Shell strength: a crucial component of egg quality

The avian egg is seen as the most complex amniotic egg in oviparous vertebrates. With complexity comes challenge, and producers must work hard in order to produce the best possible eggs they can from their hens. Many factors influence the quality of an egg, but often shell strength is regarded as crucial. Cracks are a significant contributing factor to downgrades, and producers must be mindful of this, especially considering that second-class egg percentages are critical to profitability.

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It is well known that the shell has an important function in providing a sealed, protected environment for an embryo to grow within, while allowing the transfer of gases and water that are vital to development. Clearly, in table egg production, embryogenesis is not essential. However, the shell is still crucial to providing strength and protection to the contents within.

A complex structure

The shell is a complex structure, composed primarily of calcium carbonate ($CaCO_3$), made up of multiple layers. The base layer (mammillary body) is formed first and is comprised of the mammillary cones, which then provide a platform on which other components can form.

The palisade layer forms on top of this, followed by the transitional vertical crystal layer and the cuticle. Each layer consists of a highly specific structure, which provides high resistance to compressive stress.

These structures have $CaCO_3$ components, but their structural integrity is withheld in the organic matrix by glycoproteins and glycosaminoglycans. Ensuring that the structure of the shell is optimal will improve strength, helping to prevent breakages and hairline cracks.

The mechanism behind the creation of structural layers is multifactorial, and, as such, many things can influence their composition. The shell is created from components fed to the hen in their diet. If the diet is of poor quality, it is likely that the shell will also be poor quality. Egg formation is a complex and energy-rich process.

The hen's nutritional needs

Generally, an egg is produced every day and, in order to maintain production, the hen must be able to digest and absorb all of the energy and nutrients she needs from her diet. The yolk passes out of the ovary through the reproductive system. Each step, be that albumen formation or shell formation, requires specific minerals.

It is important that hens have all of their nutritional needs met, but some minerals are vital. Zinc (Zn) is a good example. Not only does it perform functions in the cells of the immune system, it also works as a co-factor for an enzyme involved in the production of $CaCO_3$, one of the main components of the shell, contributing to strength. If the bird is not able to absorb enough Zn, it can lead to weak shells.

Manganese (Mn) activates an enzyme involved in the production of glycoproteins and glycosamino-glycans, which constitute between 2-4% of the eggshell through their roles in the organic matrix.

Collagen is part of the eggshell membrane surrounding the yolk and albumen and is the layer on which the shell is laid. Copper (Cu) is involved in the formation of collagen. Selenium (Se) is crucial as a natural antioxidant, but also in the egg itself, and has a big impact on maintaining freshness in eggs.

Diet quality, as discussed above, is crucial to shell strength, but the constituent quality is also critical. Mineral form has a significant influence on strength. Inorganic minerals are typically ionically bound compounds, meaning that upon entering the gastrointestinal tract they can dissociate into ions.

So, in the case of copper sulphate, the ions would split to Cu^{2+} and SO_4^{2-}. These ions are more reactive and can interact with other diet components, such as vitamins and minerals, reducing the absorption levels and, hence, bioavailability for the bird.

Another consideration is that, due to the low absorption levels, inorganic mineral forms are often excreted, creating environmental concerns. Organic minerals, in contrast, are not ionically bound.

As a result, they are less reactive, with stronger bonds meaning that they reach the site of absorption in the most readily available form. This means that organic minerals can be added to diets at much lower inclusion levels and reduced mineral leaching is seen, while bird performance is improved.

So, why does mineral form influence shell structure and strength?

Different types of minerals have different chemical compositions, charges and structures. These minerals are absorbed by the bird and then utilised for bodily functions and the creation of the yolk, albumen and shell.

As mentioned above, $CaCO_3$ constitutes a large proportion of the shell and is responsible for a large part of the strength. It is laid down in the mammillary cone layer, but the physical structure of the molecule can be influenced by the mineral form, with aragonite and calcite shapes.

Typically, calcite is considered a more stable shape and is often seen when birds have been fed on organic minerals. This, alongside better bioavailability, helps to explain why Alltech, upon measuring 15 million eggs, found a consistently improved shell strength when hens had been fed Bioplex organic minerals when compared to inorganic forms.

One factor of egg quality that is not often discussed is eggshell strength variance. Variance is the amount by which the strength differs across all of the eggs produced. If variance is low (less than one), it means that all the eggs produced are of similar strength, which ensures that the producer has a more uniform product.

If variance is high (greater than one), it would highlight that perhaps there are uniformity issues within the flock. A lower level of variance in the eggs will help to ensure that producers get the minimum amount of variability in the flock, which helps with planning.

Organic mineral forms tend to reduce variance, meaning that downgrades from eggshell breaks are more even throughout the flock.

Increased demand

Due to Covid-19, demand for eggs has sky-rocketed, with people spending more time at home, baking and cooking. This has been good for the egg market in terms of an upturn in growth, and even when returning to a sense of normality, it is expected that demand will remain high.

With this in mind, it becomes ever more important for producers to gain as many class A eggs as possible to help meet the demand.

Shell strength should be a focal point when aiming for better downgrade levels, and this is possible by looking at the mineral form. However, the importance of a good quality diet and gut health should also not be overlooked. ■