eggs separately from dirty eggs.

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