Trace minerals in poultry nutrition - 5

Reaching optimal egg shell formation

An egg – produced either for production or consumption - is not just an egg. For either of these purposes, there are many similarities for which both environmental as well as nutritional factors greatly influence the formation of a strong and good shell.

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What is the function of the eggshell? Well, to some extent it depends on the destiny of the egg. If it is the product of the layer bird, then its prime function is protection against microbial penetration and so it must be intact, free from blemishes, and clean. In terms of size, the larger egg must, like the family sized cornflake box, represent value for money, but unlike the cornflake box, egg size does influence shell quality. Shell colour, too, enters the equation and in the classic example of the book being judged by its cover, brown evenly pigmented shells will be purchased before their paler neighbours.

If the egg is destined for the hatchery then regularity of form and intactness occupy pole position together with cleanliness. The shell must be sufficiently strong to afford physical protection to the growing embryo, and it must be constructed in such a way as to provide an efficient conduit for gaseous exchange and inhibit bacterial ingress. The shell must also, by virtue of its structure, enable the withdrawal of calcium and other trace elements by the embryo and in so doing facilitate shell thinning through this process of dissolution. In common parlance no pressure then!

Photo 1 - Wrinkled eggs usually indicates the incidence of Infectious Bronchitis (IB).

Pressure intensified

With egg production comes waste. In recent years, the pressure has intensified with legislation controlling the nature and volume of surplus nutrients released into the environment. To that end, considerable attention has been given to the use of organic sources of trace minerals and their effect at reduced inclusion levels on productivity and product quality.

As it emerges from the cloaca after its 24-hour journey through the oviduct, it is important to remember that the egg is the product of a number of anatomically and physiologically diverse systems, including the endocrine glands, the gastrointestinal tract, and the skeletal system with its discrete foci of medullary bone, the whole maintained in a state of equilibrium by a competent immune system.

On a 24-hour basis, the eggshell is a regular indicator of the bird's harmony with its environment. Disease, dietary imbalance and environmental stresses all change the pattern of mineralisation, rendering the egg unacceptable either as a consumer product or as an embryonic chamber; viz the slab-sided egg caused by egg retention in response to environmental stress, the wrinkled shelled egg characteristic of birds challenged with Infectious Bronchitis (*Photo 1*) and the pale eggs laid by many free-range birds in the heat of the summer. Such shells are consistent with premature oviposition as they have no cuticle.

Matrix proteins

Achieving the 'perfect egg' is accordingly no mean feat. The organic/inorganic composite consists primarily of calcium carbonate in its calcite modification supported by an organic matrix that varies in its composition and disposition throughout the shell. The proteins that constitute the matrix are functionally distinct, thus ovalbumin, which has been located in the innermost layer of the shell (the mammillary layer), is acknowledged to drive calcium affinity molecules and so influence the initiation of shell formation. Ovotransferin - also recovered from the mammillary layer - binds iron and clusterin, a mammillary and palisade layer protein has been described as a chaperone protein facilitating assembly into the protein scaffold of the shell. The palisade layer forms the bulk of the shell (*Photo 2*).

Trace minerals in their inorganic state are normally added to the bulk proteins and other constituents of the layer and breeder diet by feed supplementation. In recent years, concern has been expressed about the level of inclusion of these trace elements, their bioavailability, and the interaction between individual elements. Consequently, an impressive volume of research into the use of organic 'minerals', chelates of protein/amino acid containing minerals, has emerged. Data supports the contention

that in their organic form, the mineral proteinates display enhanced digestibility and improved retention even at a lower level of inclusion. The improvement in performance is cross-species and independent of rearing conditions.

Further incentive to usage

Turkey trials have demonstrated increased egg mineral levels and improved shell quality with a diet providing a 50% reduction in trace minerals in their organic form. Likewise, a low concentration of organic trace minerals improved weight gain in an experimental group of broilers compared with controls, and had no deleterious effect on feed conversion.

The message emerging from this global assessment of the effect of these bioplexed minerals on bird performance is that the bird responds positively - it is nutritionally satisfied and is reproductively active. The literature also cites 'improved shell quality' as a further incentive to usage, but how is this defined? Increased weight, increased egg size, fewer downgrades? Do these gross measurements adequately describe the precise role played by the diverse population of essential macrominerals and microminerals, which in association with minor minerals such as aluminium and fluorine constitute the inorganic component of the diet?

Ultrastructure and mineral localisation

In order to gain some understanding into the role played by trace elements in shell quality, it is necessary to consider the process at ultrastructural level, thus where within the shell do any of these macro/micro elements appear?

The major macro constituent is of course calcium derived from the diet and supplemented by the cyclical breakdown of medullary bone. In the hard shelled eggs of birds and many reptiles it exists in its most thermodynamically stable form – calcite, although in cases of stress where soft shelled eggs are produced, the aragonite form of calcium carbonate is frequently observed within the mammillary layer. Calcium carbonate as vaterite, the least stable form, will occasionally occur on the cuticular surface following egg retention.

According to the literature the shell is the main source of magnesium. Earlier EDAX analysis of forming eggs expelled from the active oviduct show that it is primarily associated with the mammillary layer. It is this layer, which by virtue of its intimate connection with the membrane fibres that is dissolved prior to hatching. If this bond is not established during the early stages of shell formation then the resultant shell will be structurally disorganised and the chick therein nutritionally and environmentally compromised.

Honeycomb appearance

Following formation of the mammillary layer, the bird constructs the thickest aspect of the shell, the palisade layer. Under the scanning electron microscope the latter is revealed to be permeated by vesicular holes, which give it a honeycomb appearance. Towards its outer surface it adopts a more compact configuration. Onto this compact composite is deposited the vertical crystal layer, which in turn supports the outer covering of the shell, the cuticle (*Photo 2*).

Analysis of the junction between these two outer aspects of the shell has corroborated the presence of hydroxyapatite (the bone crystal). Towards the end of calcification, blood phosphate levels rise. According to the literature, phosphorus acts as a crystal poison and so brings the calcification mechanism to an abrupt closure. This narrow band of phosphate-containing crystals may bear witness to such a process.

The essential micro-minerals, which include iodine, iron and manganese, are more difficult to locate spatially as specific shell components. As previously stated, ovotransferin, a mammillary layer protein, binds iron, but the functional significance of this association remains obscure.

Manganese deficiency is associated with poor hatchability. However, whether this is due to a direct influence on shell function or whether the effect is ultimately reflecting bone impairment, and hence the ability of the latter to satisfy the calcium requirements of the shell, has also to be established.

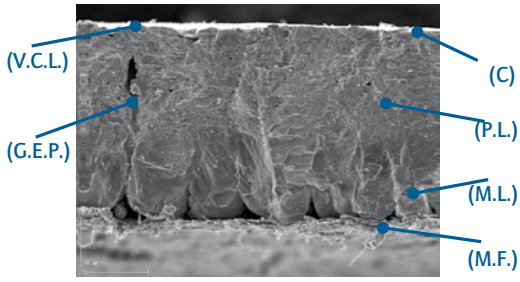
Selenium influential

With respect to selenium, the story is a little more advanced. It is defined as a biological antioxidant, and according to the literature has a role to play in resistance to viral infections. It has also been shown to improve fertility and promote growth.

In a recent experiment designed to observe the effect of Sel-Plex® (Alltech) on the shell structure and egg quality of the hatching egg between 22-54 weeks of age, changes were observed at the level of the mammillary layer at the end of the trial period. Thus, in comparison with the control flock, the range and incidence of structural defects was reduced and the number of nucleation points per unit area increased. The data was consistent with improved hatchability at 54 weeks (*Photos 3 and 4*).

But how did Sel-Plex exert its function? Was it purely acting in its capacity as an antioxidant? Did it encourage protein expression and so enable the formation of increased numbers of nucleation sites? Every observation generates another question, but that is the nature of science.

There is no question, however, as to the fundamental and crucial role played by trace elements. This 'greening' world will rightly demand that they are provided in the most environmentally friendly forms and in that respect, the bioplexed minerals appear to fit the bill. With respect to the biosecurity of the end product, i.e. the egg, the synergistic action of diet, environment and management will enable the formation of a packaging unchallenged in terms of its multiple functions by any machine-made wrapping. ■



(V.C.L.): Vertical crystal later
(G.E.P.): Gas exchange pore
(C): Cuticle
(P.L.): Palisade layer
(M.L.): Mammillary layer
(M.F.): Membrane fibres

Photo 2 - Cross section through the shell.

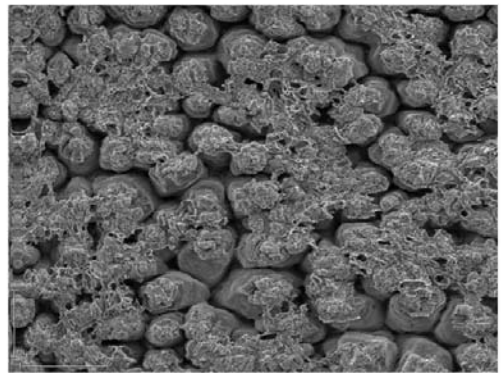


Photo 3 - The mammillae are fused.

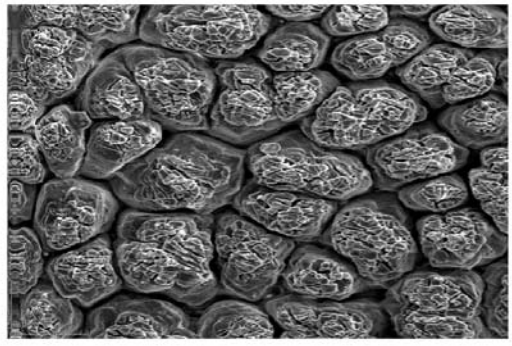


Photo 4 - Normal mammillary layer.