Making sure poor eggshell quality is a thing of the past

Keeping laying hens up to 100 weeks of age (producing 500 eggs) without moulting is no longer an utopian idea. Such long production periods require new tools to support the hen to produce high quality eggs until the end of the laying cycle. Maintaining good eggshell quality is especially crucial.

Independent of egg weight, the eggshell weight and therefore the amount of calcium (Ca) deposited remains more or less constant over time.

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This means that for each egg the hen needs to deposit approximately 2g Ca or almost 10% of the total body Ca per day in the form of calcium carbonate ($CaCO_3$).

As Ca cannot be stored in the uterus, eggshell formation depends, among other factors, on sufficient amounts of available Ca in the blood during the period of eggshell formation as well as on the proper function of the Ca-metabolism.

One of the most important elements in Ca-metabolism is vitamin D. Vitamin D_3 is converted in the liver by the enzyme 25-hydroxylase to the storage form 25-hydroxyvitamin D_3 (25OHD_3). The second step to the metabolic active form 1,25-dihydroxycholecalciferol (1,25(OH)$_2$D$_3$) takes place in the kidney and is mediated by the enzyme 1α-hydroxylase. 1,25(OH)$_2$D$_3$ is released into the bloodstream and docks to the vitamin D receptor (VDR) which is present in different tissues, such as bones and the kidney.

In the gut the interaction of 1,25(OH)$_2$D$_3$ with VDR leads to an increase in the expression of genes involved in Ca absorption from the intestinal lumen and Ca transport through the cell with calbindin (Fig. 1).

In contrast to intestinal calbindin, uterine calbindin in laying hens does not seem to be directly dependent on 1,25(OH)$_2$D$_3$.

However, the presence of a rather high concentration of VDR in the eggshell gland indicates that 1,25(OH)$_2$D$_3$ is essential for the functionality of the eggshell gland and proper eggshell formation.

Due to the complex metabolism of vitamin D, disruption can occur either in the liver (for example inflammation, mycotoxicosis, fatty liver syndrome) and/or in the kidney (inflammation, mycotoxicosis), impacting the formation of 25(OH)D$_3$ and 1,25(OH)$_2$D$_3$.

Besides, there are also indirect effects on co-factors in the vitamin D metabolism, impairing synthesis of 1,25(OH)$_2$D$_3$ (for example reduced synthesis of oestrogen during heat stress). Such conditions are a challenge even for younger hens.

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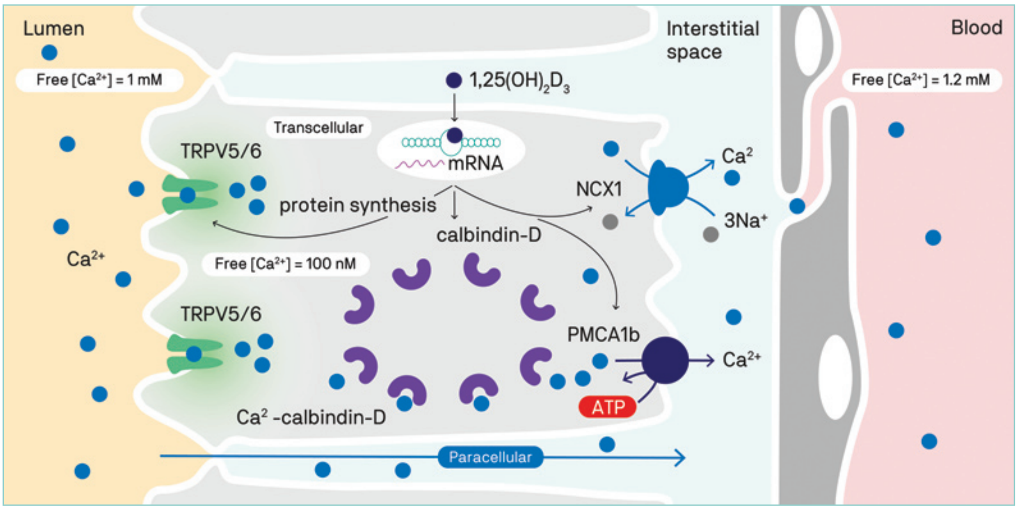

Fig. 1. Mechanism of epithelial Ca2+ transport. Epithelia can absorb Ca^{2+} by (passive) paracellular and (active) transcellular transport. 1,25(OH)$_2$D$_3$ stimulates the individual steps of transcellular Ca^{2+} transport by increasing the expression levels of the luminal Ca2+ channels, calbindins, and the extrusion system on the basal side of the epithelial cell (adapted from Hoenderop et al., 2005).

Table 1. Eggshell quality, plasma concentrations of 25-hydroxyvitamin D_3 (25(OH)$_2$D$_3$) and 1,25-dihydroxycholecalciferol (1,25(OH)$_2$D$_3$) and bone ash content in white Leghorn hens of different ages[1] (from Abe et al., 1982).

Group	1	2	3
Age (days)	235	638	854
Eggshell quality			
Thickness (mm)	0.34 ± 0.00	0.30 ± 0.01**	0.27 ± 0.00**
Strength (kg)	4.28 ± 0.13	2.42 ± 0.16**	1.62 ± 0.13**
Cracked/soft-shelled (%)	0	21.4 ± 11.3	58.6 ± 13.2**
Plasma concentrations			
25(OH)D$_3$ (ng/ml)	29.3 ± 2.7	24.6 ± 4.1	22.5 ± 3.2*
1,25(OH)$_2$D$_3$ (pg/ml)	595 ± 124	262 ± 64*	[2]
Bone ash (femur)			
Cortical bone (g)	6.6 ± 0.2	6.6 ± 0.2	6.8 ± 0.1
Medullary bone (g)	2.5 ± 0.2	2.0 ± 0.1	1.8 ± 0.1*

[1]Values show mean ± SEM of 5-6 hens; [2] no value given in original publication
* significantly different from Group 1 ($p<0.05$); ** significantly different from Group 1 ($p<0.01$)

Table 2. Eggshell abnormalities (%) in laying hens fed a control diet (control) or a diet supplemented with Solanum glaucophyllum (SG).

	Control	SG
74-79 weeks	1.5	1.2
80-83 weeks	2.3	1.2
84-87 weeks	2.2	0.8
88-91 weeks	2.1	0.9
92-95 weeks	1.5	1.1

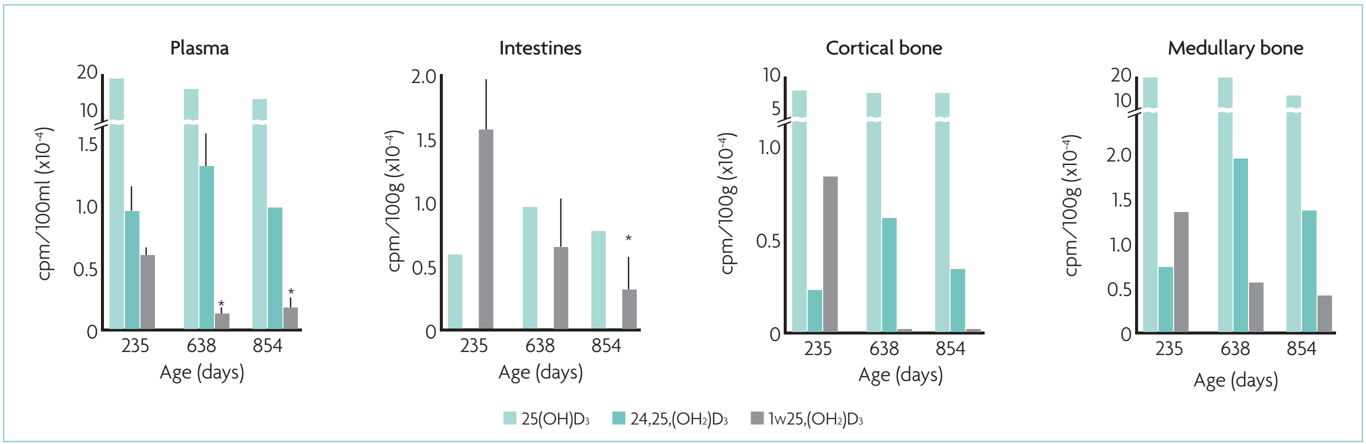

Fig. 2. Changes in the accumulation of radioactive metabolites in target tissues 16 hours after intravenous injection of 1µCi of $25(OH)[^3H]D_3$ into three hens in each group. Plasma and intestine were extracted individually in each bird. Cortical and medullary bones were pooled in each group and extracted together. The bars indicate standard errors. *: significantly different from young hens ($p < 0.01$) (from Abe et al., 1982).

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In older laying hens, physiological changes add to the above-mentioned challenges.

Abe et al. (1982) described a negative correlation between age and serum $1,25(OH)_2D_3$ content in their study with white Leghorn hens.

This coincided with a significantly reduced eggshell quality (Table 1) and increased incidence of cracked and soft-shelled eggs from 0% in 30 week old hens to 58.6% in hens at 120 weeks old.

By injecting radioactively labelled $25(OH)D_3$ and then measuring the amount of the labelled metabolites $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$, the authors discovered that the formation of $1,25(OH)_2D_3$ was impaired (-50%) in hens aged 90 weeks compared to hens aged 30 weeks (Fig. 2), which was caused by the reduced activity of the renal 1α-hydroxylase, the enzyme that is crucial for the transformation of $25(OH)D_3$ into $1,25(OH)_2D_3$.

A simple and efficient method to overcome this reduced activity of 1α-hydroxylase in aged laying hens is dietary supplementation of $1,25(OH)_2D_3$-glycosides.

When fed to the bird the $1,25(OH)_2D_3$-glycosides are hydroxylated by intestinal enzymes and the free $1,25(OH)_2D_3$ molecule is absorbed and can support mineral metabolism in the bird.

Fig. 3. Laying rate in laying hens fed a control or a diet supplemented with Solanum glaucophyllum (SG).

One of the few plants naturally producing $1,25(OH)_2D_3$-glycosides as a source of the metabolic active form of vitamin D_3 is waxy-leaf nightshade (Solanum glaucophyllum, SG). This plant naturally grows in humid areas in South America, mainly Argentina.

When added to commercial layer feed on top of the usual vitamin D supplementation, increased eggshell quality, especially in the second laying period, can be observed. Furthermore, the persistency of the laying rate was improved.

In a research site trial conducted with 300 Lohmann Brown (LB) and 200 Lohmann Selected Leghorn (LSL) hens were divided in two groups per breed. Half of the animals received a commercial diet (control), whereas the other half received the same commercial diet supplemented with 100g/t of a standardised mixture of SG, providing 1µg of $1,25(OH)_2D_3$-glycosides/kg feed. The trial lasted for 84 days from 76-87 weeks of age.

Effects of breed or SG treatment were not statistically significant, although there was a trend for a positive effect of SG on laying rate (Fig. 3) and a reduction in damaged eggshells (Fig. 4).

Egg weight was numerically reduced by SG, which was reflected in the lower fraction of XL-sized and higher fraction of M-sized eggs.

In a second trial at a European University, a total of 300 Lohmann Brown hens aged 74 weeks were either fed a commercial diet (control) or the commercial diet supplemented with 100g of SG/t feed (SG) during 21 weeks.

At the end of the experiment, the laying rate per hen housed was higher in hens fed the supplemented diets (62.0%) than in the birds fed the control diet (60.5%). In addition, FCR (2.663 vs. 2.829) and mortality (30.9 vs. 27.4%) were reduced in the supplemented group.

Eggshell quality was improved as observed in the first trial (Table 2).

The increase in eggshell quality was also reflected in improved eggshell breaking strength throughout the experimental period (Fig. 5).

It can therefore be concluded that the addition of a standardised mixture based on Solanum glaucophyllum on top of the usual vitamin D supplementation can compensate for age related reduction in eggshell quality and support the hen in providing high quality eggs throughout the whole laying cycle. ■

References are available from the authors on request

Fig. 4. Reduction of damaged eggs in laying hens fed a control diet supplemented with Solanum glaucophyllum (SG) compared to the unsupplemented control.

Fig. 5. Development of eggshell strength in laying hens from 74-95 weeks of age fed either a control diet or a control diet supplemented with Solanum glaucophyllum (SG).