Egg Quality Reference Manual

A RESOURCE TO FURTHER INFORM PRODUCERS ABOUT EGG AND EGG SHELL QUALITY

By Julie R. Roberts | Funded by Australian Eggs Limited | FIRST EDITION

Australian eggs

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Egg Quality Reference Manual

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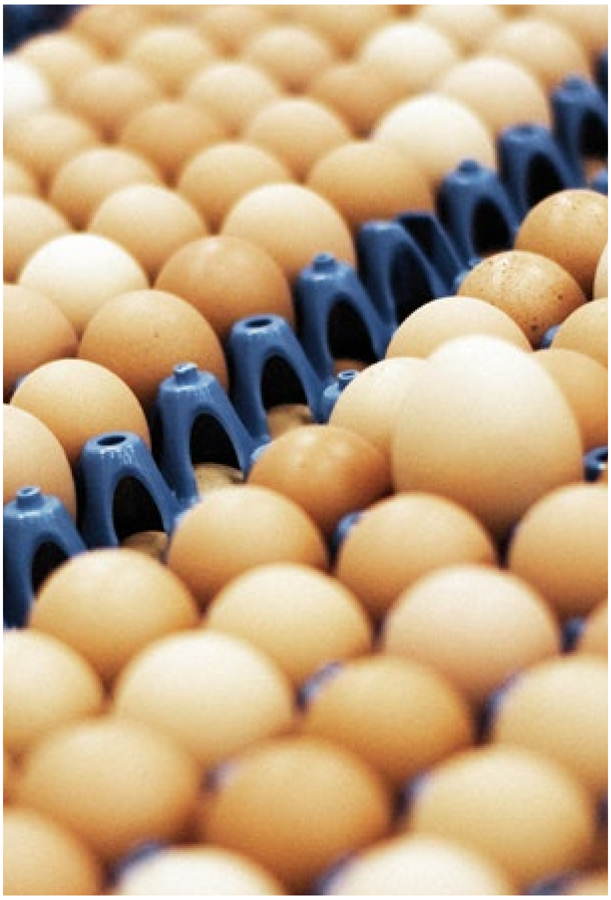
Introduction

The main purpose of this booklet is to provide sufficient information for producers to be able to compare the egg internal quality and egg shell quality of their flocks with typical data from the industry in order to make informed production decisions.



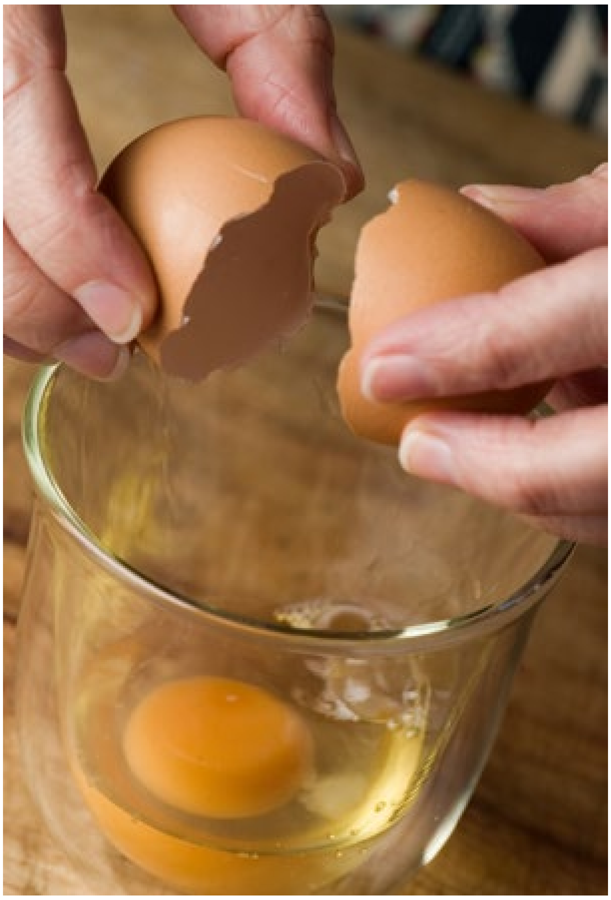
Information obtained from egg grading facilities indicates that a large percentage of eggs are lost to shell quality problems. In today's market of high supermarket standards, shell quality, albumen quality as well as egg yolk characteristics are important to consumers.

Considered egg quality characteristics include:

EXTERNAL FACTORS	INTERNAL FACTORS
Clean oval shape	Yolk colour
Smooth strong shell	Yolk centrally held, firm and round
Uniformity of shell colour	Distinct thick inner albumen

Egg quality issues have further flow on effects in the case of breeder birds, and fertile egg production, affecting embryo viability and chick hatchability.

It is critical for the Australian egg industry to have available guidelines on the levels of egg shell quality and internal quality realistically able to be achieved in a commercial setting.



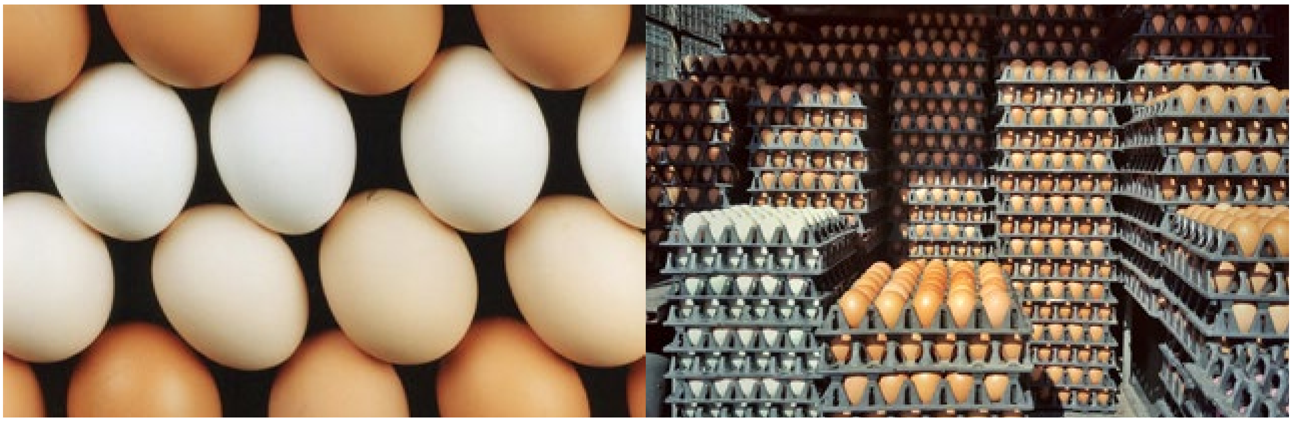


Figure 1 – Brown, tinted and white coloured eggs

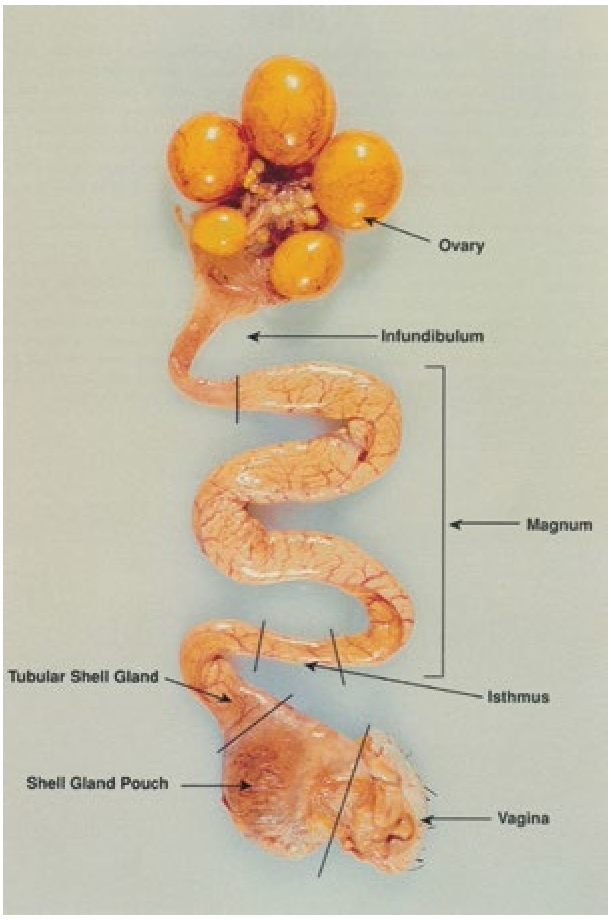


Figure 2 – The ovary and oviduct of the mature laying hen

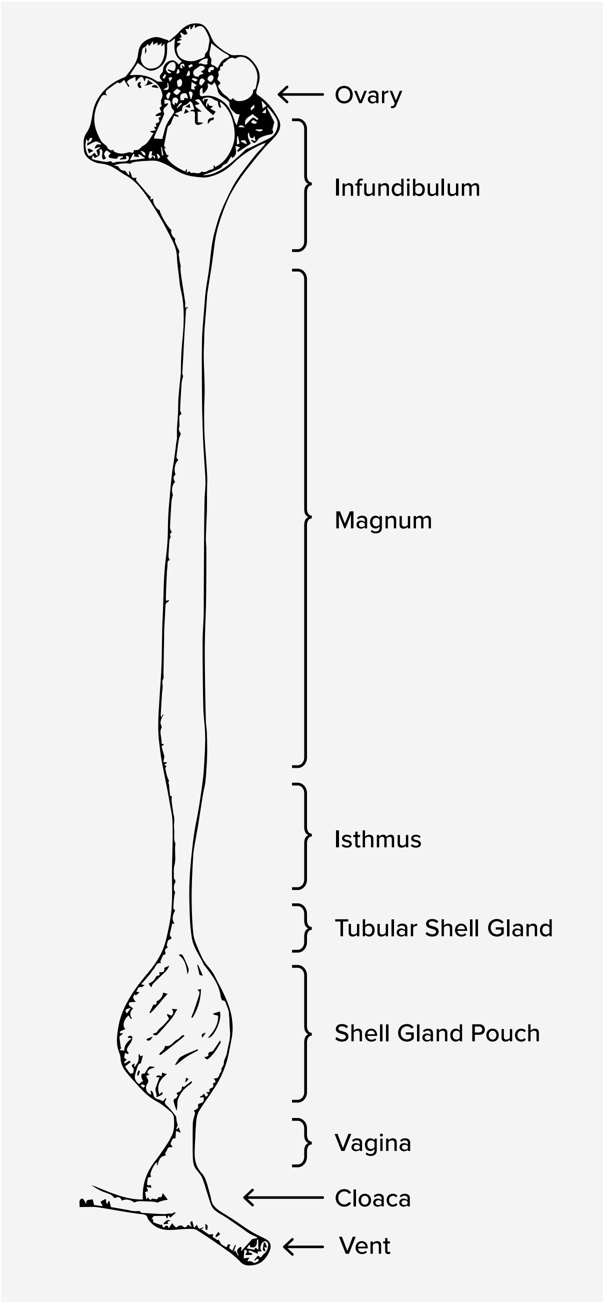


Figure 3 – The ovary and oviduct of the mature laying hen

1 Egg and eggshell formation

In order to evaluate the causes and solutions of problems associated with shell quality, it is necessary to understand the processes of egg and eggshell formation.

1.1 The ovary and oviduct

Figures 2 and *3* show the reproductive system of the domestic hen. Birds are unique among animals because only one ovary (the left) matures to the stage where it releases eggs or ova into the oviduct. The ovary of a mature hen contains thousands of immature oocytes that develop sequentially into follicles (known also as ova or yolks) ready for release into the oviduct. The oviduct is a tube-like structure that completes the formation of the egg. The oviduct is divided into different sections, each performing its own individual role in egg formation; these sections are the infundibulum, magnum, isthmus, shell gland and vagina.

1.2 Egg formation

The process of egg formation is a well-researched area. The structure of the egg and the physiological role of the oviduct during egg formation are quite well understood. This brief summary will concentrate on the structure of the egg as it is formed rather than on the physiology of the reproductive tract.

At ovulation, the yolk is released from the ovary into the body cavity. The infundibulum is the first section of the oviduct and its main role is to actively capture the yolk from the body cavity and direct it into the oviduct. The yolk remains in the infundibulum for 20 minutes. During this time, if sperm are present, fertilisation occurs and the egg will have the potential to form a new chicken.

The infundibulum also has roles in the addition of the membrane that immediately surrounds the yolk (perivitelline membrane) and in the formation of the chalazae (the ‘anchor-like’ structures that hold the yolk in place).

The magnum is the next and longest section of the oviduct. However, the yolk spends only four hours travelling through it. During this time, the addition of egg white protein occurs. There are many different proteins that make up the egg white. The layers of proteins provide mechanical and bacterial protection for the yolk as well as creating a template for the formation of the shell membranes and shell. This template is created from a layer of sulphated mucus applied in the final portion of the magnum.

The yolk with its layers of egg white now passes into the isthmus where it remains for one hour. The isthmus contains many secretory cells that produce the fibres that make up the inner and outer shell membranes. This is a rapid procedure and the egg moves quickly into the next section of the oviduct.

The egg then enters the shell gland, which is responsible for producing the final volume of egg white (albumen) and completing the eggshell. The shell gland is divided into two sections: the tubular shell gland and the shell gland pouch. The egg spends about 19 hours in the shell gland and the first five hours are spent in the tubular shell gland.

The tubular shell gland has two responsibilities:

(1) It causes an increase in the albumen volume by facilitating the movement of water (approx. 8 mL), rich in electrolytes, into the egg; and

(2) It arranges the outermost fibres of the shell membrane into mammillary cores (which are chemically modified end portions of the shell membrane) through the transfer of calcium salts on to the shell membrane fibres.

The mammillary cores are of importance because they act as points of contact for the crystals of calcium carbonate that form the majority of the eggshell. Although the time spent in this section of the shell gland is a lot shorter than the time spent in the shell gland pouch, this organisation of the mammillary cores is a critical step in determining the eggshell quality of the completed egg.

The egg then moves into the lower part of the shell gland, the shell gland pouch. Here the process termed calcification occurs, where calcium carbonate layers are added to form the eggshell. The process of calcification can be divided into two phases. Phase one occurs over the first four hours and involves a relatively slow rate of calcification. The calcium is transferred from the blood through the shell gland into the shell gland fluid. Once the calcium is in the shell gland fluid it supports the precipitation of calcium carbonate crystals (in the form of calcite)

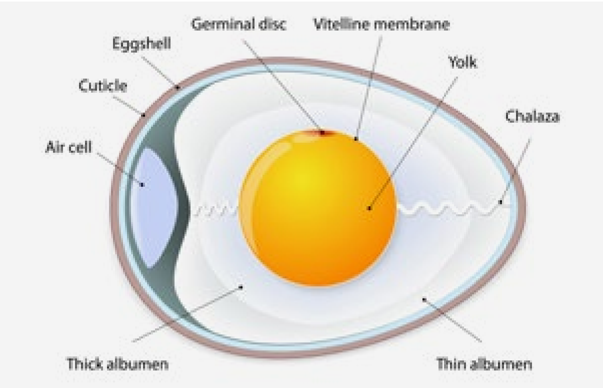


Figure 4 – The structure of the hen's egg

into the shell structure. 'Plumping' (hydration), a process that involves the uptake of salts, glucose and water into the albumen, occurs during phase one of the calcification. This movement of fluid causes the albumen volume to increase and it is thought that this swelling exposes the mammillary cores on the shell membrane. The now exposed mammillary cores initiate the next phase of calcification.

Phase two involves the bulk of eggshell formation as the layers of calcium carbonate crystals are laid down rapidly. During the last two hours of shell formation the bulk of the pigment is produced and deposited into the outer layers of the shell, including the cuticle, which is laid down to provide protection against penetration of the shell by microbes and the loss of water from the egg's contents. The result of the calcification process is an eggshell that consists of approximately 95% calcium carbonate and 5% organic material. The completed egg is pushed into the external environment through the vagina and cloaca.

1.3 The structure of the egg

The physical arrangement of the egg's structures can be seen clearly in *Figure 4*. It is of interest to note the proportional composition of the egg. The shell accounts for only 9-14% of the total egg while the yolk and albumen account for 32-35% and 52-58%, respectively. The shell therefore accounts for much less of the egg structure than the other components, yet it has perhaps the greatest effect on the egg's quality and therefore its marketability.

1.4 What is meant by eggshell quality and why is it important?

The eggshell quality, and thus the egg quality in many cases, can be defined as the visual and physical characteristics of the egg that affect its acceptability to the purchaser of the product. This definition is, of course, in terms of the table egg. Those members of the poultry industry who are involved with breeder birds look at eggshell quality in terms of hatchability. This requires different aspects of the egg's structure to be placed under emphasis, such as the density of pores in the shell. However, it must be remembered that the egg and eggshell quality are influenced not only by the quality of the freshly laid egg but also by the time period and handling procedures that the egg experiences prior to setting for hatching or being sold as a table egg.

1.5 How is eggshell quality measured?

Despite the extent of research and development that has occurred in this area, the 'perfect' technique for the measurement of eggshell quality does not exist. The answer to 'Why Not?' is simply in the nature of the egg. The egg is a fresh animal product that has time limitations on its use as either a table egg or as an incubator for hatching chicks, and both of these processes are dependent on the unique structure of the shell. The shell is the biological packaging that allows the handling and distribution of the egg to the market place in essentially the form in which it is laid. This may be why the egg is consumed world-wide by people of many different cultures and religious beliefs. The perfect method of studying the egg would be a completely non-invasive process that allowed us to determine the egg and eggshell quality without rendering the egg useless for sale or hatching. This, of course, is difficult to achieve and is why a range of techniques is used.

There are many different techniques for assessing shell quality. Most of these are designed to estimate, directly or indirectly, the strength of the eggshell as the prime determinant of shell quality. Listed below are the most commonly used and the most recently developed methods of measuring quality characteristics of the eggshell. Some methods are suitable for use during in-line processing at commercial facilities. Other methods are used in research facilities and in the Quality Assurance (QA) testing unit in commercial facilities.

(1) **Candling:** The oldest and most common technique that is used routinely in processing procedures involves placing the egg in front of a light source to examine the internal and external quality of the egg.

(2) **Indirect measurements of eggshell quality:** The methods of indirect measurement include specific gravity and non-destructive deformation (the extent to which the eggshell can be deformed

Figures 5 – Commercial egg processing

Electronic crack detector

Egg candling station

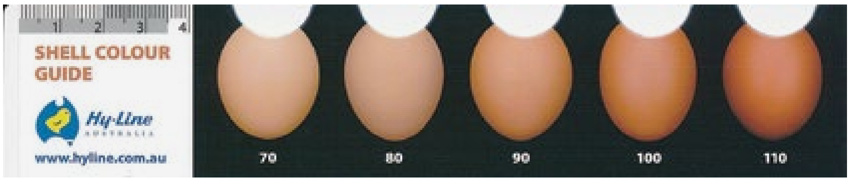
Figures 6 – Equipment used for research or commercial QA egg quality testing

Shell reflectivity and egg weight

Microprocessor

Shell thickness

Shell breaking strength and deformation



Hy-Line Shell Colour Guide

Laboratory candler

Portable equipment for measuring albumen height and Haugh unit

Commercial QA setup

Nabel digital egg tester (Japan)

without breaking). All of these involve fast and non-destructive multiple measurements that do not disrupt the egg in any way and therefore allow the egg to be hatched or sold. The negative side of these measurements is that they are not measuring quality directly but rather a previously characterised relationship between different aspects of the egg.

Electronic crack detection is an automated technique based on the vibrational response of the eggshell after it has been struck by a small steel ball which bounces back. If the eggshell is cracked, the small steel ball does not bounce back as far. This measurement provides information on the shell's integrity and strength. Research has shown that this type of technology has a 95% degree of accuracy in the detection of eggshell cracks.

(3) **Direct measurements of eggshell quality:** The quasi-static compression fracture force, puncture force, egg weight, eggshell thickness, shell weight, size and shape of the egg are all methods of directly measuring the eggshell quality. Quasi-static compression fracture force is determined by compressing the egg at a constant rate until the shell cracks. The force at which the shell fails is known as the fracture force. Most of these measurements are of a destructive nature and so disturb the eggshell to the extent where it can no longer be sold or hatched. However, they are measuring something directly and therefore the values are not limited by the presumptions involved in a characterised relationship.

(4) **Ultrastructure:** The ultrastructure of the eggshell is examined using the scanning electron microscope. This allows the quality of construction of the eggshell to be assessed, and is used only in some research applications.

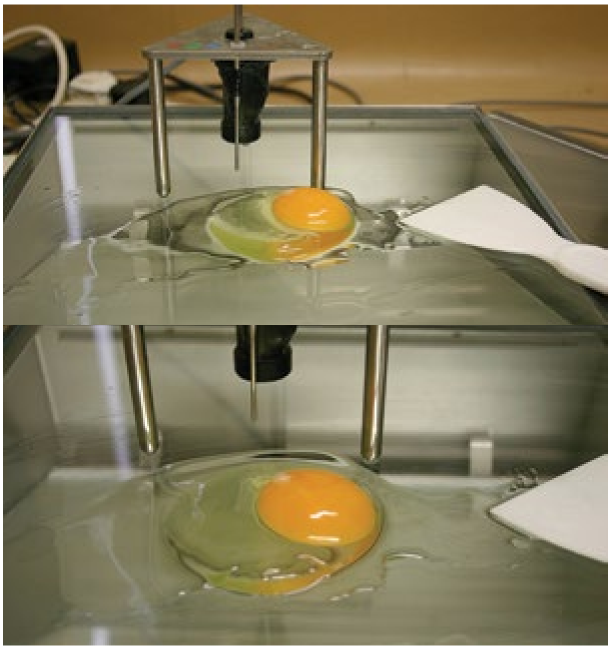


Figure 7 – Measurement of albumen quality

1.6 How is egg internal quality measured?

1.6.1 Albumen height and Haugh unit

Albumen height is the height that the albumen or white of the egg stands up when an egg is broken out onto a flat surface. The equipment measures the albumen height via a probe that detects, electrically, when the surface of the albumen is reached.

Haugh units are calculated from albumen height and egg weight by the formula developed by Haugh in 1937. The Haugh unit takes into account the size of the egg. Albumen height and Haugh units are used as indicators of internal egg quality or freshness. The equation for calculation of Haugh units is:

$$\text{H.U.} = 100\text{LOG}\left[H - \frac{\sqrt{G}(30W^{0.37} - 100)}{100} + 1.9\right]$$

H.U. = Haugh units

H = albumen height in mm

G = 32.2

W = weight of whole egg in grams

Figure 8 – Measurement of yolk colour using a yolk colorimeter or yolk colour fan

1.6.2 Yolk colour score

Yolk colour is determined on the Roche Scale and is most frequently measured using a colour fan. A yolk colorimeter measures the colour by measuring the wavelength of light reflected from the yolk. There is no user-error associated with this measurement.

2 Abnormal eggs

Figure 9 – White banded egg

Figure 10 – Slab-sided egg

2.1 White banded eggs

A white banded egg occurs when the hen retains an egg in the shell gland pouch and a second egg enters, which results in two eggs coming in contact with each other. At the point where the eggs touch, normal calcification is interrupted. The egg that was in the pouch first is virtually completed, therefore the result of retention is an extra layer of calcium seen as the white band marking. This problem may be caused by stress from a disturbance, changes in the lighting pattern or the presence of an infection.

2.2 Slab-sided eggs

The slab-sided egg is the second egg that enters the pouch. The second egg is not as complete as the first egg and is flattened at the point where the eggs make contact. This is why it is known as a 'slab-sided' egg. The slab-sided egg accounts for less than 1% of total production and is caused by the same factors as the white banded egg.

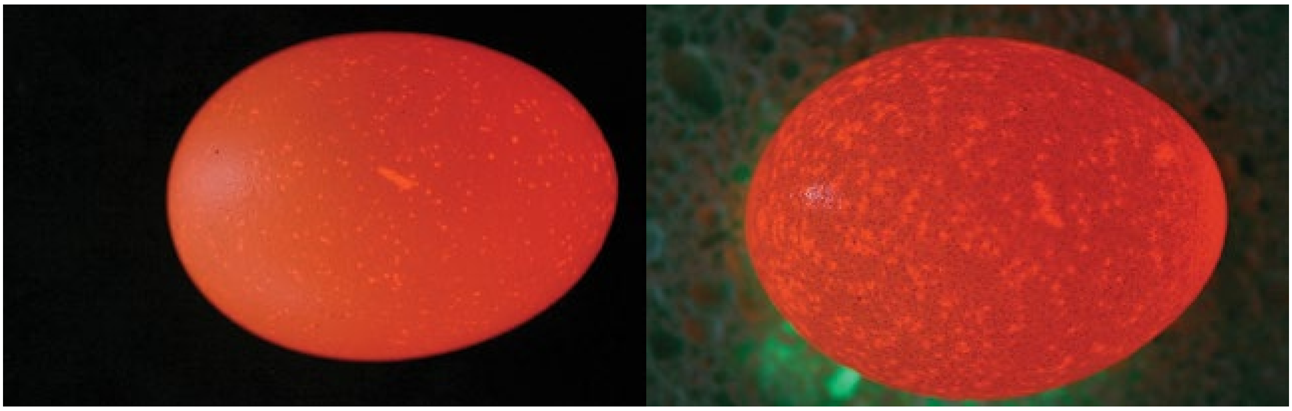


Figure 11 – Translucent eggs viewed over a light source

2.3 Translucency

Translucent areas of an egg which, when placed in front of a light source, appear mottled or glassy. This translucency is caused by structural irregularities. Other conditions known to cause translucent eggs are high humidity in the shed, disease or overcrowding. This is often not considered a problem, unless severe, as most forms pass through the grading system. The incidence varies between farms, from 2% to 11%.

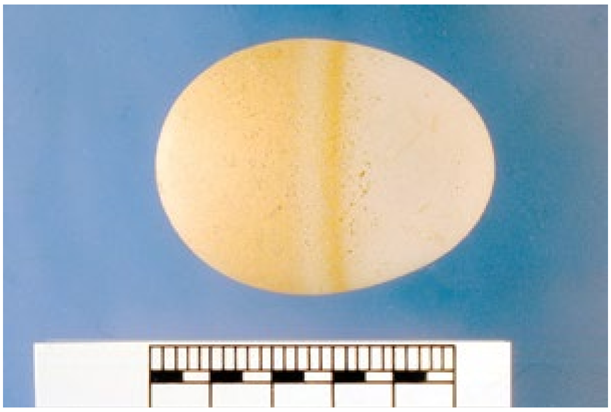


Figure 12 – Calcium coated egg

2.4 Calcium coated eggs

Calcium coated eggs have an extra layer of calcium over part of the egg. Coated eggs take on many forms. These range from an extra thin coating of calcium all over the egg to the presence of extra calcium deposits on just one of the ends of the egg. Incidence of calcium coating ranges from 5% to 20%. Some of these may cause problems for the producer if eggs are downgraded, although mild forms pass through the grading system.

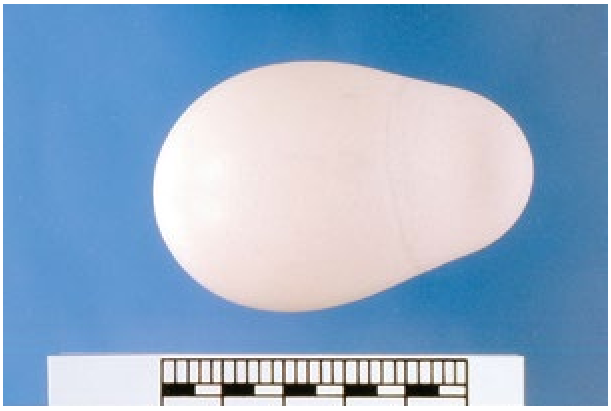


Figure 13 – Misshapen egg

2.5 Misshapen eggs

A misshapen egg is an egg that differs from the 'normal' shape and size. This includes eggs that are too small or too large, round instead of oval, or that have gross changes in the shape as shown here. Misshapen eggs have been estimated to reach up to 2% of production or 5% of second grade eggs. Misshapen eggs may be caused by many factors including an immature shell gland, disease, stress from disturbances and overcrowding.

Figure 14 – Body-checked egg

2.6 Body-checked eggs

The body-checked egg is the result of an egg being cracked in the shell gland pouch and then repaired before lay. The incidence of body-checked eggs increases with age, from about 1% of production up to 9% in the very late stages of lay. Body-checked eggs are caused by incorrect lighting, disturbances, and overcrowding.

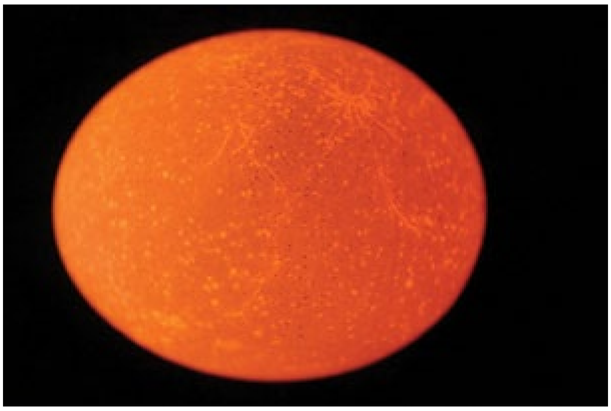


Figure 15 – Cracked egg viewed over a light source

2.7 Cracked eggs

There are many different types of cracks in eggshells, ranging from hair line cracks that are not detected without the help of candling to gross cracks that result in a hole in the shell. The incidence of cracks can range from 1% to 5% of production. In New South Wales, Australia, cracks can account for anywhere from 48% to 85% of the second quality eggs. Cracks are caused by many different factors including heat stress, saline water, bird age and poor nutrition.

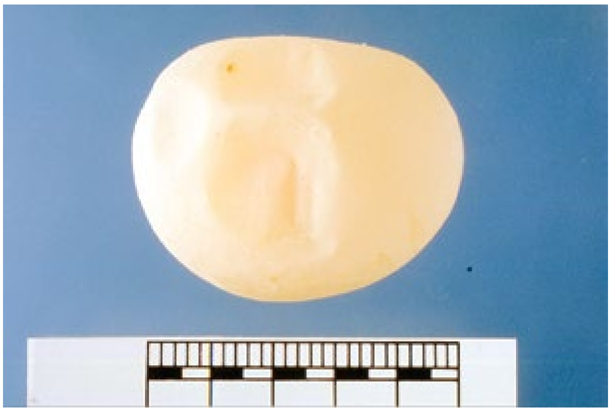


Figure 16 – Soft-shelled egg

2.8 Soft-shelled eggs

These are eggs that are laid with an incomplete shell. Therefore the egg may be protected by only the shell membrane and a thin layer of calcium. The incidence for this shell defect ranges from 0.5% to 6% of production. This problem is commonly caused by an immature shell gland, inadequate nutrition, saline water, disease and stress.

Figure 17 – Pimpled egg

2.9 Pimpled eggs

Pimpled eggs appear to have small lumps all over the shell. These are calcified material on the eggshell. Some pimples may be removed by simple rubbing, whereas others are formed from the internal membrane layers of the shell and, if removed, may leave small holes in the shell. The incidence of pimples is about 1% of production. Pimples, depending on the severity, can be caused by foreign material during the calcification process that may be related to the bird's age, strain, and nutritional status.

Figure 18 – Egg with calcium deposits

2.10 Calcium deposits

Calcium deposits are irregular shaped spots on the external surface of the shell. They have only a visual effect on the shell. These calcium spots may be caused by a defective shell gland, disturbances during calcification, retention of the egg within the shell gland and poor nutrition.

Figure 19 – Corrugated egg

2.11 Corrugated eggs

Corrugated eggs have a very rough and corrugated surface. These are thought to be produced when there is an inability to control and terminate plumping. Their production has also been reported as being associated with the presence of some diseases such as infectious bronchitis, although this has not been conclusively demonstrated.

Figure 20 – Wrinkled egg

2.12 Wrinkled eggs

Wrinkled eggs appear with thinly creased and wrinkled surfaces. The wrinkles may occur anywhere on the egg, in any direction. Wrinkles may occur as a result of stress, disease, a defective shell gland and crowding.

Figure 21 – White speckled egg

2.13 White speckled eggs

White speckled eggs are similar to eggs with calcium deposits, except that the speckles are smaller and may be laid down either before or after the cuticle, and are pigmented white.

Figure 22 – Brown speckled egg

2.14 Brown speckled eggs

Brown speckled eggs, as for white speckled eggs, are similar to eggs with calcium deposits, except that the speckles are smaller and may be laid down before or after the cuticle, and are pigmented brown.

Figure 23 – Lilac egg

2.15 Lilac eggs

Lilac eggs may also be known as pink eggs, and are named this way because the egg actually appears to be a lilac or pink colour. The difference in colour appears because of the association between the cuticle and an extra calcium layer. Lilac eggs, as with other eggs with extra calcium deposits such as speckled eggs, often result from stress or excess calcium in the feed.

Figure 24 – Broken and mended egg

2.16 Broken and mended eggshells

Broken and mended eggshells are just that – they have been broken (in this case a diagonal break) during formation and mended again before lay. Often this defect occurs when the bird is stressed during the period of calcification.

3 Known or suspected causes of egg and eggshell quality problems and proposed solutions

Many common eggshell quality problems have been identified and characterised. In this section, some of these problems will be discussed under individual headings. In the commercial situation, eggshell quality problems rarely have a single cause. Also, a problem may manifest itself in a range of shell defects. For each factor that is known to affect eggshell quality, we have covered: the problem, the cause, eggshell quality problems, the solution, and additional information.

At Section 3.11 there is a list of recommendations aimed at preventing eggshell quality problems from occurring. Together, this list and the summaries below should assist producers in reducing the incidence of eggshell quality problems.

3.1 The influence of genetics and strain

The Problem

There is significant evidence that genetic differences in egg and eggshell quality occur among species, strains and lines within strains. Genetically-determined eggshell quality characteristics are those that cannot be altered by medication, husbandry or dietary manipulation.

The Cause

The basis of genetically inherited traits is the gene. Genes contain DNA and pass information from the parent to the offspring. The information held within the genes of the animal is responsible for controlling its basic appearance and metabolic functions. Most aspects of eggshell quality are generally believed to have a moderate heritability.

Eggshell Quality Problems

The genetic variation experienced in eggshell quality has been linked to shell thickness, which is directly related to the breaking strength of the eggshell. This relationship has been shown to exist in lines that produce either a thin-shelled or a thick-shelled egg. Other characteristics directly influenced by genetics include the size, weight, and colour of the egg as well as predisposition to a specific defect such as shell-less or soft-shelled eggs.

The Solution

Genetic traits are biological and cannot be directly manipulated by the producer. Breeding programs that select for desired eggshell quality characteristics are the only method of changing the genetic influence. The main brown egg laying strains used in commercial production in Australia are very similar. In addition, new genetic material is imported on a regular basis. Breeder companies are very responsive to feedback provided about egg quality problems and attempt to select against the incidence of such problems, where there is a genetic basis. Traditional local Australian strains that lay tinted eggs are currently used by only a small number of commercial producers, mainly in free range production.

Additional Information

- Selection for one characteristic often selects, inadvertently, for some other undesirable characteristics and for this reason breeding programs need to be well constructed and monitored.
- A potential example of manipulating genes too far is the production of a thick eggshell. It would not break easily resulting in fewer eggs cracking before they reach the table of the consumer. However, at the same time, breeding eggs from the same stock may suffer an increase in embryo mortality because the developing chick cannot get enough gas exchange across the shell and cannot break the shell to get out. Incidentally, a similar problem arises when selection occurs for low-cholesterol eggs. The eggs then contain insufficient lipid to support a developing chick and the hatchability declines.
- Research has shown that the egg weight of the laying hen is related closely to body weight. This suggests that breeding towards large hens would result in a heavier egg but, as in any breeding program, this is offset by the financial costs of maintaining a larger bird.

See the graphs of egg and eggshell quality below, which show the results of egg and eggshell measurements over the laying life of the flock for current commercial brown egg laying hens.

3.2 Effects of hen age

3.2.1 Egg weight

Egg weight is the weight of the egg in grams. As hens grow older, egg weight increases to the peak of lay. Beyond that point, it is desirable for egg weight to remain relatively constant but it does increase in some flocks.

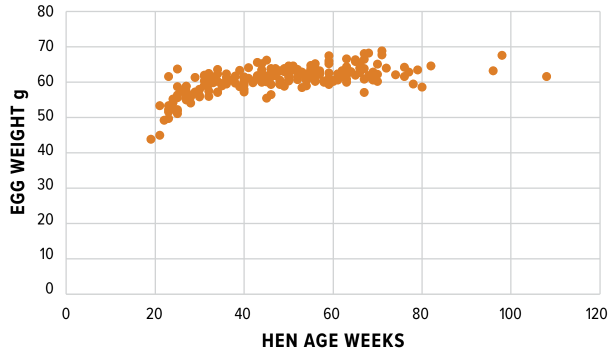


Figure 25 – Egg weight versus hen age

3.2.2 Shell colour

Shell colour is measured as shell reflectivity, expressed as a percentage, which is the amount of light that is reflected from the surface of an egg. It is an indication of shell colour lightness – the higher the value, the lighter the colour of the eggshell. Shell colour generally becomes lighter as hens age. In the graph, the three flocks with very high shell reflectivity were free range flocks. However, free range flocks do not always have lighter coloured eggshells.

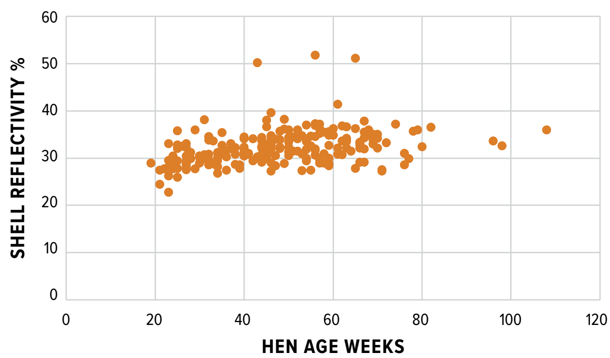


Figure 26 – Shell colour versus hen age

3.2.3 Shell breaking strength

Shell breaking strength, in Newtons, is the force that must be applied to the egg before it fails. There is a tendency for shell breaking strength to decrease as hens get older.

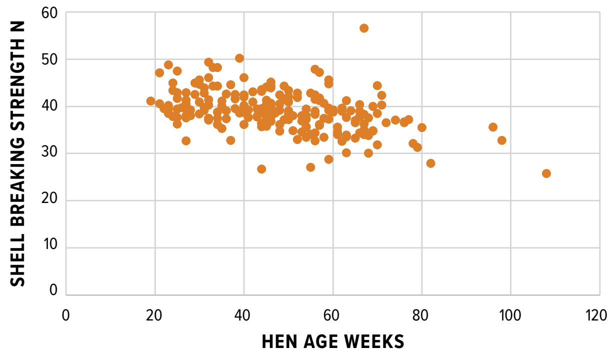


Figure 27 – Shell breaking strength versus hen age

3.2.4 Shell deformation to breaking

Shell deformation is the distance in micrometres that the egg is depressed by the eggshell breaking strength machine before the egg fails. It is an indicator of the elasticity of the eggshell. Shell deformation is quite variable but tends to decrease as hens age.

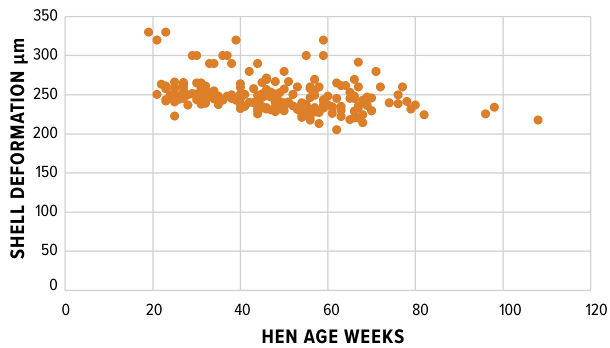


Figure 28 – Deformation versus hen age

3.2.5 Shell weight

Shell weight is the weight, in grams, of the shell after it has been carefully washed out and dried. Shell weight increases to peak of lay and generally stays relatively constant, although it may decrease in very old flocks

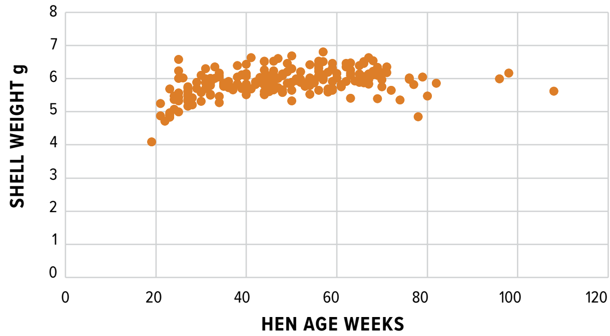


Figure 29 – Shell weight versus hen age

3.2.6 Percentage shell

Percentage shell is calculated as shell weight divided by egg weight, multiplied by 100 to obtain a percentage. Percentage shell tends to remain relatively constant from peak of lay but may decline in very old flocks.

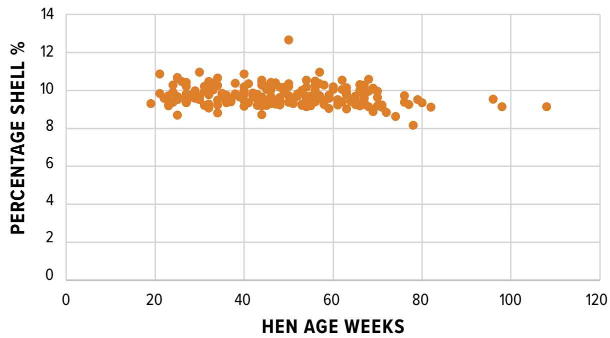


Figure 30 – Percentage shell versus hen age

3.2.7 Shell thickness

Shell thickness is measured in micrometres, using a custom-built gauge, based on a Mitutoyo Dial Comparator Gauge. Shell thickness generally remains relatively constant from peak of lay but may decline in very old flocks

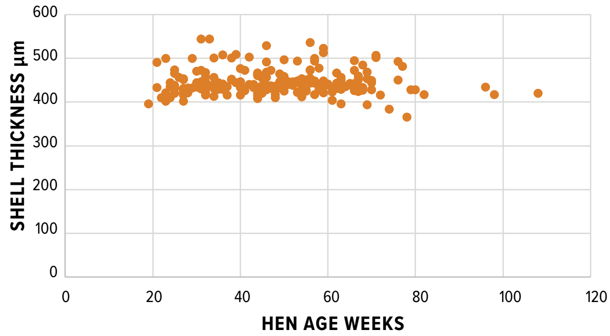


Figure 31 – Shell thickness versus hen age

3.2.8 Shell quality

The Problem

It is widely known in the egg industry that an increase in bird age results in a decrease in overall shell quality and can be associated with an increase in egg size.

The Cause

As the bird ages, the metabolic processes of the bird change slightly and, as a result, so does its dietary requirements. The bird's ability to produce as many eggs and eggs of the same quality decreases.

Eggshell Quality Problems

The effect of age will be seen in the form of increased egg size, changes in shell colour, increased number of cracks, increase in the severity of pimpling in hens that lay pimply eggs, increased incidence of soft-shelled and shell-less eggs, and increases in the number of body-checked eggs. All of these contribute to the increase in the number of eggs downgraded from an 'old' flock.

The Solution

The problem of the increased incidence of eggshell defects as the hen reaches the end of lay is not easily solved but careful attention to all stages of production including the hatchery and rearing conditions is vital. Catering for changed dietary needs does help but will not solve the problem completely. A well-known solution to increase the egg quality of aged hens is the practice of induced moulting, although the mechanisms that cause this to work are still not fully understood. Moulting causes the quality of the eggs to increase when the birds return to lay, but has been found by some producers and researchers to be less effective in the current brown egg laying strains than in the earlier traditional Australian strains, and it is not always economically viable. There are many different procedures used to moult birds but these will not be discussed here.

Additional Information

- The increase in the shell thickness of eggs from 'old' hens is thought to occur when the egg size increases from unknown causes while the amount of eggshell remains the same. In other words, the eggshell must extend further to cover a larger internal egg size and as a consequence the shell becomes thinner and weaker resulting in an increased number of broken and cracked eggs.
- Research into the possibility of manipulating the increase in egg size by management and dietary means may provide some solutions. Current husbandry practices aim to restrict the increase in egg size, once the optimal egg size is achieved.
- There is some evidence that the end of lay is associated with a detrimental change in the protein matrix that supports the calcium carbonate crystals. If this is true, it would lead to a decrease in the strength of the eggshell and thus an overall increase in second grade eggs produced during the later stages of lay.
- At the onset of lay, a common phenomenon is the occurrence of double-yolked eggs. In general, the egg and shell weight of these eggs are higher than a single-yolked egg. However, the percentage shell is lower, which makes them more prone to cracks because the shell is quite thin.

3.3 Changes in eggshell colour

The Problem

The colour of an eggshell is not always uniform. There is variability in the colour of the eggshell (white, tinted and brown) within individuals from day to day, between individual hens, and among strains. The major concerns involving changes in shell colour appear to be the variability of colour from different brown egg laying flocks and the decline in the intensity of the shell colour as the flock ages.

The Cause

At this stage, the cause for the decline in colour as flocks age is not completely understood. It has been suggested that, as the egg size increases with age, the amount of pigment remains the same and therefore the egg is a lighter colour overall. Other suggestions include a decreased ability of the aging hen to produce the pigment. In younger birds the presence of a disease, or some medications used to treat a disease, may cause loss of some or all of the eggshell pigment for a short period of time. Changes in pigment can also occur as the result of stress, disease (e.g. infectious bronchitis virus) or a defective shell gland and these may result in a lilac colouring or extra calcium deposits on the shell's surface. Loss of shell colour is associated with some free range flocks. This may be attributable to stress or to a combination of factors.

Eggshell Quality Problems

Current research indicates that the colour of the eggshell has not been linked with other important shell characteristics such as thickness and breaking strength. However, if the change in pigmentation is the result of stress, other eggshell defects may also be present in the flock, and in this case see Section 3.4 for stress related defects.

The Solution

If there is a dramatic change in the colour of the eggshells in a young flock, either a stress agent or a disease is likely to be present. Check the recent history of the flock for any changes in the routine such as inclement weather, visitors, or any signs that may indicate the presence of a disease. Once you have isolated the suspected cause of the decline in colour, refer to the sections on stress, disease and the list of recommended parameters to prevent eggshell quality problems for further steps to a solution. Remember, if your flock is being treated for a disease by the administration of a medicant (such as an anticoccidial agent), then this may be causing the depigmentation. This is temporary and the pigment will return at the end of the treatment. Unfortunately, because the cause is not fully understood, there is no solution to the decline in shell colour as the bird ages.

Additional Information

- Both brown and tinted eggshells contain pigment, it is just the amount of pigment that varies.
- One of the reasons that the colour of the eggshell is not necessarily linked to its strength is the fact that the majority of the pigment is found in the outermost layers of the eggshell.
- In birds in general, the pigment of the shell provides camouflage in the wild and acts as a temperature control via its ability to reflect or absorb heat depending on the colour intensity of the shell. Economic value has been placed on the colour of the egg by consumer preference and not necessarily by actual physical advantages of the shell determined by the colour.

3.3.1 Loss of shell colour

Shell colour loss in a free range flock

There are intermittent problems with loss of shell colour in free range flocks. This loss of shell colour is frequently reversible, with shells returning to their normal brown colour if birds are confined to the internal shed or moved into cages. However, what causes the loss of colour is still poorly understood.

Figure 32 – Shell colour loss in a free range flock (barn – left top; cage – right top; free range – below)

Loss of colour resulting from nicarbazin ingestion

Ingestion of the coccidiostat nicarbazin results in loss of shell colour, depending on the dose ingested. Contamination of layer feed with nicarbazin has occasionally occurred at feed mills.

Figure 33 – Loss of colour resulting from nicarbazin ingestion (top two rows nicarbazin treated; lower three rows control)

3.4 Stress

The Problem

Stress can occur at any time or place where a stimulus causes mental, emotional or physical strain to the animal.

3.4.1 General stress

The Problem

Laying hens, like most other animals, follow simple behavioural habits. If a stimulus has never been seen or experienced by the bird before (or has only rarely been experienced), then it most likely will cause some degree of stress to the animal. In other words, unfamiliar objects or actions will cause the bird to experience stress as a fright response.

The Cause

The cause of stress can be anything from a change in colour of the handler's clothing from day to day, a snake in the immediate area, or a loud thunder storm outside. Stress can be caused by poor management including food deprivation, extreme temperatures in the shed and overcrowding. Stress is a natural state that will be experienced in cage, barn and free range systems, and it becomes a problem when it occurs too frequently or for prolonged periods as this affects the productive performance of the hen.

Eggshell Quality Problems

Depending on the nature and severity of the stimulus that produces the stress, the hens may exhibit stress as only a loud chatter for a few minutes or a long-term reduction in the overall eggshell quality. A short period of stress causes defects such as body-checked and misshapen shells as a result of the egg being squeezed in the shell gland by contraction of the uterine muscles during the initial fright. Calcium coated eggs are also common if the bird is stressed.

The Solution

Usually stress can be addressed directly by changes in the management strategy. After consultation with a poultry veterinarian or other qualified person, a management strategy to minimise the cause of the stress and therefore the amount of stress the bird experiences can be implemented. See Section 3.11 for more suggestions for minimising stress.

Additional Information

- Research has shown a direct link between the type of shell defect and the time during egg formation at which the bird is stressed, as well as the amount of time the egg is retained. It has been shown that, if a bird is stressed during the early stages of egg formation, a misshapen egg will result. However, if the bird is stressed late in egg formation, a calcium-coated egg will appear.
- Evidence of this type suggests that handling or stressing the birds during early calcification is likely to cause eggs that are body-checked and misshapen.
- Note that good stockmanship is very important in reducing the amount of stress experienced by the hen. Incorrect treatment may cause a stress response in the hen, which will be reflected in her eggshell quality.

3.4.2 Temperature stress

The Problem

Temperature stress is caused by extremes in temperature, either low temperatures or high temperatures.

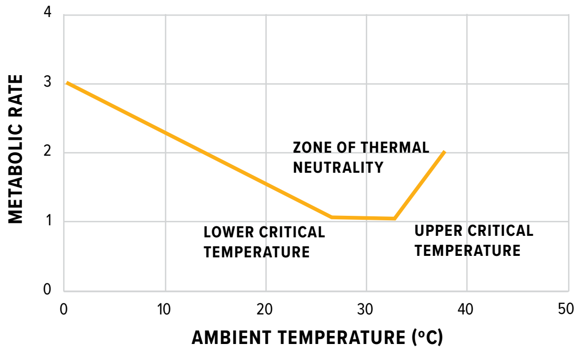


Figure 34 – Zone of thermal neutrality of the laying hen

The Cause

Figure 34 shows what is called the 'zone of thermal neutrality' of a laying hen. There is a range of ambient (environmental) temperatures across which the rate of metabolism (metabolic rate) of the hen remains relatively constant. If the ambient temperature falls below this range (i.e. below the lower critical temperature) the metabolic rate increases. If the ambient temperature increases above this range (i.e. above the upper critical temperature), metabolic rate also increases. When the metabolic rate increases, so does the amount of heat produced by the hen. The actual temperature at which the bird becomes stressed is dependent on the strain and its previous history with such temperatures (this is due to the bird's ability to acclimatise). Hens, like many other animal species, experience stress in these situations because they are trying to maintain a constant body temperature that allows them to function normally. The term 'heat stress' is generally used to describe the bird's response to an increase in the temperature to the point that panting is observed. However the negative effects of high temperatures on eggshell quality may begin before panting is observed.

Eggshell Quality Problems

High temperatures cause hens to consume less food and produce fewer eggs, and result in an overall reduction in eggshell quality that is displayed in a variety of eggshell defects. Typically, eggs are smaller and lighter in colour.

The Solution

The main aim of any treatment for heat stress is either to reduce the shed temperature or increase the bird's ability to cope with the increasing heat. Treatments suggested include mist spraying, evaporative cooling, increased ventilation/fans, having water available for head immersion, dietary manipulation including both the type of food and time of feeding, dietary supplements such as sodium zeolite, and supplying cool/chilled or carbonated drinking water.

Additional Information

- At high temperatures, egg production and quality are reduced as a result of:
    - changes in the metabolic functioning of the hen; and
    - reduction in feed consumption, which results in less calcium available for absorption and utilisation.
- During heat stress, respiratory alkalosis caused by panting can result. In acute heat stress, fasting the animals and/or using a diet free of carbohydrates will increase the survival time by inducing metabolic acidosis that helps keep a constant pH level in the response to the respiratory alkalosis.
- Carbonated drinking water may significantly reduce the number of thin shells that result from high temperatures.
- A supplement of sodium bicarbonate (dietary 1%) has been shown in some cases of heat stress to improve shell quality. One suggestion as to why sodium bicarbonate has this effect is its influence on the acid-base balance of the hen that is said to influence shell deposition. The second reason that this supplement may be beneficial is because of its ability to increase the bird's water consumption.
- The effect of ascorbic acid (Vitamin C) in high temperatures is still controversial. Some data show that, while ascorbic acid may have a beneficial effect during high temperatures, the same ascorbic acid may prove detrimental at lower/'normal' environmental temperatures. Other data show that ascorbic acid may have no effect at all.
- The 'thermic effect': This is the name given to the internal rise in temperature in the bird's body that occurs as the result of digestive activity. It is suggested that during times of heat stress, feed consumption should occur at least 3 to 8 hours before the maximum environmental temperature is expected. This is to ensure that the highest phase of both temperature rises (i.e. the bird's body temperature and environmental temperatures) do not occur simultaneously.
- Cool drinking water helps during heat stress as it provides an avenue through which the hen can expel excess heat, during the heating of the water to body temperature.
- Some studies have shown that sodium zeolite supplementation had a positive effect on eggshell quality.

3.5 Nutrition

The diet of the laying hen is of vital importance at all stages of the life of the hen. Nutritional effects on egg quality are many and will not be reviewed comprehensively here. Important aspects of hen nutrition include:

- Energy content and feed intake.
- Protein and amino acid content.
- Fatty acids, e.g. Linoleic acid.
- Anti-nutritional factors such as non-starch polysaccharides (NSPs).
- Particle size, whole grains, time of feeding.
- Calcium and Ca:P ratio, Ca particle size, bird age.
- Vitamins, e.g. Vit D for Ca, Vit C and Vit E for stress.
- Trace elements, e.g. Cu, Zn, Mn for shell and shell membranes.
- Enzymes such as phytase, xylanase.
- Type and cultivar of grain.
- Leguminous seeds (anti-nutritional factors).

Nutritional problems occur because of a deficiency of nutrients, an excess of nutrients or an imbalance of nutrients. Diets inadequate in any way can result in reduced egg production, a decrease in eggshell quality, as well as compromised bird health. Eggshell quality problems are of importance because, more often than not, mild nutritional problems are displayed as subclinical signs only. These include reduced production or an increase in the incidence of shell defects.

3.5.1 Imbalance of calcium to phosphorus

The Problem

The ratio of calcium to phosphorus in layer diets is very important. Imbalances in early life can cause kidney problems and may lead to leg weakness problems (rickets). Eggshell quality problems associated with inadequate levels of calcium are also experienced.

The Cause

It has been shown through research that the levels of phosphorus and calcium absorbed into the body are closely related. This relationship results from the chemical association between calcium and phosphorus in the intestinal lumen. This means that the absorption of either compound is directly influenced by the concentration of the other – e.g. an increasing level of phosphorus causes a decreasing amount of calcium to be absorbed, and vice-versa.

Eggshell Quality Problems

Since calcium is so important to the production of eggshells the obvious effect of a low level of calcium is displayed as a decreased shell thickness and therefore an increase in the number of thin/shell-less and cracked shells.

The Solution

Ensure that the diet contains the correct balance of calcium to available phosphorus. For further information see the recommended parameters to prevent eggshell quality problems, at Section 3.11.

Additional Information

- The age at which birds are changed from a prelayer to a layer diet is of great importance. The balance of calcium to phosphorus is different between these two diets, and changing too early may result in the development of kidney damage. The age at which diets should be changed is dependent on strain and also the age at which the birds are brought into lay.
- Experimental work has shown that the ability of the bird to absorb the required amount of calcium is not a limiting factor in the production of eggs with good shell quality.
- Calcium limitations in terms of eggshell quality result from not enough calcium in the diet, other compounds such as phosphorus restricting the amount of calcium available for absorption, or a metabolic limitation that occurs in the hen's body after the calcium has been absorbed.

3.5.2 Inadequate calcium

The Problem

Calcium is required for many metabolic functions in the hen, with a major demand being the production of eggshells. Inadequate levels of calcium lead to problems with eggshell quality.

The Cause

The amount of calcium present is influenced by environmental conditions, the physiological state of the bird, age and the diet. The cause of inadequate calcium is usually low levels in the feed. In general, as a short-term solution to a low level of calcium the bird will maintain its positive calcium balance by regulating the amount of calcium it uses to produce each eggshell (by both the number of eggs produced and how much shell is on each egg). Generally, a reduction in calcium causes a decrease in the amount of calcium deposited on the eggshell, and therefore a reduction in eggshell quality results. Inadequate calcium in the diet may also have long-term negative effects on bone strength. The particle size of the calcium provided in the diet is also important.

Eggshell Quality Problems

Any significant decrease in the availability of calcium will have an adverse effect on the eggshell. This will be evident in the increase in shell defects as a whole – in particular, the size of the egg, shell thickness, the number of thin/shell-less eggs, and the number of cracked shells.

The Solution

Ensure that the diet is adequate in calcium, and that the calcium is provided at the appropriate particle size. It is recommended that particle size should exceed 2 mm (2-5 mm) for 50% to 70% of the calcium supplied and that this is particularly important towards the end of lay and in hot climates. For further information see the recommended parameters to prevent eggshell quality problems, see Section 3.11

Additional Information

- During the intense calcification process when most of the eggshell is formed, up to two grams of calcium can be deposited, which is a significant proportion of the calcium present in the hen's body. Therefore, it is quite obvious why, when the supply of calcium is limited, the eggshell suffers the first and greatest loss of the calcium.
- Vitamin D has a very important role in the bird's ability to control calcium movement. Vitamin D stimulates calcium reabsorption from the bones and increases the amount of calcium absorbed from the gut. It also helps control the amount of calcium lost in the urine and increases the production of calcium binding proteins, which are important in moving the calcium to where it is required.

- Calcium absorption is not affected by increased temperature. However, during times of heat stress, the feed consumption is reduced and, as a result, calcium absorption is reduced and eggshell quality will be affected. There is some suggestion that a larger particle will remain in the gut longer and increase the amount of calcium available to the bird during the night when the shell is being deposited.
- Research has found evidence that the amount of food consumed is directly related to the level of calcium present. This implies that hens have a separate calcium appetite to the other nutrients.

3.5.3 Mycotoxins in the feed

The Problem

Fungal growth is associated with the production of toxins. The name given to all of these toxins is mycotoxins. There are many different types of mycotoxins, some of which, if consumed by poultry, can cause adverse effects.

The Cause

Incorrect methods of harvesting, storage, processing and handling of raw feed ingredients and finished feeds can lead to the presence of fungi and mycotoxins. In particular, hot and damp conditions provide the perfect environment for fungal growth.

Eggshell Quality Problems

Each of the different mycotoxins may have different effects. Generally the effect of the toxins will be displayed in visibly similar clinical signs. For example, aflatoxin causes decreased egg production and egg weight. Hatchability of fertile eggs is reduced, however, it does not directly affect fertility.

The Solution

Maintaining dry feed with only fresh uncontaminated ingredients reduces the risk of fungal growth and therefore the presence of mycotoxins. Emphasis must also be placed on the condition of your silos. Ensure that proper turnover is achieved so that feed is not retained in the silo for an excessive amount of time.

Additional Information

- Research indicates that, in Australia, mycotoxins from the following groups can be commonly found: aflatoxins, zeralenone, nivalenol, deoxynivalenol, cyclopiazonic acid, T-2 toxin, cytochalasins and tenuazonic acid.
- Of the toxins found in Australia, usually only aflatoxins and zeralenone are present in quantities that may harm poultry or are known to be a substantial grain contaminant.
- Weather damage to grain crops in Australia, in particular rain at harvest time, is on average about 8% but can go as high as 20% in a 'bad' year. Grain provides the perfect environment for fungal growth, and this is why the presence of mycotoxins is such a serious issue. Total prevention of crop damage is impossible and therefore storage and handling procedures become the main points of control.
- Mycotoxins frequently occur in animal feeds, however, in most cases the amount present is not sufficient to cause harm. In more extreme cases the toxins can cause substantial animal production losses as well as death.

3.6 Drinking water quality

Drinking water is an essential requirement. Compounds that are found in water are generally rapidly absorbed into the animal's body. For this reason, many of the supplements that are given to animals, and particularly in disease control, are administered through the drinking water. However, the opposite is also true, in that undesirable compounds that cause harm to the bird easily enter the bird's body through this route.

3.6.1 Saline drinking water

The Problem

Saline drinking water causes a decrease in shell quality and can result in a reduction of egg production and feed consumption, which causes a lowered level of calcium and other nutrients to be available to the hen.

The Cause

Saline drinking water is the term used for water that contains high levels of salt. This type of water can occur naturally (e.g. in bore water). The salts that have been shown to cause problems with eggshell quality are sodium chloride, potassium chloride, calcium chloride and copper sulphate.

Eggshell Quality Problems

An increase in plasma calcium and phosphorus, the number of damaged and shell-less eggs, plus a decrease in shell weight, thickness, shell calcium and breaking strength can be seen as a result of the consumption of saline drinking water. Hatcheries also find a reduction in the number of day-old chicks as a result of a decrease in the number of eggs suitable for setting as well as reduced hatchability.

The Solution

In the case of saline drinking water, prevention is better than cure. The options include: desalination of the water, supplementation with ascorbic acid (Vitamin C, which has been shown to be effective, although the mechanism is unknown and the effect is dose dependent) and supplementation with a zinc compound (usually zinc-methionine, although other studies have shown zinc-sulphate and chelated zinc-EDTA also to be effective).

Additional Information

- The supplementation with zinc compounds is thought to have its actions via the zinc-dependent enzyme carbonic anhydrase.
- The mechanism behind the decrease in shell quality, because of the intake of saline water, is related to the supply of bicarbonate rather than calcium to the shell gland during shell formation. This is related to a decrease in activity of carbonic anhydrase in the shell gland, which results in limiting the supply of bicarbonate, as well as the dependent calcium, to the site of shell formation. In general, saline drinking water causes a decrease in calcium binding protein, which in turn causes a decrease in the activity of carbonic anhydrase.
- Chlorinated Water and Sanitation: Chlorinated water is used to improve the hygienic quality of water. The addition of chlorine should be sufficient to control microbes, but not be in excess. It has been suggested for poultry farms that chlorine works in concentrations as low as 3-10 ppm (1-2 ppm of free available chlorine), although chlorine concentrations up to 50-100 ppm will be tolerated by hens. There is no scientific evidence that these levels of added chlorine have any adverse effects on eggshell quality.
- Good quality drinking water at all times is essential for your flock.

3.7 Hatching eggs

The Problem

Selection of eggs that are laid for hatching focuses on different attributes of shell quality from those used as table eggs. The eggshells of hatching eggs are the incubators for the embryo, providing protection, a semi-permeable surface that allows the movement of gas and water, and they supply nutrients to the developing embryo. Embryonic development requires the eggshell to be of the correct size and composition to allow the right amount of gaseous/water exchange. At the same time the internal temperature of the egg must be controlled.

The Cause

Changes in the thickness of the eggshell (amount of calcium available) and the porosity of the shell (rate of exchange of gases and water vapour) become important eggshell characteristics that influence hatchability. If the eggshell is too impermeable, a decrease in hatchability will be seen as the exchange of carbon dioxide for oxygen is limited, as well as the diffusion of water vapour into and out of the shell. If the eggshell is too permeable there will also be a reduction in hatchability as the eggshell loses its ability to incubate the developing chick. Shell thickness and microscopic structural abnormalities such as deformed or blocked pores, will also have a great influence on the rate of exchange of gases and water vapour.

Eggshell Quality

Visually ‘abnormal’ eggs will not normally be set, however, the problem here is when to classify the eggshell as ‘abnormal’. A number of apparently ‘normal’ looking eggshells will be unsuitable for setting and hatching, due to a defect in the thickness of the shell, shell structure or its porosity. Discussed already in the influence of genetics and strain, the selection of certain eggshell characteristics for the hatching egg involves different criteria than those set for table eggs.

The Solution

Many of these eggshell characteristics are genetically related, and selection over time will reduce the appearance of problems due to shell structure and porosity. As always the hen’s nutrition is of great importance. With the eggshell thickness being of particular importance, the calcium level in the diet must be adequate. As with all other laying birds, an increase in the age of the hen will result in a decrease in eggshell quality and thus hatchability (see the section on age for more information).

Additional Information

- Egg shape is also important because of the effect it can have on the setting position of the egg. If the egg is rounded to the point that it is difficult to distinguish the different poles, determining the correct position for setting the egg becomes troublesome. In other words, egg shape may influence hatchability by determining the position of the air cell during incubation.

- Factors that influence porosity include pore density (number of pores per unit area), length of the pores (shell thickness), shape of the pores, the cuticle over the end of the pores and blockage of the pores by 'debris'.
- The thickness of the eggshell is important because the shell must be strong enough to incubate the embryo safely for the entire incubation period as well as supply an adequate amount of calcium. However, it must also allow the chick to break free at hatching.
- At approximately day 9-10 of incubation the embryo starts to remove calcium from the shell. By day 12 the erosion of the shell is visible under a microscope. As the shell is eroded away the thickness of the shell decreases. This is when it becomes important that the original thickness of the shell is able to sustain this erosion while still incubating the embryo.
- Saline drinking water has been shown to have an effect on the number of settable eggs and hatchability. For more information on the effect of saline drinking water on eggshell quality refer to Section 3.6.1.

3.8 Alternative egg production systems

The most common non-cage systems, the barn, aviary and free range egg production systems, are still intensive farming methods that require clear management strategies. These alternative systems have strict regulations involving husbandry practices and marketing of the product. For more information on these guidelines contact your state or territory authority or egg marketing organisation.

The Problem

Problems that are associated with alternative systems often include feather pecking, cannibalism, increased bacterial load on the eggs, soiled/dirty eggs, thin eggshells and broodiness. Many of the problems with shell quality that occurred early in the introduction of the alternative, non-cage, production systems have been solved by modifications made to the housing systems. However, there are still problems that appear to be specific to the non-cage systems or, at least, occur more commonly in those systems.

The Cause

In this section we will give a brief overview of the factors that influence the problems listed above.

(1) Feather-pecking and cannibalism: Chickens are very sociable creatures and, within a group of hens sharing the same living space, a hierarchy develops. This results in some members of the group being bullied (feather-pecked) by the stronger and more dominant members. Since, in general, only minimum beak trimming in barn systems and little or no beak trimming in free range is allowed, feather pecking can result in cannibalism. Insufficient and/or incorrect nest sites/space can cause prolapse cannibalism to occur. This occurs when, during laying of the egg, the hen cannot adequately retreat into a safe area. Other hens will peck her cloaca while the egg is in the process of being expelled. Some strains appear to cause much greater problems than others.

(2) Broodiness: This is a natural behaviour and therefore, in any system that allows increased freedom, broodiness may result.

Broodiness has been actively selected against in breeding programs, although it is doubtful if it will ever be eliminated completely. The problem with broody birds is that they become very aggressive, take over a nest site as their own and stop laying eggs.

(3) Bacterial load and dirty eggs: The increased bacterial load and the increase in the number of dirty eggs are a result of floor laid eggs or lack of separation of the egg from the hens' excreta.

(4) Thin and cracked shells: These types of shell defects are usually as a result of old age or lack of calcium in the diet. Calcium is of particular importance for birds that have moulted (naturally or forced) because their body calcium store is drained during the moult, and is very important for eggshell quality when they return to lay.

Eggshell Quality

As mentioned above producers report that the increased number of thin, weak, fragile and cracked shells can be a problem in alternative systems. Producers also report an increased incidence of shell defects including rough shells, discolouration of the shell and calcium splashes or coatings. From time to time, a serious problem can be loss of shell colour.

The Solution

Common causes of thin, weak, fragile and cracked shells are the age of the hen or the amount of calcium available. If the hen is above 70 weeks of age, a decrease in eggshell quality is inevitable. Refer to Sections 3.2 and 3.3 for more details on the effects of age on eggshell quality. The depigmentation of the shell colour is also an age-related phenomenon. The amount of calcium required by a laying hen is quite large. Unless a flock receives some type of calcium supplement or a calcium enriched feed then it may be deficient in this mineral. There are many different types of natural calcium supplements available. Choose a supplement that meets the needs of the flock: different particle sizes and sources should be obtained easily from local rural supply outlets (e.g. oyster shell and marble chips).

Calcium splashes are often displayed as a result of stress, and minimising stress as discussed in Section 3.4 is an ongoing commitment. Free range production involves the added responsibility of reducing stress from predators such as foxes, predatory birds and snakes. Good and continually-checked biosecure fences are necessary, as well as shutting the flock in the sheds at night. A specially trained dog such as a Maremma that lives and protects the flock 24 hours a day is another reported method of reducing predation. Exclusion from a nesting box of a hen used to laying in a nest will cause disturbed prelaying behaviour resulting in the retention of the egg and thus a calcium coated egg. If this occurs, the number of nest boxes available may not be adequate.

The previous housing system and the age at which you receive your flock (if a mature hen) will influence the number of cracked eggs as a result of the number of eggs laid on the floor. Eggs laid on the floor are more likely to be contaminated by excreta and cracked from direct insult by moving hens. The rearing environment influences the number of floor eggs greatly. For hens reared from day old in a bam or free range system, this should not be a problem unless not enough nest boxes are available.

Management practices to minimise broodiness in a flock include making sure there is adequate nesting space, the correct duration of light in a uniform manner, training the birds not to nest in deep litter or on slats, culling any continuously broody hens and breaking up broody hens by the use of broody pens. Breeder companies select for decreased broodiness in laying hens.

The bacterial load of the eggshell is increased in any system that does not separate the eggs from the hen. To minimise this bacterial load frequent egg collection is necessary. The number of dirty eggs increases with the increased contact of the egg with the external environment such as the ground where birds eat, drink and defaecate. Again the frequency of egg collection, plus an adequate number of nest sites, nesting boxes with egg rollout facility and a minimum number of broody birds influences this greatly.

The intermittent problem of loss of shell colour in free range systems is still poorly understood. The mechanisms of this occurrence are not clear as the pale coloured eggs produced may still have a cuticle on the outside.

Additional Information

There is some suggestion that the rate of decrease in eggshell quality as a factor of age occurs at a faster rate in free range systems than caged systems. Research in this area is currently being undertaken. One suggestion is that the increase in stressors in the open environment may speed up the decrease in shell quality.

3.9 Disease

The Problem

A disease is any impairment that interrupts the ability of the hen to maintain normal physiological functioning, that is, to perform normally and produce at the expected levels.

The Cause

In poultry this can be separated into two causes: infectious and non-infectious. Infectious diseases are caused by pathogens, which are organisms that have the potential to harm the bird. Infectious disease can be caused by any of the following factors: viruses, chlamydia, mycoplasma, bacteria, fungi, protozoa, and internal and external parasites. Non-infectious disease is either genetically influenced or developed due to environmental pressures. Problem areas that can be classed as non-infectious disease include stress/trauma, environment, toxins, nutrition, mites, genetic influences and tumours.

Eggshell Quality Problems

Eggshell quality defects may represent clinical signs of poultry disease. This is because poultry disease states often cause a decrease in food consumption, which is quickly reflected in the external properties of the eggshell. The most obvious problem commonly shared among diseases is partial or total loss of egg production. Individual diseases will result in different eggshell defects or perhaps none at all. This is why the appearance of an increased incidence of one particular eggshell defect may give an indication of the possible diseases present.

The Solution

In general, the treatment of a disease that has infected the entire flock is costly and time consuming. Transmission of disease pathogens varies, with some being mobile in their own right. Others infect through ingestion, transmission vertically via the egg, or by movement of the wind, dust, poultry equipment and vehicles between affected and non-affected areas. The risk of disease in a flock is reduced by management practices such as maintaining good hygiene, separating young birds from older birds and supplying birds with dry feed based on fresh, uncontaminated ingredients. Strict overall quarantine measures and correctly vaccinated flocks are also a part of responsible management procedures. In poultry, the emphasis is on prevention of disease.

Additional Information

Abnormal eggshells and disease (or deficiencies):

- Soft and shell-less eggs: Soft shelled and shell-less eggs can be caused by mycotoxins, Egg Drop Syndrome, a deficiency of calcium in the diet and the first stages of acute infections such as Avian Influenza.
- Wrinkled shells: Wrinkled eggshells may be seen as clinical signs of Infectious Bronchitis, Egg Drop Syndrome, Newcastle Disease or as an after effect of a magnesium imbalance in the diet.
- Calcium deposits: Calcium deposits on the eggshell can result from excessive consumption of calcium or from disturbance of the birds.
- Rough shells: An increase in the number of rough eggshells can be associated with the presence of Infectious Bronchitis, Egg Drop Syndrome and Newcastle Disease.
- Change in pigment: There are some diseases that can affect the pigment of the eggshell, including Newcastle Disease, Infectious Bronchitis and Egg Drop Syndrome.
- Decreased hatchability: Diseases that can cause a decrease in hatchability include Avian Influenza, mycoplasmosis, salmonellosis, Avian Encephalomyelitis and Erysipelas.

Because this is not a booklet devoted to disease, the individual diseases and solutions will not be reviewed here. The most important concept to take away from this section is that a disease outbreak needs to be diagnosed and treated by a trained qualified person and, if appropriate, reported quickly to the relevant authority.

3.10 Known or suspected causes of egg internal quality problems and proposed solutions

3.10.1 Age of hen

Albumen height

Albumen height decreases as hen age increases. The trend is similar when albumen height is measured at the cage front (on-farm) and in the laboratory. The higher albumen height in eggs measured on-farm is due to the fact that the eggs are fresher (they have only just been laid).

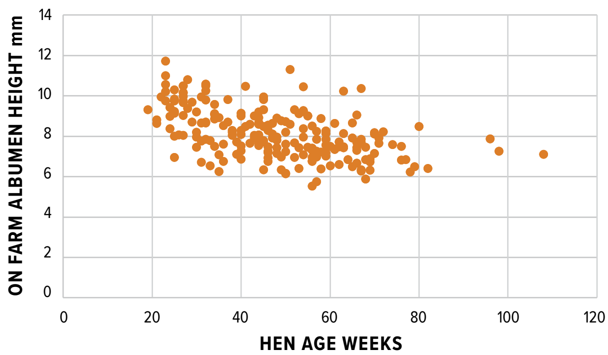


Figure 35 – Albumen height measured on-farm versus hen age

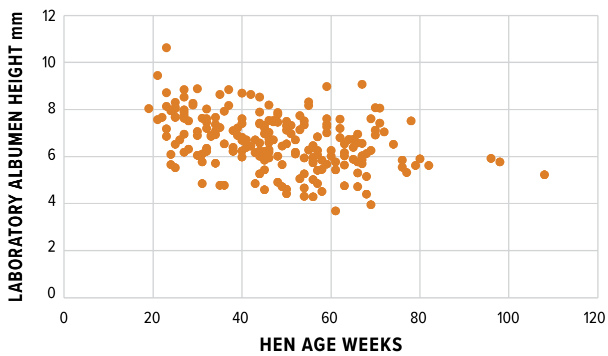


Figure 36 – Albumen height measured in the laboratory versus hen age

Haugh unit

The trend for the effect of hen age on Haugh unit is the same as for albumen height.

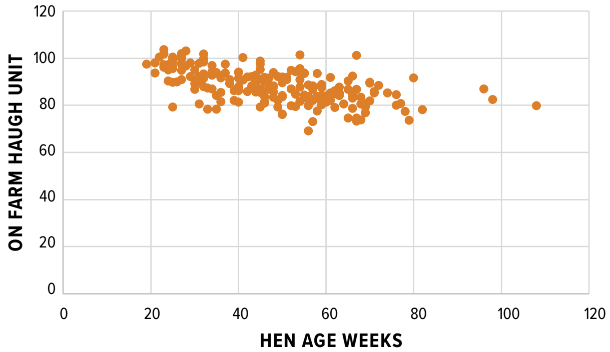


Figure 37 – Haugh unit measured on-farm versus hen age

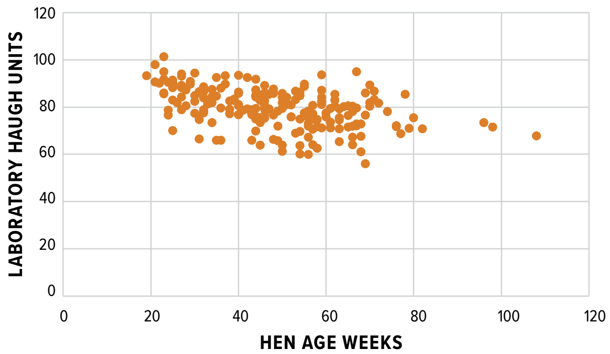


Figure 38 – Haugh unit measured in the laboratory versus hen age

Yolk colour score

Yolk colour score is determined primarily by the amount of suitable pigment present in the feed or otherwise ingested by the bird (e.g. foraging in a free range system), whether it be a natural or synthetic pigment.

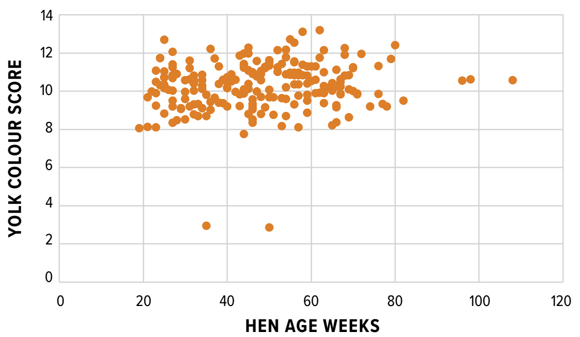


Figure 39 – Yolk colour versus hen age

3.10.2 Effects of egg storage time and temperature

Egg weight

When eggs are stored, water evaporates through the pores of the eggshell and the egg becomes lighter in weight. This occurs more quickly at higher temperatures.

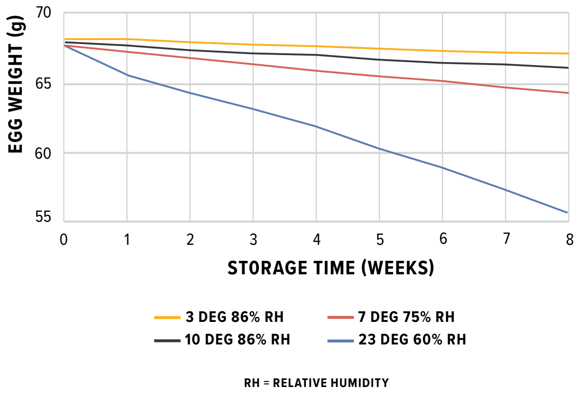


Figure 40 – Egg weight versus storage time at four different temperatures: 3, 7, 10, 23˚C

Change in egg weight

The percentage change in egg weight during storage at different temperatures follows a pattern similar to that of egg weight.

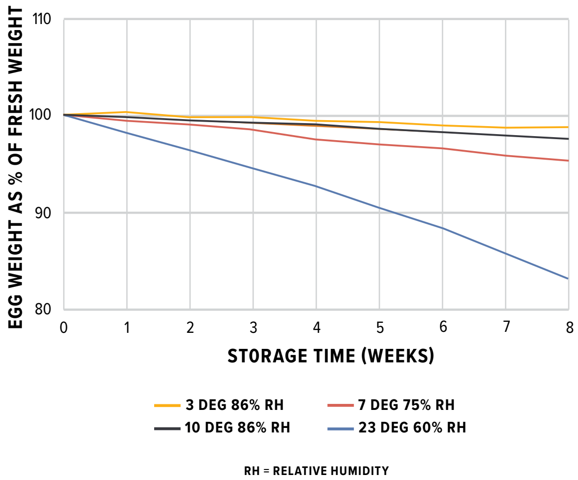


Figure 41 – Percentage change in egg weight versus storage time at four different temperatures: 3, 7, 10, 23˚C

Albumen height

Albumen height decreases during egg storage and this occurs more quickly at higher temperatures.

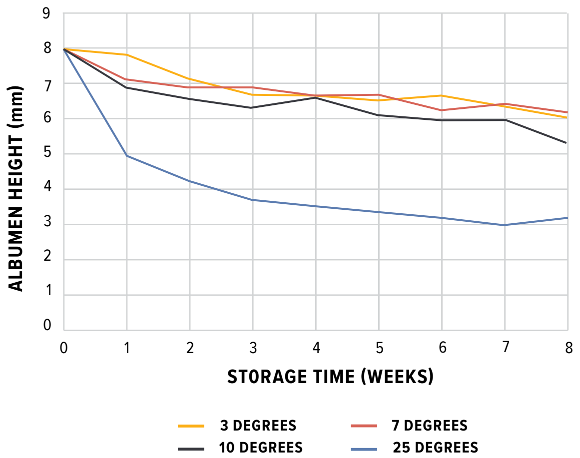


Figure 42 – Albumen height versus storage time at four different temperatures: 3, 7, 10, 25˚C in Isa Brown hens

Haugh unit

The trend for the effect of storage conditions on Haugh unit is the same as for albumen height. Haugh unit is affected by both storage time and temperature.

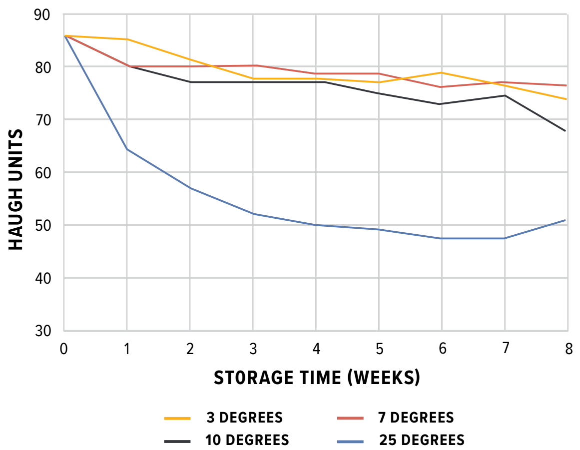


Figure 43 – Haugh unit versus storage time at four different temperatures: 3, 7, 10, 25˚C in Isa Brown hens

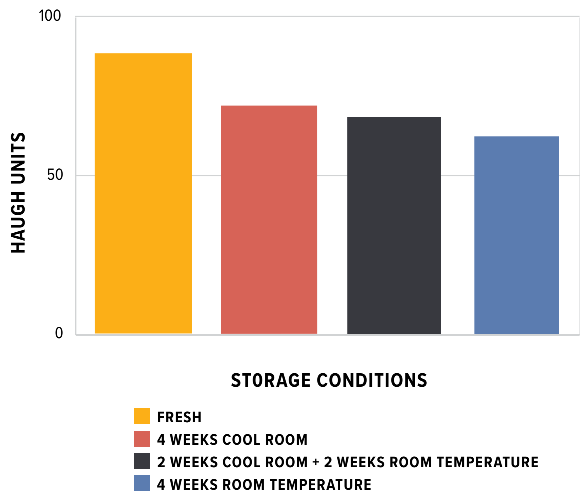


Figure 44 – Effect of storage conditions on Haugh unit in eggs of Isa Brown hens

3.10.3 Nutrition

Reports on nutritional factors affecting egg internal quality are variable and not consistent. Some suggested factors are:

- Type and cultivar of grain.
- Dietary protein and amino acid content with increased content leading to decreased albumen quality.
- Lysine concentration with higher dietary lysine level resulting in improved albumen quality.
- Neem kernel meal, which is reported to decrease albumen quality.
- Vitamin E supplementation improving albumen quality especially at high ambient temperature.
- Ascorbic acid (Vitamin C) supplementation, which may improve albumen quality.

3.10.4 Disease

Infectious bronchitis virus has been shown repeatedly to decrease albumen quality.

Contaminants

Mycotoxins have been shown to have a negative effect on albumen quality.

3.11 Recommendations to prevent eggshell quality problems

(1) Diet

What is most important is a well-formulated diet, fed to the correct age group, as well as making sure that the feed meets the specifications. A good example of the importance of the correct diet formulation, fed to the correct age group, is the calcium:phosphorus ratio. The quantity of calcium and phosphorus in the diet is extremely important as already discussed in Section 3.5.

The importance is related not only to the amount of each of these minerals present, but is also closely related to the age of the bird. For young, growing birds (prelay) an optimal ratio around 1:1.2 (phosphorus:calcium) is required. Once the hen is laying, a ratio more like 1: 6.3 (phosphorus:calcium) is recommended to meet the needs of the hen. Note that the type of calcium and phosphorus is also very important in these calculations and that the values given here are an example of the importance of understanding nutritional guidelines.

For more information on calcium and phosphorus and other nutritional guidelines see recommended sources such as the NRC – Nutrient Requirements of Poultry; and Feeding Standards for Australian Livestock: Poultry, by the Standing Committee on Agriculture. For further information on nutritional guidelines in general, or help in setting up a protocol, we suggest consultation with your nutritionist or poultry veterinarian.

(2) Appropriate strain

Selection of an appropriate strain for a particular producer will depend on a number of factors. Eggshell quality is not necessarily better in brown egg laying strains because, although these strains have heavier and thicker shells, this may simply compensate for the increased size of the eggs.

The current situation with respect to strain and disease susceptibility is not entirely clear. There is no clear evidence at this stage that any strain is particularly suited to hot climates. Many factors are involved in selection of strains of birds, and consultation with your nutritionist and poultry veterinarian will assist in this regard.

(3) General environment

At all ages, the hen's egg production is influenced greatly by the environment. The following environmental and management factors can lead to a brief slump in egg production, and therefore must be regulated and minimised where possible.

- A change in temperature, barometric pressure and ventilation in the sheds (such as a draft).
- Inadequate water availability.
- Noise that is loud and frightening, any disturbance that can be made simply by a passing vehicle, visitors, pets or a lawn mower.
- Unfamiliarity with staff.
- General care in handling, to avoid injury and stress.
- Change in the type or consistency of the feed can cause a drop in feed consumption, as can inadequate feed supply or uneven distribution throughout the shed.
- Nutritional problems arise when there is an omission, deficiency, toxic level or imbalance of one or several ingredients.
- Incorrect number of hours or intensity of the lighting.
- Good management aims at minimising the above influences or eradicating them completely.

(4) Management and disease protocol

Disease prevention is aimed at reducing the number of risks to a point that ensures that birds remain disease free, and good management revolves around achieving maximum production while maintaining the health of the birds. The practices outlined in *Table 1* are general management and disease protocols, as a guide for members of the poultry industry.

Table 1 – Good management practices and disease protocols

PROCEDURE	PRACTICE
Isolation (from the source of infection)	Includes the farm's location in relation to: 1. Other farms. 2. Wild birds, people, pets, rodents, vehicles, equipment, feedbags and other poultry. 3. The farm design such as shed separation, drainage, pest exclusion and the separation of different age flocks.
Selection (genetic selection for disease resistant flocks)	This is an effective method of disease control, which will be practised by the breeder companies and the options are usually one of the following: 1. Import breeding stock from an overseas reputable breeder. 2. Source breeding stock from a reputable local breeder. 3. Gather genetic material from various sources and develop strains in a genetic breeding program.
Vaccination (there are 3 types that aim to build up antibodies in the bloodstream to fight off future infections)	1. Controlled exposure where the bird is injected with a vaccine in a particular part of the body or stage of life when the vaccine will cause little or no harm to the animal, e.g. avian encephalomyelitis (AE) given at a set age (3-4 months). 2. Inactivated or killed vaccines where the disease-causing organism has been altered so it no longer causes the disease, or the organism has been killed. 3. Attenuated vaccination where a weakened form of the disease-causing organism is injected; it may cause no effect at all or the bird may suffer only a mild form of the disease. Notes – Vaccinations are cost effective and work in most cases, however, they are not a 100% guarantee against disease (e.g. a more virulent form of the disease may overcome the protection of the vaccination). This is an example of why all aspects of disease control need to be implemented. Government regulations control the type of vaccines that may be used in the poultry industry, and there are strict standards of safety and effectiveness. Correct vaccination is very important.
Sanitation	1. Involves the removal of organic material such as manure, litter, dusts and feathers that provide the perfect environment for the survival and proliferation of disease-causing organisms. 2. Effective sanitation requires the removal of any such material and disinfection of items that cannot be removed from the area. 3. Routine sanitation and quarantine should be closely adhered to in order to prevent disease outbreaks.
Investigation	1. Investigation and education are closely linked. A staff member who is well educated with respect to poultry diseases can observe and report a change in the flock, allowing for quick and effective investigation into the cause of the change (which may be the first sign of a disease and which you may be able to stop before it causes damage, or quarantine the flock from other birds before the disease spreads). 2. It is the staff and manager's responsibility to notice the change and act on that information. It is the veterinarian's job to decide the cause, effect, treatment and control strategies. 3. Routine monitoring (e.g. serology).
Medication	1. Medication is any substance used to treat or prevent a disease. 2. Medicines such as antibiotics may be administered by veterinarians as a result of a disease outbreak. Withholding times on sale of eggs may apply. 3. Medicines may also be used in a preventative way, such as using an appropriate antibiotic if a disease has affected surrounding farms, or regular and strategic supplementation of multivitamins and electrolytes to combat factors out of the producer's control, e.g. extreme temperatures that can cause disease states.
Eradication	1. This is the term used for the removal of the organism that caused the disease. 2. Eradication can occur at the farm level, state/territory level and, with the cooperation of all, the national level. Eradication is a long-term goal that is the ultimate preventative measure against disease.

Gilchrist P. and Poole G. (1995) Health and Welfare. Murrumbidgee College of Agriculture, NSW Agriculture. Active Print, Wagga Wagga, NSW Australia.

3.12 Recommendations to prevent egg internal quality problems

Factors to consider in order to maintain good egg internal quality are:

- Age of hen.
- Appropriate diet.
- Egg storage time and temperature.
- Prevention of disease.
- Prevention of ingestion of contaminants.

3.13 Treatments that have been reported to improve eggshell quality

Below we have discussed some of the treatments that have been reported to improve eggshell quality. This section is not a set of recommendations but more an explanation of the concepts behind these treatments. Most of these treatments have a basis in providing essential vitamins and minerals in the required concentrations. It is important to realise that, if these products improve eggshell quality, this may indicate that the diet was deficient in the first place. In other words, a deficiency in the vitamins and minerals that your birds consume must exist before some of these products will increase the shell quality on your farm. In drawing your attention to this fact, it must also be noted that deficiencies in micro-nutrients such as vitamins and minerals are often very difficult to detect.

(1) The use of particulate calcium

Calcium solubilisation affects the efficiency of calcium use by the laying hen. The calcium consumed by the hen must first be solubilised to allow absorption. Studies have shown that the particle size of the calcium that the birds receive influences the retention time of the calcium in the gizzard, and therefore its solubility in vivo. It has been shown that, in general, the larger the calcium particle (>0.8 mm) the longer the bird retains the calcium in its gizzard. The longer the calcium remains in the gizzard the higher the solubility. The importance of this revolves around the slow dissolving of the calcium, which results in the calcium being available hours after the bird has fed. The calcium is therefore available in the night hours, when there is an increase in the calcium demand, as the forming eggshell undergoes calcification. The use of large calcium particles has been shown to be of greater benefit in heat-stressed birds. It has been suggested that calcium supplied in particles smaller than 0.8 mm is not retained in the gizzard and therefore passes through the gastrointestinal system and out in the excreta, relatively unused.

It has not been clearly shown that there is any real difference between oyster shell and limestone as the calcium source. An important factor that may influence the calcium consumption of your birds is the shape of the calcium source as it is presented. There has been very little research in this area, but the data available suggest that hens consume flat shells, more readily than those that are cone shaped. This is an area that requires more research before recommendations can be made.

(2) Bicarbonate in feed or water

Bicarbonate in the feed or water has become an issue in poultry because, during high temperatures, there is a change in the electrolyte balance in the hen's blood including changes in bicarbonate. Bicarbonate is important to egg-laying hens because this nutrient is also required in eggshell production. During heat stress the hen pants, resulting in respiratory alkalosis, which causes the kidneys to eliminate bicarbonate from the body. At this point, bicarbonate is in demand from the shell gland for eggshell production and by the kidney for excretion. There is one commonly suggested way to correct this imbalance – the addition of bicarbonate to the feed or water. Sodium bicarbonate can be used in feed but studies have found conflicting evidence for the effect this has on eggshell quality. A number of studies show an improvement in shell quality, whereas other studies indicate no effect on eggshell quality with the addition of bicarbonate during heat stress.

The bicarbonate may also be placed in the water. Carbon dioxide can be dissolved in water to produce carbonated water, which is then supplied to the hens. Most studies on carbonated water have found positive effects on eggshell quality. However, it must be noted that more than one study has shown that, even if there is a positive effect of bicarbonate during heat stress, during normal temperature the bicarbonate may have no effect at all. Some studies even show a negative effect at normal temperatures where the bicarbonate may depress egg production.

(3) Zeolite and bentonite

Zeolites are a mineral rich clay, which has been proposed to function in poultry production as a feed additive to improve feed efficiency, a substance which helps control litter management and/or an overall quality control factor. There have been many claims about the actions of zeolites in poultry feed.

These include improving egg production, egg size, shell quality, reducing the number of shell defects present related to age, and improved fertility in breeders. Zeolites have also been suggested to improve eggshell quality in heat stress situations. Experiments that have been conducted on both synthetic and natural zeolites show conflicting results.

Bentonite is similar to zeolite. Bentonite is a clay consisting of natural aluminium silicates and is claimed to increase production, feed efficiency, the size of the egg, and eggshell quality. Studies on bentonite have similar findings to those of zeolite, where the results from different studies have been conflicting. Both zeolites and bentonites are inert materials that can be used as fillers or diluents in poultry feeds. Bentonites are used to improve the durability of the pellets, while zeolites may help control the ammonia levels in the poultry house.

(4) Proprietary products

Over the years, a range of proprietary products has been produced, aimed at improving egg quality. These products have included Eggshell 49 (Alltech Inc, U.S.A), Iron Egg (All Farm Animal Health, Australia), Egg Booster (a name that appears to have been used for a range of products), Hy-D® (DSM) and calcium pidolate. Eggshell 49 was a mineral supplement for layers. Its properties in decreasing the number of eggs lost to eggshell defects were based on the roles of minerals in the production of the eggshell membranes or their role in enzyme activity. The supplement contained copper, manganese, calcium and zinc. It is believed that manganese has an important influence on the membrane formation and thus any subsequent eggshell formation.

Carbonate is very important in eggshell formation for the production of calcium carbonate, the major component of the eggshell. The enzyme carbonic anhydrase controls the amount of carbonate present in the shell gland, and this enzyme in turn is dependent on the mineral zinc.

Eggshell 49 also supplied a zinc-manganese supplement in a bioactive form that is thought to increase the availability of these minerals to the sites that require them. Overall this product was based on the premise that minerals other than phosphorus and calcium have been overlooked for their importance in eggshell formation. Results from trials on the use of this product suggested that the improvement from use of this supplement increases with the age of the hen. Eggshell 49 does not appear to be available at the present time.

Iron Egg was also a mineral supplement, containing chelated iron, manganese, copper, zinc and calcium. Iron Egg was formulated to maximise the bioavailability of the minerals in the correct balance in order to decrease the number of eggs lost to eggshell defects. It was claimed that this product had particular value for layers after a moult or where there has been the presence of a disease such as Egg Drop Syndrome, IB and mycoplasma, or for heat stressed birds. Iron Egg does not appear to be available at the present time.

Hy-D® (DSM) is the rapidly available metabolite of Vitamin D3 and aims to improve eggshell quality and bone strength. It is frequently incorporated into the diets of laying hens as part of the Vitamin D3.

Calcium pidolate has been used to treat osteoporosis in humans on the basis that it is a more soluble form of calcium. It has been tested in poultry diets, with some studies having reported an improvement in eggshell quality with use of calcium pidolate whereas other studies report no effect.

The overall consensus is that these proprietary products have the potential to improve eggshell quality but do not necessarily do so, depending on the circumstances including the formulation of the diet and whether or not there are any deficiencies present.

3.14 Egg quality and product safety

3.14.1 Routes of transmission of *Salmonella* into eggs

There are two possible ways for bacteria to enter into an egg – either from an infected ovary or oviduct, or across the shell from the outside of the egg.

- Vertical (trans-ovarian) – this occurs when the ovary and/or oviduct of the hen become infected by the bacterium, which is then able to enter the egg prior to the laying down of the shell. The organism that is known to be transmitted in this way is *Salmonella* Enteritidis (SE), which causes human illness in a range of countries. Fortunately, SE is not endemic in Australian layer flocks. It is periodically brought into the country in the digestive tract of people coming from overseas and could, in theory, be passed on to flocks of laying hens. However, this can be prevented by having all staff who have contact with poultry practice careful biosecurity such as showering and washing of hands. Appropriate toilet and bathroom facilities on-farm are very important in this regard.

- Horizontal (trans-shell) – this occurs when bacteria on the outside of the eggshell are able to penetrate the shell and enter the egg contents. This is the way in which eggs become contaminated in Australian flocks. The most significant bacterium is some forms of *Salmonella* Typhimurium although other *Salmonella* serotypes can cause illness also.

3.14.2 Egg natural defences against microbial contamination

Because nature's role for the egg is as an incubator for the development of a new chick, the egg possesses a wide range of antibacterial properties. These are designed to protect the developing chick but they also function to make eggs safe for human consumption.

Some of these properties are:

- *Lactobacillus* flora in cloaca and vagina have an inhibitory effect on SE.
- Eggs with intact cuticle blocking pores are less likely to be contaminated.
- Eggshell matrix contains antibacterial proteins – only weak action on SE.
- Shell membranes contain bacteriolytic enzymes.
- Albumen contains antibacterial substances
  - Lysozyme
  - Ovoinhibitor
  - Cystatin
  - Ovotransferrin (binds iron).
- Perivitelline membrane acts as a barrier.

3.14.3 Egg quality risk factors for egg contamination

- Cracks or pin holes.
- Thin shells.
- Inadequate cuticle (needs to plug the pores).
- Storage time and conditions.

3.14.4 Summary and recommendations

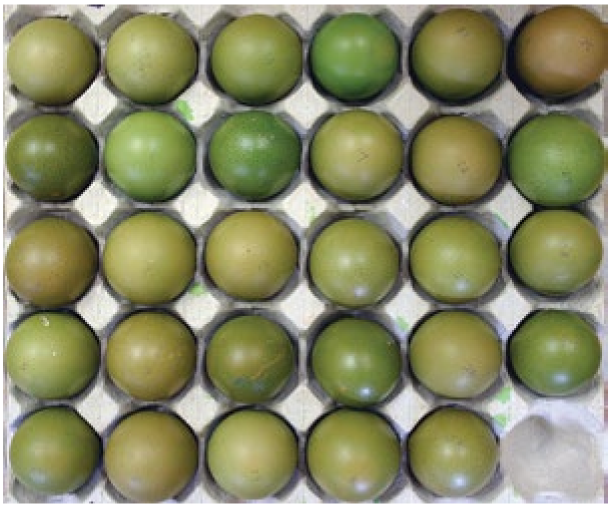
- SE is not currently a problem in eggs in Australia but is a serious threat in many countries.
- *Salmonella* Typhimurium is the main culprit in Australia.
- Regular monitoring of layer flocks for identification of the *Salmonella* serovars present.
- Use of *Salmonella*-free feed, where possible (pelleting has been shown to kill bacteria).
- Maintenance of good eggshell quality.
- Removal of faecal material from eggs as quickly as possible.
- Maintenance of eggs at refrigeration temperatures throughout the production chain.

3.14.5 Research investigations of the importance of the presence of cuticle

The amount of cuticle present on an eggshell can be determined by staining with a special dye, Cuticle Blue Dye. The colour of the eggshell can be measured with a handheld spectrophotometer before and after staining with the cuticle dye. The green staining indicates the presence of cuticle. The latest research results indicate that the most important thing for the safety of the egg contents is to have cuticle blocking the pores of the eggshell.

Figure 45 – Eggshells stained with cuticle blue dye and the handheld spectrophotometer used to measure the colour

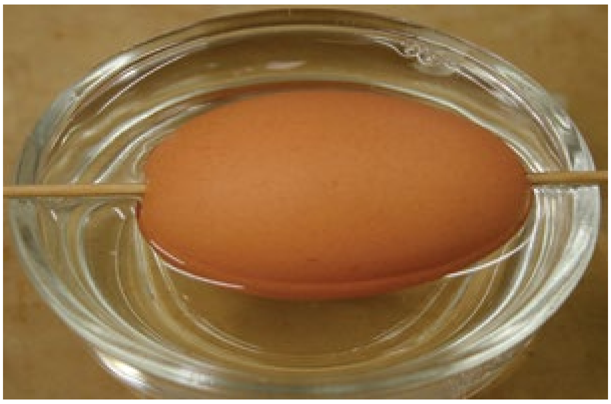
Table eggs



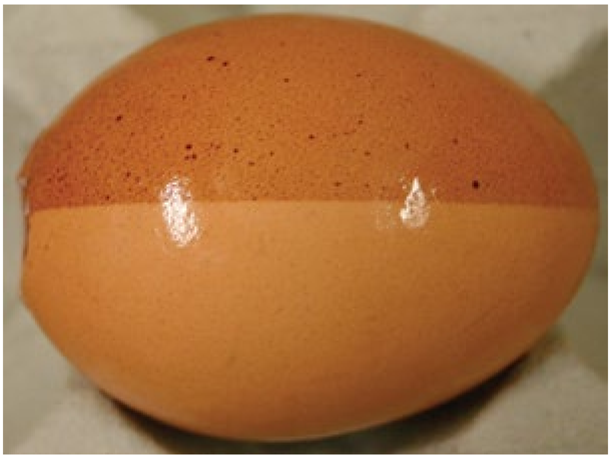
Broiler breeder eggs

Konica Spectrophotometer used to measure the shell colour before and after staining

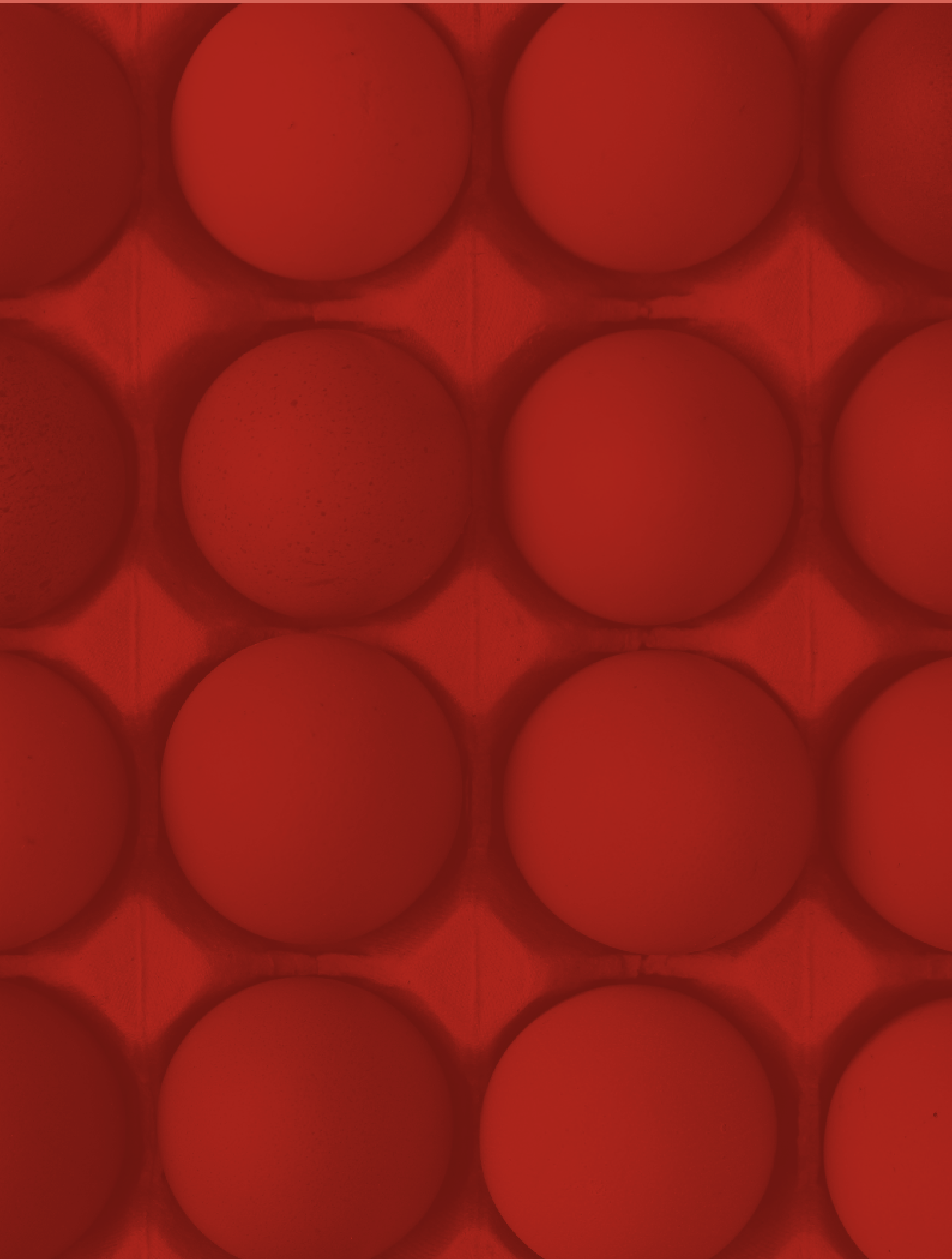
Figure 46 – Removal of cuticle with EDTA for the purposes of studying the importance of cuticle cover for product safety



Cuticle removed using EDTA



Egg with cuticle partly removed



4 Possible causes of specific eggshell defects

The following list (*Table 2*) summarises the possible causes of specific eggshell defects. These causes have been cross-referenced with the accompanying checklist (Section 5) to allow quick and easy diagnosis if an excessive number of eggshell defects has appeared in your egg collections. The checklist is intended to serve as a reminder of the factors that need to be under constant observation on a poultry farm.

The letters in brackets after each possible cause refer to the respective columns in the checklist:

M – Management; F – Feed; W – Water; and D – Disease. For further explanations of the eggshell defects refer to Section 2.

Table 2 – Possible causes of eggshell defects

EGGSHELL DEFECT	POSSIBLE CAUSES
White banded and Slab-sided eggs	Stress from disturbances (M), changes in lighting (M) and infection (D)
Translucent eggs	Structural irregularities, high humidity in the shed (M), disease (D) and overcrowding (M)
Calcium coated eggs	Stress from disturbances (M), incorrect level of calcium in the diet (F) or a defective shell gland (D)
Misshapen eggs	Immature shell gland, disease (D), stress from disturbances (M), bird age (M) and overcrowding (M)
Body-checked eggs	Incorrect lighting (M), stress (M), bird age (M) and overcrowding (M)
Cracked eggs	Heat stress (M), saline water (W), bird age (M) and poor nutrition (F)
Soft-shelled eggs	Immature shell gland, inadequate nutrition (F), saline water (W), bird age (M) diseases like EDS and AI (D), and stress (M)
Pimpled eggs	Foreign materials during calcification, bird age (M), strain (M), nutritional status (F) and disease (D)
Calcium deposits – White and Brown Lilac eggs	Defective shell gland, disturbances that cause stress during calcification (M), and incorrect speckled and nutrition (F) such as excessive calcium in the feed
Corrugated eggs	Defective shell gland and disease (D)
Wrinkled eggs	Stress (M), diseases such as IB and EDS (D), defective shell gland, over crowding (M) and nutritional deficiencies (F) such as magnesium deficiency

5 Eggshell quality checklist

Feed

- Adequate feed available at all times.
- If there has been a recent change in feed, e.g. new batch or new supplier, check for the following:
    - The formulation is correct for your strain and age of bird.
    - The formulation is correct for the time of year.
    - The diet meets formulated specifications (energy, protein and premix).
    - Does feed contain new seasons wheat?
    - Are premix levels correct?
    - Are calcium levels correct?
    - Does feed contain anti-nutritional factors?
    - Does feed contain any toxins e.g. Mycotoxins?
- If you are mixing your own feed, do you consult with a poultry nutritionist and/or have your feed analysed?

Water

- Fresh drinking water available at all times.
- Is there a problem with your water quality, e.g.:
    - Saline drinking water.
    - Too much organic matter in the water.
    - Has water been effectively sanitised?
    - Microbiological contamination.
    - Temperature of the water at the drinking points.

Disease

A drop in production may be associated with the presence of a disease. Check for clinical signs of:

- General disease state e.g. peritonitis and chronic respiratory disease (CRD).
- Diarrhoea (wet droppings).
- Respiratory disease.
- Metabolic problems, e.g. cage layer fatigue.

Some eggshell defects are characteristic of **particular diseases**. For further information refer to Section 3.9.

Management

Rearing Period

Rearing conditions are very important and problems in rearing may affect the birds throughout their laying life. Rearing conditions may also affect the suitability of birds for different production systems. Check the following during rearing:

- Feeding regime.
- Lighting program.
- Vaccination program.
- Type of housing.

Lay Period

Shell quality problems may be caused by a variety of factors including:

- Feeding regime (e.g. inappropriate pre-lay diet).
- Temperature stress (temperatures below 13°C or above 29°C).
- Unfamiliar personnel.
- Storms and other disturbances.
- Predators in the vicinity.
- Vaccination programs.
- Lighting.
- Age of birds.

Alternative production systems

- Are birds receiving particulate calcium of an appropriate particle size?
- Is water supply accessible to wild birds or vermin?
- If free range:
    - Is artificial lighting used?
    - Do birds have adequate shelter?
    - Check for signs of
        - (a) External parasites
        - (b) Internal parasites.

6 Further reading

6.1 General books (with good illustrations)

Kashimori, A. 2017. *The Illustrated Egg Handbook*. Context Publications, U.K. ISBN 9781899043743, 158 pp. (sponsored by Nabel Co. Ltd and DSM). (www.contextbookshop.com)

Simons, P. 2017. *Poultry Signals: Egg Signals – a practical guide to improving egg quality*. Roodbont Publishers B.V., The Netherlands, ISBN 9789087402723, 159 pp. (www.eggsignals.com)

6.2 Specialist books

Nys, Y., Bain, M. and Van Immerseel, F. (Eds). 2011. *Improving the safety and quality of eggs and egg products Volume 1: Egg chemistry, production and consumption*. Woodhead Publishing, Cambridge, U.K. ISBN: 978-1-84569-754-9, 602 pp.

Van Immerseel, F., Nys, Y. and Bain, M. (Eds). 2011. *Improving the safety and quality of eggs and egg products Volume 2*. Woodhead Publishing, Cambridge, U.K. eBook ISBN: 9780857093929; Hardcover ISBN: 9780857090720; Paperback ISBN: 9780081016800, 581 pp.

Roberts, J.R. (Ed). 2017. *Achieving sustainable production of eggs. Volume 1. Safety and quality*. Burleigh Dodds Science Publishing, Cambridge, U.K., ISBN-13: 9781786760760, 17 chapters, 430 pp.

Roberts, J.R. (Ed). 2017. *Achieving sustainable production of eggs. Volume 2. Animal welfare and sustainability*. Burleigh Dodds Science Publishing, Cambridge, U.K. ISBN-13: 9781786760807, 10 chapters, 234 pp.

Hester, P. (Ed). 2017. *Egg Innovation and Strategies for Improvement*. Elsevier, eBook ISBN: 9780128011515; Hardcover ISBN: 9780128008799, 55 chapters, 646 pp.

7 Glossary

acidosis – when the body fluids of the bird become too acidic.

alkalosis – when the body fluids of the bird become too alkaline.

ascorbic acid – Vitamin C.

bacterial load – the number of bacteria on the eggshell surface.

barn system – laying birds kept in deep litter housing that is fully enclosed.

bentonite – a type of clay consisting of natural aluminium silicates – sometimes used as a dietary filler or diluent.

breaking strength – the force which must be applied to an eggshell in order to cause failure or cracking of the shell.

broodiness – occurs when a hen stops laying and sits on the eggs in an attempt to hatch them.

cannibalism – pecking of one bird by another, which results in injury or death.

carbonated water – water containing a significant amount of dissolved carbon dioxide.

chalazae – rope-like structures in the albumen of the egg, which hold the yolk in place.

chelated zinc-EDTA – zinc bound to ethylene diamine tetra acetic acid.

cloaca – the terminal region of the digestive tract into which open also the urinary and reproductive tracts.

cuticle – the thin waxy layer composed of protein, polysaccharide and lipid, which is found on the outside of the eggshell.

deficiency – lack of a particular substance.

eggshell quality – features of the shell that affect the appearance and functionality of the egg.

free range system – laying birds that are housed on the ground in groups with access to outside areas.

genetics – relating to the genes or inherited characteristics of the bird.

hatchability – the proportion of settable eggs that hatch live chicks.

imbalance – incorrect proportions of substances (e.g. in feed).

infundibulum – the upper end of the oviduct, which directs the yolk mass into the oviduct and is involved in the formation of the perivitelline membrane and the chalazae. Fertilisation occurs in the infundibulum.

isthmus – the third region of the oviduct, which produces the inner and outer shell membranes.

magnum – the second region of the oviduct, which forms the majority of the albumen (egg white).

mammillary core – areas of organic material that are embedded in the outer shell membrane and are the initial sites of calcification of the eggshell.

mammillary layer – the innermost layer of the eggshell – the 'foundation' of the shell.

metabolism – the chemical processes that occur in all living things.

moulting – the forced or natural loss of a large number of feathers associated with other changes such as the regression of the reproduction tract.

mycotoxins – toxic substances produced by moulds and fungi.

ovary – the reproductive organ of the hen (only the left one is present), which contains a number of follicles (each containing an ovum) at different stages of development.

oviduct – the reproductive duct, which transports the egg from the ovary to the outside of the hen, and which produces the perivitelline membrane albumen, eggshell membranes and eggshell.

oviposition – the laying of the egg.

ovulation – the release of the mature ovum (egg cell plus yolk) from the ovary.

ovum (plural = **ova)** – the egg (consisting of egg cell plus yolk).

palisade layer – the layer that makes up the bulk of the eggshell (between the mammillary layer and the surface crystal layer).

particulate calcium – calcium in particle form (e.g. >1 mm), such as marble chip or oyster shell grit.

perivitelline (vitelline) membrane – the membrane around the yolk, which consists of three layers – the inner, continuous and outer layers, and is composed mainly of protein.

pigment – the chemical substances that give the eggshell its colour.

plumping – the process whereby water and electrolytes are added to the albumen in the shell gland pouch.

pore density – the number of pores in an eggshell, per unit of surface area.

prolapse cannibalism – pecking directed at the reproductive tract of the hen, which has become extruded out through the cloaca (cloacal eversion).

saline – salty.

sanitation – the control of infective organisms, e.g. in drinking water.

semi-permeable surface – a surface (e.g. the eggshell) that allows the movement of some substances but not others.

shell gland pouch – the fifth region of the oviduct in which most of eggshell formation occurs and where 'plumping' fluid is added to the egg albumen.

shell membrane – the eggshell membrane consists of two main layers, the inner and outer membranes, as well as the thin innermost limiting membrane. The membranes consist of overlapping and inter-twining fibres.

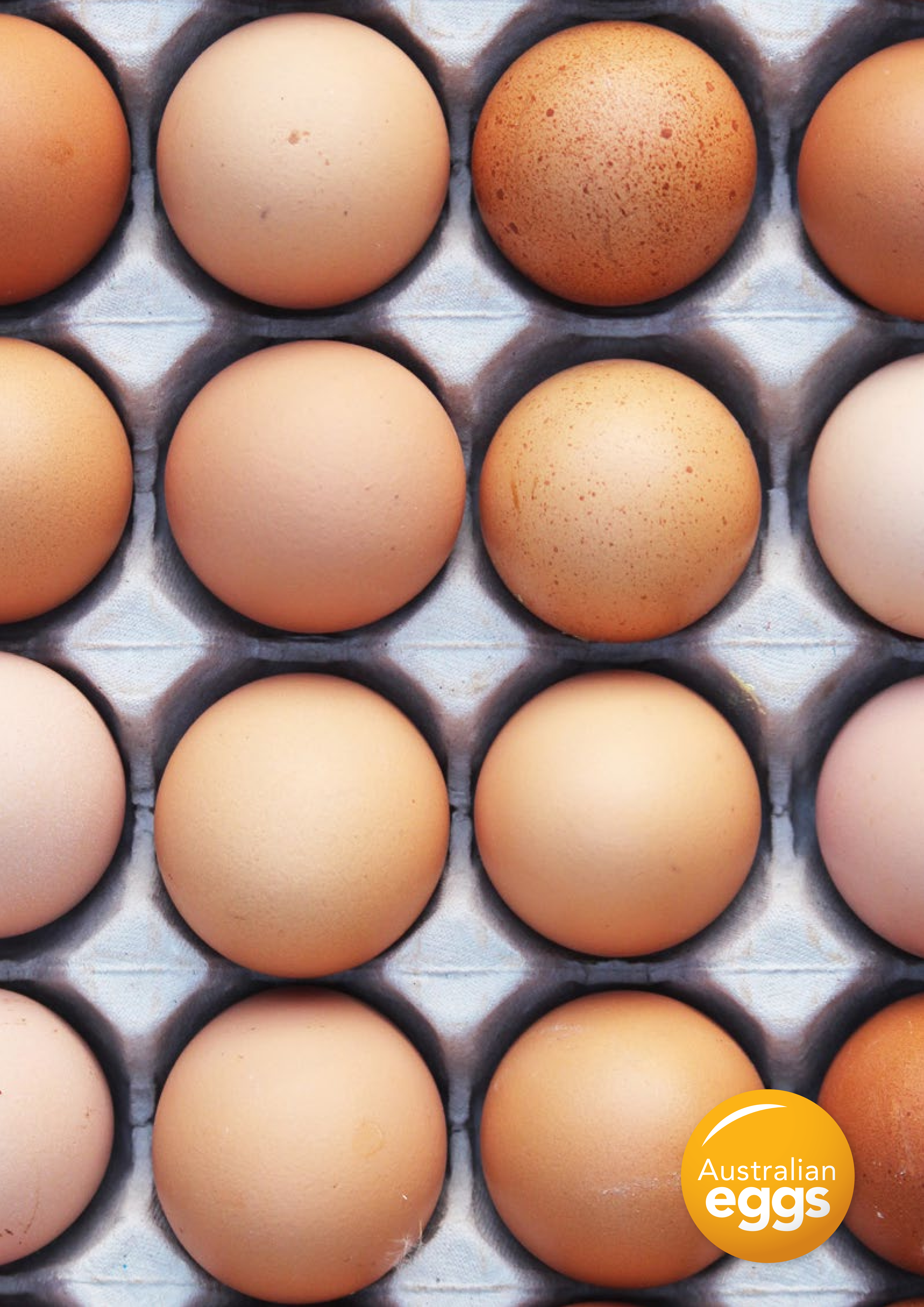
strain – the type or breed of the bird.

tubular shell gland – the fourth region of the oviduct in which the initial stages of eggshell formation occur.

ultrastructure – the fine (microscopic) structure.

vagina – the most posterior region of the oviduct, which opens into the cloaca.

zeolite – a type of clay made of hydrated aluminium silicates associated with cations (e.g. sodium, potassium, magnesium and calcium).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