Vitamin nutrition for optimal productivity

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It is well established that in commercial poultry operations today there are benefits from the routine use of higher levels of vitamins in feed than recommendations published in reviews such as NRC 1994.

Today's elevated levels not only help ensure simple deficiencies are rare, but also help the bird cope with the increased stress and disease challenge of commercial production.

In addition, they also go someway towards allowing the bird to fully benefit from the significant changes in genetic potential management practice and in dietary ingredient usage following the challenges of consumer pressure.

Recent data on vitamin requirements of the modern bird suggests that in some, particularly stress, situations there may be benefits of still higher levels of routine supplementation of certain vitamins.

Vitamin C (mg/kg)	Egg production (eggs/100 hens/day)	Egg weight (g)	Cracked eggs (%)	FCR
0	52.8	49.17	20.96	3.96
200	57.7	48.92	14.34	3.75
400	61.9	50.33	10.68	3.40
600	64.7	49.19	6.72	3.40

Table 1. Effect of vitamin C on laying hens performance in heat stressed environment.

There is also evidence that the bird's performance can be enhanced by the strategic use of certain vitamins at levels higher that would be economic if fed on a routine basis. Supplementation of certain vitamin metabolites, which have improved efficiency, can also help the bird cope more adequately with particular metabolic conditions. One convenient and economic way of achieving the required flexibility to take advantage of these benefits is by strategically administering vitamins in the drinking water.

Birds live surrounded by pathogenic micro organisms that can cause infectious disease.

One side effect of extensive genetic selection for production parameters in poultry has been a compromising of the immune system rendering the bird more susceptible to disease challenge.

With the imminent removal of antibiotic growth promoters from diets in some markets this susceptibility can only increase.

	Dietary vitamin E (mg/kg)	Temperature Normal	Stress
Plasma Vg	10	2.24±0.46	1.16±0.55
(mg Zn/l)	300	2.36±0.46	1.65±0.31
Liver Vg	10	2.02±0.42	3.80±0.86
(ug Zn/g)	300	2.37±0.31	2.38±0.95
Plasma: Liver Vg	10	1.11	0.31
	300	1.00	0.69

Table 2. Plasma and liver vitellogenin (Vg) in heat stressed hens.

Supplementation with increased levels of certain vitamins can help offset some of these challenges, particularly in situations where the bird's immune response has been compromised further by environmental or physiological stress.

Over, or prolonged, stimulation should however be avoided as the associated catabolic response can also effect performance adversely.

Where possible, immune stimulation with increased vitamin usage should only occur at key times in the production cycle.

Vitamin E is probably the most widely studied vitamin with respect to immune stimulation. Most studies fall into two designs; supplementing marginal or deficient diets with moderate levels (25-100mg/kg) or supplementing conventional diets (for example 30mg/kg) with a high level of addition (100-1000mg/kg).

Clear immunomodulatory responses are seen but these studies fail to determine optimal levels.

More recently, an attempt was made to define a dose response curve in broilers.

This work showed that moderate (35-60 mg/kg) levels were most immunomodulatory and that high levels (210mg/kg) were less effective. However, the actual amount of vitamin E that should be supplemented to achieve the effective levels described will depend on the levels expected to be lost during pelleting and storage.

Similar responses have been seen in heat stressed laying hens where vitamin E (65mg/kg diet) enhanced lymphocyte proliferative responses to concanavalin A and lipopolyssacharide.

Vitamin C (1000g/l drinking water) gave a similar response and even in the absence of heat stress, may benefit the immune system. For example 1000mg/kg feed vitamin C has been shown to give higher bursa and thymus indices, white blood cell counts and HI titres.

The above response probably also explains data which shows increased disease resistance, performance and processing characteristics in broilers supplemented with elevated levels of vitamin E.

For example, in a US based study, five groups of broilers totalling 1.5 million birds were given one of two vitamin E supplements (30 or 187mg/kg) from 0-20 days of age.

Feed to gain, liveweight and liveability were all improved (-2.3%, +0.7% and +0.1% respectively) and the level of condemnations (birds showing signs of toxaemia, septicaemia or inflammation at processing) were reduced (34, 25 and 64% respectively).

Egg type pullets have also been shown to benefit from elevated levels of vitamin E (50-100mg/kg) with improved feed conversion ratios and reduced tracheal lesion scores following an infectious bronchitis challenge.

The immune response of broiler chickens also seems to be enhanced by high levels of vitamin A. Dose response studies have shown that vitamin A levels of 6-7mg/kg produce a maximum immune response to casein antigen and antigen from Mycobacterium tuberculosis. Growth rates across the same range were not affected.

Vitamins that are immunomodulatory also have the potential to enhance the antiparasitic activity of cells and, therefore, the resistance of host intestine to coccidiosis. Vitamin C has been shown to enhance performance of broiler chicks exposed to multiple stressors including coccidiosis without a reduction in the lesion scores after Eimeria tenella and E. acervulina infections.

Improved weight gains and reduced mortality from E. tenella infected birds were also reported when treated with vitamin E. It is likely that activities of these vitamins may be related to their antioxidant and membrane stabilising properties.

Through an effect on the immune system, vitamins E, C and A can also increase the resistance of the bird to collibacillosis. Use of 100mg/kg feed vitamin C can increase the resistance of white Leghorn type layers to the effects of Newcastle disease and mycoplasma and to the secondary E.coli.

Use of 330mg/kg appears effective against a primary E.coli infection. Supplementation with vitamin E (300mg/kg) or vitamin A (60,000 IU/kg) alone increased the protection of six week old chicks against E. coli infection.

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Table 3. Effect of dietary riboflavin in relation to normal temperature (N) or chronic heat stress (CHS) on broiler performance at 3 weeks.

	Temp	Dietary riboflavin (mg/kg) 2.8	3.3	7	15
Liveweight (g)	N	526	661	625	698
	CHS	507	567	539	558
Curled toe paralysis (%)	N	22	0	0	0
	CHS	20	4	2	0

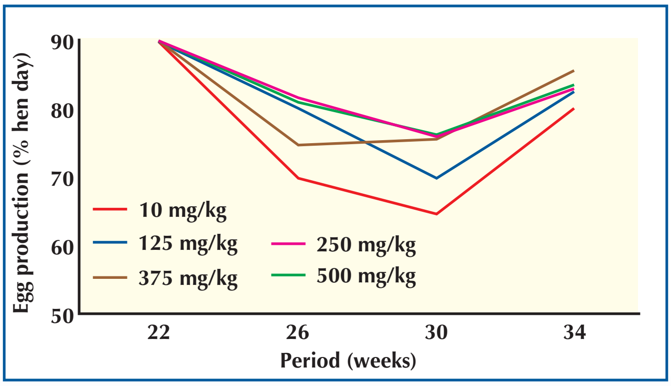

Fig.1. Egg production (% hen day) of laying hens fed on diets different vitamin E content (10, 125, 250, 375 or 500mg) and subjected to a period of chronic heat stress between 26 and 30 weeks of age.

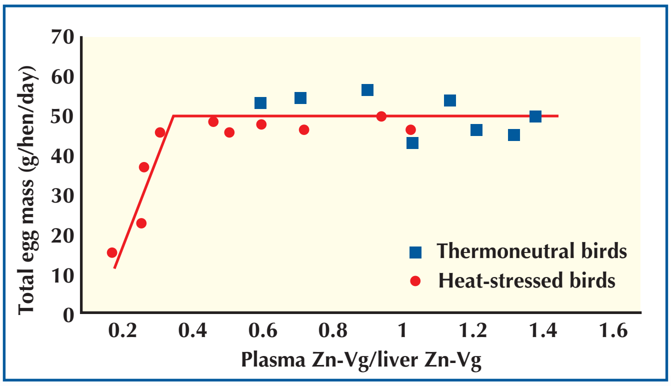

Fig. 2. Relationship between egg output and plasma/liver vitellogenin in normal and heat stressed hens.

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Environmental stress is a general term used to describe the sum of non-specific responses to defence mechanisms of the body when faced with abnormal or extreme environmental conditions.

Such stress evokes a combination of behavioural, biochemical and physiological adaptations, which generally result in a reduction in the performance of poultry. Supplementation with elevated levels of certain vitamins during periods of environmental stress can help maintain performance.

For broilers reared under heat stress situations, supplementation with vitamin C has been shown to help alleviate some of the associated metabolic problems and allow improved weight gain, FCR and liveability.

Optimum responses appear to occur with a daily intake of around 20mg per day depending on the degree of heat stress and pre exposure. In laying hens, decreased mortality, improved eggshell quality, improved egg production and feed intake are seen when supplementing the diet or water with vitamin C (Table 1).

Table 4. Effect of nicotinic acid on broiler liveweight at 3 weeks under heat stress (CHS) and immunological challenge (SRBC).

Temperature	Immune challenge	Supplemental nicotinic acid (mg/kg) 0	20	50	80
Normal	Control	654	671	636	700
	SRBC	603	645	636	726
CHS	Control	560	572	663	622
	SRBC	584	596	647	614

Studies supplementing increasing levels of vitamin E (10, 125, 250, 375 and 500 mg/kg) to laying hens experiencing heat stress have shown consistent benefits in alleviating the depression in egg production (Figure 1).

Dose response work suggests that 250 mg of vitamin E is optimal for alleviating, at least in part, the adverse effects of chronic heat stress in laying hens.

For optimal results, however, it is important to supplement the vitamin not only before stress but also during and after.

Increasing the level of vitamin E also increases the plasma: liver vitellogenin (yolk pre-cursor)

Trait	Dietary calcium (%)	avP (%)	Dietary vitamin D (IU/kg) 200	800	5000	10000
Liveweight at 14 days (g)	1.00	0.45	302a	298a	307a	327b
	0.80	0.35	315a	311a	316a	336b
Liveweight at 42 days (g)	1.00	0.45	1.95a1	2.35b	2.40b	2.38b
	0.80	0.35	1.73a2	2.35b	2.33b	2.46b
Tibia Strength at 14 days (N)	1.00	0.45	59.5a	80.4b	92.1c	101.3c
	0.80	0.35	61.0a	78.1b	90.9c	93.5c
Tibia Strength at 42 days (N)	1.00	0.45	500a1	362b	379b	376b
	0.80	0.35	448a2	395ab	345c	376bc
Tibia Ash at 14 days (%)	1.00	0.45	31.0a	35.1b	37.2c	37.7c
	0.80	0.35	29.8a	32.5b	35.5c	36.6c

Table 5. Response of broilers at 14 and 42 days to different vitamin D, calcium and available phosphorus (avP) content. (Within a trait and comparison, values followed by different letters (in a row) or number (in a column) differ significantly (p<0.05))

ratio. In heat stressed birds this ratio is generally reduced (Table 2) and is related to the reduced egg mass output observed. By increasing the ratio with vitamin E supplementation, the total egg mass output per bird can be increased (Figure 2).

Heat stress has been shown to have a significant impact on the requirement for riboflavin in broilers. Under normal conditions the requirement for optimal liveweight gain (2-3mg/kg) appears not to have changed since it was reviewed by NRC in 1994, despite the change in genetic potential of the bird.

However, when birds are exposed to heat stress there is evidence that heat stress can significantly increase the bird's requirement for the vitamin in order to prevent deficiency lesions (curled toe paralysis) (Table 3).

In contrast, requirements for biotin, folic acid and nicotinic acid in the broiler relative to the NRC requirement and current commercial supplementation levels have all been shown to have increased in recent experimental work.

Although data is not available for biotin and folic acid, the response to increasing niacin levels during heat or immunological stress is unchanged relative to normal conditions (Table 4).

Skeletal abnormalities in meat type poultry, particularly leg disorders, have been a major cause of poor welfare and lost production. Vitamin D is essential for good bone formation and a deficiency results in hypocalcaemic rickets.

There is, however, some uncertainty over the vitamin D requirements of broilers. The requirement proposed by NRC (1994) is 200 IU/kg, but there are complications in determining the true requirement, given the interaction of vitamin D with other nutrients.

Imbalances of calcium and phosphorus are known to increase vitamin D requirements. It is therefore not surprising that there is significant variation in other estimates of the requirement of vitamin D from 200 to 1000 IU/kg.

The possibility of these interactions has to be taken into account when setting practical allowances. Dietary specifications of between 3 and 5000 IU are frequently used and appear beneficial in supporting performance and minimising cases of rickets.

Recent experimental evidence suggests the need for even higher dietary vitamin D concentrations than are currently used in commercial practice. For example, above 5000 IU/kg may be needed in starter diets for today's broiler to optimise bone values (Table 5).

This is probably related to the higher calcium requirements of fast growing broilers to meet the requirements of normal growth plate development that in turn reflects the change in bone structure, seen in modern broilers.

Rickets still occasionally occurs even when diets contain these apparently high levels of vitamin D supplementation and are seemingly adequate in calcium and phosphorus. These cases of 'field' rickets may be attributed to other metabolic disturbances such as infections or factors causing malabsorption of nutrients.

Such conditions are often accompanied by femoral head necrosis when bacteria, particularly staphylococci, become located in areas of abnormal cartilage in the proximal femur. If such conditions can be identified early in the life of a flock treatment with a water based vitamin D supplement is often beneficial.

The condition of tibial dyschondroplasia (TD) is another leg abnormality seen in commercial broiler production. TD is the result of a failure of chondrocyte differentiation in the growth plate leading to an accumulation of prehypertrophic chondrocytes. Unlike rickets, it does not appear to respond to vitamin D supplementation (Table 6).

Supplementation with vitamin D metabolites however, has been shown to be an effective means of preventing TD, possibly through their ability to speed up the differentiation of chondrocytes at the growth plate.

Supplementation with 1,25 – dihydroxyvitamin D has been shown to prevent TD completely (Table 6). Although this metabolite is not available commercially, another metabolite, 25 – hydroxyvitamin D, is and can also decrease TD incidence and severity although a higher dose rate is needed and the response is less reproducible. (Table 7).

Vitamin C is required for the synthesis of bone and cartilage matrix collagen and is also a component of the renal enzyme system synthesising 1, 25 dihydroxyvitamin D. Under normal conditions, endogenous vitamin C synthesis is adequate for matrix and bone quality.

However there is some evidence that supplemental vitamin C can enhance plasma 1,25 dihydroxy vitamin D levels and increase the concentration of proteoglycan and collagen in the growth plate and therefore may be advantageous in some cases of rickets and TD. Transporting birds can bring a number of stresses resulting from heat, catching and handling. It is not surprising that provision of extra vitamins, particularly E and C, can help birds better withstand the rigours of transportation, improving both the welfare and meat quality of birds arriving at the slaughterhouse.

Table 6. Prevention of TD by 1, 25 – dihydroxyvitamin D.

	Diet content (ug/kg) Vitamin D	1,25 - D	TD %
Experiment 1	25	0	47
	75	0	51
Experiment 2	25	0	36
	25	2.5	19
	25	5	0
	25	10	0

	Diet content (ug/kg) Vitamin D	25 - D	TD %
Experiment 1	75	0	47
	0	75	51
Experiment 2	75	0	28
	0	75	19
	0	250	2.5

Table 7. Prevention of TD by 25 – hydroxyvitamin D (25-D).

Vitamin C supplied in the drinking water prior to catching has been shown to reduce stress by reduced plasma corticosterone levels at the end of this procedure.

Reduced water loss and tissue breakdown associated with the lowered corticosterone levels may also explain the improved carcass yields reported in broilers given vitamin C supplement prior to transportation.

Mycotoxins are known to interact with the vitamin status of poultry adversely. Aflatoxins have been shown to reduce plasma concentrations of 1,25 dihydroxy vitamin D3. In tropical countries with higher levels of feed contamination this may therefore lead to a higher incidence of leg disorders. Direct use of vitamin D metabolites in the diet or drinking water of broilers could have a major economic impact in these regions.

Vitamin C supplementation (300mg/kg) has been shown to be beneficial during ochratoxin (3mg/kg) toxicity in laying hens under normal and elevated temperatures. Effects of ochratoxin were more severe at the higher temperature, but some of the adverse effects of ochratoxin, including depression in egg production and blood electrolyte imbalances were moderated by vitamin C treatment at both temperatures.

In summary, there is an increasing body of evidence to suggest that the use of higher levels of some vitamins than are currently routinely supplemented in the diet would be advantageous in optimising poultry performance in commercial conditions.

In some cases the level required to achieve the desired benefit is not cost effective if the increased vitamin levels are used continuously. In these situations, the strategic administration of vitamins for short periods of time, by way of a water dispersible preparations administered through the drinking water, may be the answer. ■

A full list of references used in this work is available from the author.