Using herbs to improve egg shell quality

by Dr Shivi and Dr Ali Asgar, Ayurvet Ltd, 6th Floor, Sagar Plaza, Distt. Centre, Vikas Marg, Laxmi Nagar, Delhi 110 092, India.

The avian eggshell is a complex natural biopolymer of mineralised and non-mineralised matrix. The egg shell constitutes some 9-12% of total egg weight (see Fig. 1). Good quality egg shells contain approximately 2.2g of calcium in the form of calcium carbonate and about 95% of the dry egg shell is calcium carbonate.

The average eggshell contains 0.3% phosphorus and 0.3% magnesium and traces of sodium, potassium, zinc, manganese, iron and copper.

If the calcium from the shell is removed, the organic matrix material is left behind. This organic material has calcium binding properties and its organisation during shell formation influences the strength of the shell.

The organic material must be deposited so that the size and organisation of the crystalline components (mainly calcium carbonate) are ideal, thus leading to a strong shell.

Calcium metabolism

The multi-factor mechanism of transfer of calcium ions to the egg shell consists of a vitamin D dependent absorption of calcium ions that is calbindin (calcium binding protein) mediated. Calbindin acts as a cytosolic facilitator of calcium ion diffusion from the brush border membrane to the basolateral membrane.

The induction of calbindin gene expression in the egg shell gland (ESG) is predominantly calcium dependent. In addition to the induction of calbindin-D synthesis, vit-D3 ($1,25(OH)_2D3$) exerts other effects on the intestinal epithelium that can have consequences on the calcium absorptive process.

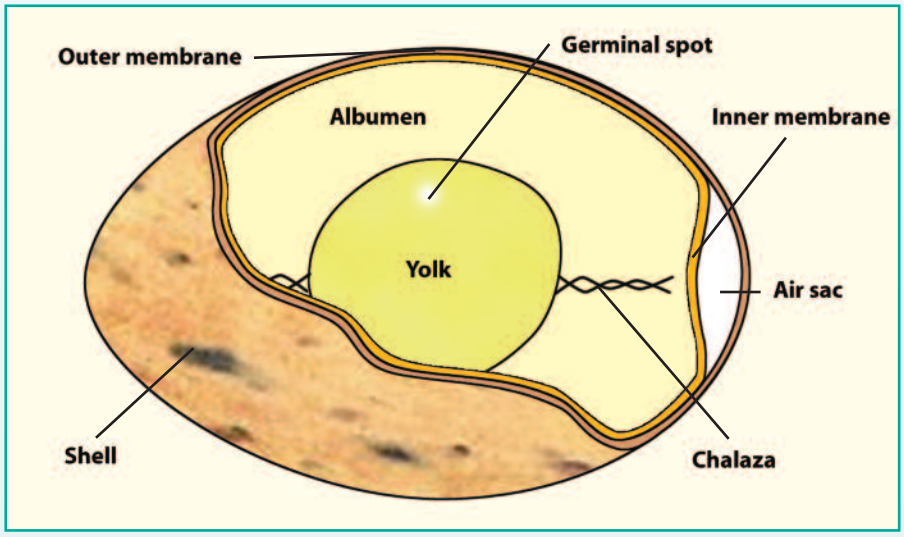
Some of these effects are summarised in Fig. 2.

There is defect in vitamin D metabolism or calbindin gene expression in old hens responsible for thin-shells. Aged hens absorb calcium with a lower efficiency due to lesser synthesis of 1,25-hydroxycholecalciferol ($1,25(OH)_2D3$), a defect in the hen's ability to alter calbindin synthesis in response to calcium needs and less duodenal and eggshell gland (ESG) calbindin than normal laying hens leading to formation of light uncalcified shells.

	Characteristics		
Vitamin D (IU/Kg)	Shell percentage (%)	Shell thickness (mm)	Specific gravity (g/ml. H_2O)
2500	8.17	0.42	1.082
3000	8.38	0.43	1.083
3500	8.47	0.43	1.083

Table 1. Egg shell quality traits of hen fed different levels of vitamin D in thermo-neutral conditions (24-27°C).

Fig. 1. Cross section of an egg. The shell makes up 9-12% of the total weight.



Egg shell quality

● Early and late layers.

Early onset of production is associated with physiological calcium deficiency as indicated by increases in kidney-1-hydroxylase and duodenal calbindin in early layers as compared with late layers. Early layers exhibit a more severe reduction in shell quality, when compared with late layers, as a result of calcium deficiency.

In one of the studies, feeding pullets with a pre-lay diet containing 3.9% calcium did not affect the performance or shell quality during the whole productive period, whether the birds started to lay early or late.

● Synergistic and antagonistic influence of dietary ingredients on calcium utilisation.

In diets with a distorted calcium:phosphorus ratio (low phosphorus concentration of 3.2g/kg with a high calcium content of 35-45g/kg) the interaction between calcium and phosphorus is manifested by strong performance depressions and a high mortality at combinations.

A dietary phosphorus content of 4.5g/kg (1.0g/kg added inorganic phosphorus) is sufficient for maintaining egg production and shell quality in aged laying hens given 36-40g/kg calcium. Increasing dietary calcium above 40g/kg may require a higher dietary phosphorus content.

However, a very high phosphorus content in the feed and excess chlorine may have a negative effect on eggshell quality. It is reported that these two elements act negatively on egg shell quality through their influ-

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ence on acid base balance (pH) in the blood.

The importance of adequate vitamin D intake by the hen is thus obvious and it is essential for proper calcium and phosphorus absorption. Excess vitamin D and its metabolites have not been shown to benefit eggshell quality when normal hens are already consuming adequate vitamin D.

Table 1 depicts the egg shell quality traits of hens fed different levels of vitamin D in thermoneutral conditions.

- **The saline drinking water and shell thickness.**

Increase in salt intake through the drinking water or the food is also known to reduce shell thickness and calcium absorption.

Sodium chloride given in the drinking water reduces shell quality and increasing plasma calcium and phosphorus more than when sodium chloride given in the food.

- Weight of shell/unit surface area.
- Egg shell pore concentration.
- Relative eggshell water vapour conductance.
- Egg specific gravity.
- Breaking strength.
- Shell thickness.
- Shell weight.
- Incubational egg weight loss.

Table 2. Factors determining the egg shell strength and quality.

- **Heat stress.**

For layers, the main consequences of heat stress are a reduction in feed intake, a decrease in intestinal blood flow and ionised calcium levels in blood, a reduction in partial pressure of carbon dioxide and interference in gonadotrophin releasing hormone action, the hypothalamic hormone that regulates the release of leuteinising hormone.

Eggshell thickness decreases markedly during heat stress. There is calcium and phosphorus loss due to acid base imbalance and alkalosis of the blood due to loss of excessive amounts of carbon dioxide by panting.

Egg weight falls by about 0.4% per °C between 23 and 27°C; above 27°C the decrease is about 0.8% per °C rise in environmental temperature. Growth at point of lay is reduced above 24°C, and is extremely low above 28°C. Rate of lay is generally only affected above 30°C. Feed conversion ratio is optimal at a temperature of about 28°C. Above 28°C FCR deteriorates, because of the failure in production.

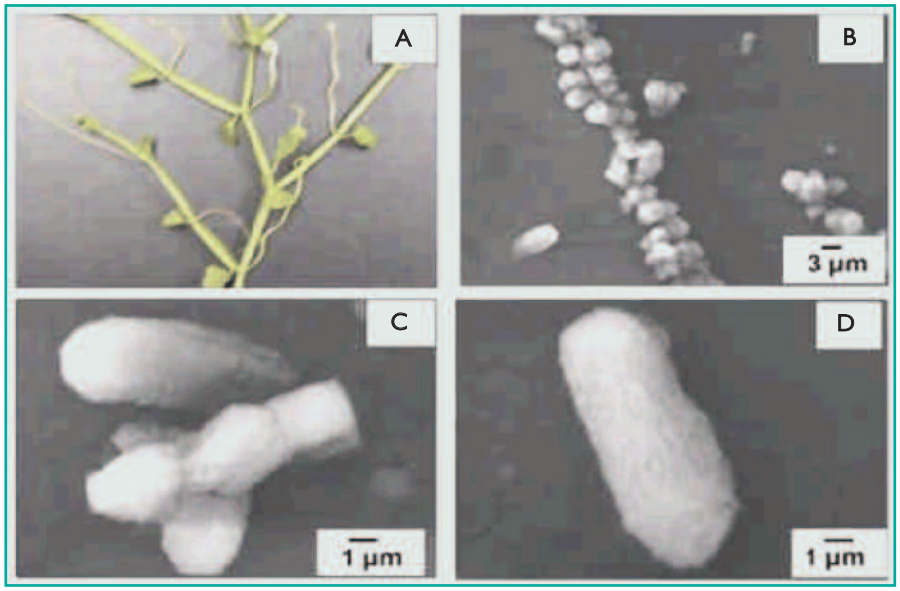

Fig. 3. Photograph of Cissus quadrangularis plant (A). Representative SEM micrographs (B, C and D) at different magnifications of calcium carbonate crystals grown in vitro from the extract of C. quadrangularis plant.

Potential problems

Problems with the quality of eggs and egg products have the potential to cause human health risks and undermine the confidence of consumers in the quality and safety of the product. Accurate assessments of eggshell quality may, therefore, allow the producer to vary one or more of these factors that influence eggshell quality in order to improve product quality. Various factors determining the eggshell strength and quality are summarised in Table 2.

Egg shells are evaluated on the basis of cleanliness, shape, texture, and soundness. Traditionally, eggshell quality has been defined in terms of the ability of an eggshell to resist breakage. Breakage or cracking of eggshells in market channels is a serious concern. Cracks result from a combination of shell strength and integrity disruption during careless handling. Other egg shell quality factors such as the formation of abnormal ridges, calcium deposits, or body checks (ridges) are important considerations in determining egg shell quality.

Quality production

Management plays an important role in the production of eggs of high quality. To ensure the production of high quality eggs, the following factors are important:

- Select a strain of birds known to produce eggs of good quality because egg quality is a heritable characteristic.
- Avoid prolonged periods of temperature above 86°F in the laying house, if possible. Practice the necessary steps to prevent disease and other physiological disturbances in the flock.
- Use high quality feeds and adjust feed formulations according to feed intake and the age of the hens.
- Ensure sufficient bioavailability of calcium and phosphorus for egg shell formation by adequate supplementation of calcium, phosphorus, vitamin D3 and proteins.

Nutritional adjustments

Dietary manipulation is the primary means for minimising the natural deterioration of

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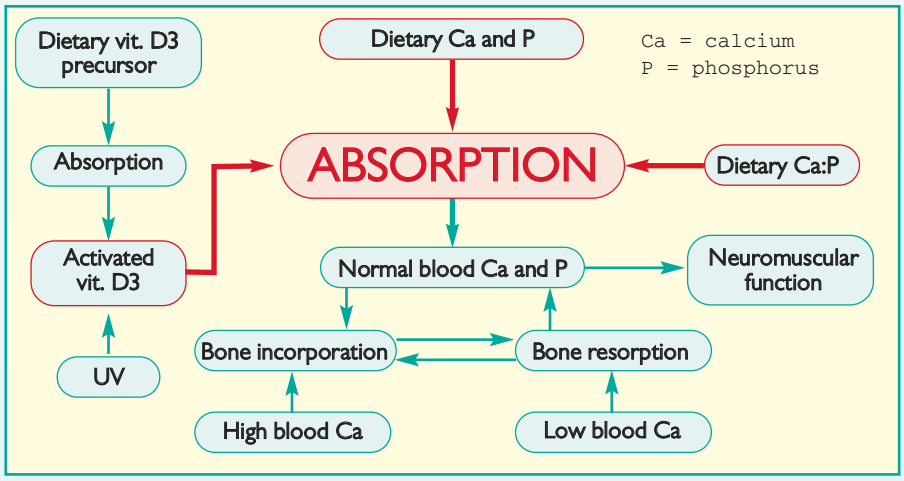
Fig. 2. Mechanism of calcium absorption.



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the eggshell quality throughout the laying period. The pre-lay feed is an intermediate feed between developer and layer feed.

The calcium content should be 2% with 50% of this amount in particles (from 2-4mm) during pre-lay period.

Solarte et al. (2006) also reported that dietary calcium requirement for white laying hens from 46 to 62 weeks of age was 3.56% in the diet or 4.02g calcium per hen daily with the average ambient temperature of 21.65°C (Table 3).

Factors	Ca requirement (%)
Egg production	3.52
Egg mass (g/hen/day)	3.54
Feed conversion (g feed/g egg)	3.62

Table 3. Nutritional calcium requirements estimated for White Leghorn at 21.65°C ambient temperature.

The intensive deposition of calcium occurs during the last part of the day and during the night. Calcification is completed for 80% of the birds two to three hours after lights on.

The higher the feed intake and the calcium intake in the afternoon, the higher the calcium deposition and, therefore, the stronger the egg shell.

An adapted feeding timetable based on this knowledge will reduce the mobilisation of the calcium from the medullary bone. The introduction of a period of light in the middle of the night improves the shell quality by allowing the hen to replenish her calcium reserves at a key time.

Eggshell quality depends to a large extent on the quantity of calcium remaining in the gizzard at the end of the calcification process and, therefore, towards the end of the night.

Absorption of calcium and its availability in the gizzard can be enhanced by the addition of certain herbs in the diet.

Herbal solutions

Many herbs are known to positively influence the absorption and assimilation of minerals such as Cissus quadrangularis, Zingiber officinale, Lepidium sativum, Terminalia arjuna, Cestrum diurnum and Uraria picta.

Cissus quadrangularis is a medicinal and culinary plant native to India and Africa. It is reported that aqueous extracts of plant Cissus quadrangularis have calcium and phosphorus mineralisation properties and this helps early completion of calciferous process and remodelling phenomenon.

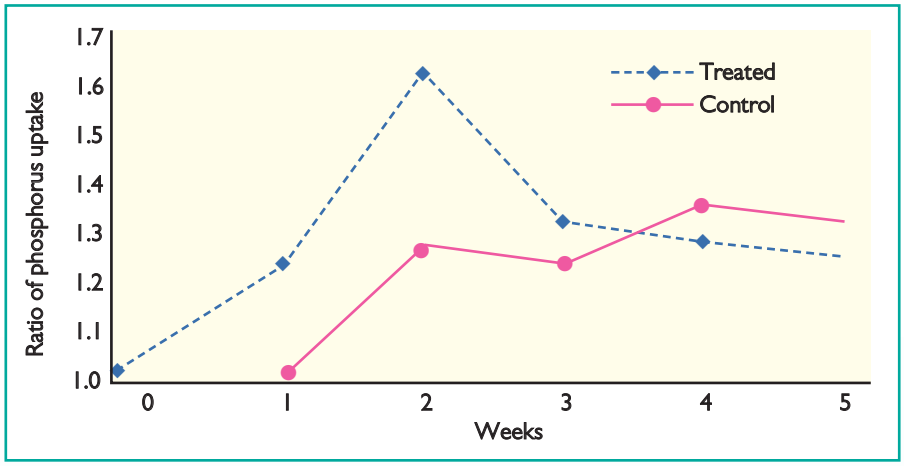

Fig. 4. Increased phosphorus uptake in albino rats treated with Uraria picta.

Its anabolic steroidal principles (β-sitosterol, δ amyrone and δ amyrin) have marked antistress activity. Udupa and Prasad, 1964, also reported the same while doing radioactive Ca^{45} uptake studies of Cissus quadrangularis.

The presence of calcium and phosphorous in the plant can also be exploited for synthesising calcium carbonate (Fig. 3) and hydroxyapatite, an important constituent for egg shell formation.

Many isotopes such as S^{35}, P^{32}, Sr^{85} and Ca^{45}, have been used in the study of utilisation of minerals such as calcium and phosphorus by supplementation of various herbs.

In one study, two weeks supplementation of Uraria picta was reported to show maximum deposition of P^{32} (Fig. 4) due to its mineralisation properties when compared to the control in albino rats .

Similarly, Zingiber officinale and Lepidium sativum are a rich source of minerals and have good immunomodulatory properties.

Zingiber officinale contains 1.2% minerals on dry matter basis (Ca 20%, P 60%, Fe 2.6mg/100g in addition to traces iodine and chlorine) and Lepidium sativum is a rich supplement source of phosphorus (1.65%), calcium (0.31%) and sulphur (0.9%).

These herbs can be supplemented in layer diet as a rich source of minerals for good quality egg shell formation.

Leaves of Cestrum diurnum have also been explored as a source of 1,25(OH)2D3 in the feed of layer birds for improving the egg shell thickness, specific gravity and weight. Incorporation of 0.3% Cestrum diurnum significantly ($P < 0.001$) improved the egg shell thickness and increased specific gravity by 0.5%.

In an another experimental study, Dhakel and Madhav, 1998, also documented an increase in uptake and utilisation of dietary Ca and P and regulation of calcium mobilisation from skeletal system to the shell glands, after three weeks supplementation of herbal ingredients of Uraria picta, Lepidium sativum, Cissus quadrangularis, Zingiber officinale in broiler breeders, thus improving the external egg shell quality in terms of % production, porosity and shell thickness (Table 4).

Mandelkar et al also reported similar findings of improvement in laying performance attributing it to synergistic action of herbs.

Thus, it can be concluded that good management practices and nutritional adjustments with supplementation of herbs can improve table egg quality by enhancing egg shell strength. ■

References are available from the author on request: info@ayurvet.com.

Table 4. Effect of supplementation of combination of herbs in broilers on egg production and quality parameters.

Experiment	Group	No. of birds	Pre-treatment (%)			Post- treatment (%)		
			Production	Hatchability	Breakage	Production	Hatchability	Breakage
I	Treated	1000	79	82	3	81	84.25	1
	Control	500	79	82	3	79	81.00	3
II	Treated	800	63	84	4	70	84.00	2
	Control	100	63	84	4	62	84.00	4