The Use of 25-hydroxy Vitamin D3 for Meat Poultry

N. E. Ward, PhD
DSM Nutritional Products, Inc.
Parsippany NJ

Introduction

Vitamin D3 (cholecalciferol) was recognized in nutrition well before 1900 when sunlight was established for its role in the prevention of rickets. Eventually, the exposure of rickets-inducing diets to ultraviolet light was shown to eliminate the inherent rachitic properties of those diets (Hess, 1924). Thus, this vitamin became known as the "sunshine vitamin."

Over a period of time, two vitamin D parent compounds were elucidated. Ergocalciferol (D2) is synthesized from ergosterol in many plants, whereas cholecalciferol (D3) is derived from 7-dehydrocholesterol in the skin of animals. Ultraviolet light transforms these compounds into 1, 25-diOH vitamin D3, the vitamin D metabolite generally considered the most active. Approximately 40 times more D2 is needed to equal D3 for poultry.

Vitamin D is best known for its role in calcium and phosphorus metabolism in skeletal development and maintenance, as well as eggshell strength. In addition, vitamin D has been recognized for cell growth and differentiation (Brown et al., 1999), as well as for its potential effects on the immune system (Reinhardt and Hustmyer, 1987), and reproduction (DeLuca, 1992). A deficiency of vitamin D can result in an elevation in blood glucose levels of chicks, and abnormal energy substrate utilization (Hunt and Nielsen, 1987).

Severe deficiency of vitamin D manifests itself in readily observable deformities of the skeleton, beak and eggshells in poultry. Gross deficiency can impair egg production, and bring about late-stage embryonic death in hatching eggs. Arguably, the most costly deficiencies are those that are marginal, thus go unnoticed, and include suboptimal feed conversion, as well as other less observable symptoms.

> The vitamin D metabolite, 25-OH D3, is usually better correlated with Ca absorption in humans than is 1, 25-diOH D3 (see Vieth, 1999; Eisman et al., 1977), while Soares et al. (1995) suggest that 25-OH vitamin D3 to be an excellent marker for ascertaining the vitamin D status of poultry. The blood level of 25-OH D3 in turkey poults with field rickets was suppressed and correlated well with ash values (Bar et al., 1987), thus might be considered when ascertaining leg deformities. In humans, once plasma levels of 25-OH D3 decline below 25 mmol/L, the onset of rickets due to vitamin D deficiency is common (Clemens and O'Riordan, 1990; Kanis, 1982).

25-Hydroxy Vitamin D3

Without a doubt, the most exciting development in vitamin D nutrition in recent years has been the commercialization of 25-OH vitamin D3 in poultry feeds. This product was given GRAS status for broilers (1995), and turkeys (1999) and laying hens (1999), and is known as HyD® and marketed by DSM Nutritional Products, Inc. Today, 25-OH D3 is used routinely in numerous commercial poultry programs. This vitamin D metabolite

may exert effects beyond those induced by vitamin D3 (Soares et al., 1995), and research in recent years indicates that some tissues may have a requirement specifically for 25-OH vitamin D3 (Vieth, 1999).

Absorption of 25-OH D3. Part, but not all, of the greater effectiveness of 25-OH vitamin D3 relative to vitamin D3 might be due to differences in absorptive characteristics. In mammals, for example, vitamin D3 as a micelle is mainly absorbed into the lymph; on the other hand, 25-OH vitamin D3, being a polar compound, is reported to be absorbed more rapidly from the proximal jejunum into the portal vein (Nechema et al., 1977; Sitrin et al., 1982). Indeed, the absorption of 25-OH D3 appears different in man than that for vitamin D3 (Compston et al., 1981).

In clinical studies with healthy individuals (Sitrin et al., 1987), patients with fat malabsorption (Davies et al., 1980; Sitrin et al., 1987; Krawitt and Chastenay, 1980), or patients with bone disease (Stamp et al., 1977), 25-OH vitamin D3 was absorbed better and faster than was vitamin D3. Noteworthy is that the absorption of 25-OH D3 occurred independent of fat absorption. Only 13% of the 25-OH D3 was carried in lymph chylomicrons (Stirin et al., 1987), and in rats, the ligation of the bile ducts essentially abolished the absorption of vitamin D3, but had virtually no effect on 25-OH-D3 (Nechama et al., 1977).

Thus, there appears to be a clear and definitive difference in the absorption of 25-OH D3 and vitamin D3, and numerous studies find poor fat absorption and a lack of bile acids to have little or no effect on the absorption of 25-OH D3. This would have important ramifications on the young bird prior to its full development of the pancreas, and bile production, that occurs at about 14-21 days of life.

> In a study with human infants suffering from iron (Fe) deficiency anemia (Heldenberg et al., 1992), blood levels of 25-OH D3 were below normal in spite of these infants receiving adequate dietary vitamin D3. The administration of Fe restored blood levels of 25-OH D3 considered to be normal. Fe deficiency can cause the malabsoprtion of fat and vitamin A. Thus, these researchers suggested that the Fe deficiency (more specifically, fat malabsorption) can lead to low vitamin D3 absorption. The absorption of 25-OH D3 would be less reliant on such relationships.

In broiler chicks, the absorption of 25-OH D3 was also reported to be faster (83%) than that for vitamin D3 (66%). This absorption occurred mainly in the upper jejunum (Bar et al., 1980), similarly as has been reported in studies with humans. Significant differences in net secretion of the two forms of vitamin D activity were also noted: 20% of the vitamin D3 and 7% of the 25-OH D3 were secreted. Thus, along with a greater absorption rate, 25-OH D3 retention in the body occurs with greater economy.

The more rapid absorption of 25-OH D3 might be attributable to intestinal binding proteins for 25-OH D3 that have been identified in intestinal cells (Nechama et al., 1977). This protein has an affinity for 25-OH D3 that is at least 1,000 times greater than for other D3 metabolites (Teegarden et al., 1997; Teegarden et al., 2000), thus it is reasonable to assume their presence facilitates the absorption of 25-OH D3, and/or Ca absorption.

The existence of intestinal binding proteins for 25-OH D3 is not inconsistent with the occurrence 25-OH D3 in a number of foodstuffs (Ovesen et al., 2003). In eggs from laying hens not fed 25-OH D3, up to 1 ug of this metabolite exists in 100 g egg yolk, while hens fed 25-OH D3 at recommended levels had about 2.5 fold higher amounts in their eggs. In broiler meat, deposition of 25-OH D3 is highly correlated with intake of this metabolite (Yarger et al., 1995). Human breast milk contained concentrations of vitamin D3 and 25-OH D3 of 38 and 845 pg/ml, resp. (Kunz et al., 1984).

Fat and 25-OH vitamin D3 absorption.

The incomplete development of the pancreas, and subsequent limited lipase secretion, has been proposed as leading to a higher incidence of rickets and/or skeletal deformities during the initial 2 to 3 weeks of life. Taken with the relationship between fat and vitamin D absorption, it is reasoned that the lack of sufficient fat absorption may be occurring at a time when bone formation occurs at a rapid pace.

A review of research on the development of the digestive system of chicks post-hatch led Jin et al. (1998) to conclude that a lag occurs in lipase secretion relative to feed intake up through 10 or more days post-hatch. The digestion of corn oil in chicks (Carew et al., 1972) or animal-vegetable fat blend in poults (Sell et al., 1986) progressively increased up through day 15 of age, indicating that approximately 14 days are needed for the complete development of the pancreas and/or secretion of lipase.

Bone deformation or improper bone development is often found early in a bird's life during the vital building the phase in bone formation when osteoclasts are especially active. Indeed, researchers at Purdue University and The Ohio State University determined that by day 21, tibia and femur epiphyseal and diaphyseal ash had attained 100% of its maximum percentage in broilers. The length and width of the tibia and femur were 60% of their respective 43-day values (Applegate and Lilburn, 2002). Likewise, University of Minnesota researchers found most leg disorders under field conditions occurred in turkey poults at 12 to 21 days of age (Bar et al., 1987), although one of these, tibial dyschondroplasia, in turkeys tends to peak between 9 to 12 weeks of age (Poulos, 1978). Thus, pressure is especially intense during the initial weeks of life to ensure the sufficient amounts of several nutrients such a Ca, P and vitamin D are consumed and absorbed for bone/skeletal development.

In one large-scale field trial with a broiler integrator that tested over four (4) million birds, 25-OH D3 was fed at 69 ug/MT during the starter period. Figure 1 illustrates the improvement that occurred in both body weight (+ 3-4%) and F/G (- 3.2 points) at the conclusion of grow-out in both with small and large birds. Similarly, a 14-day study in Australia in which 25-OH D3 was fed only alone showed a 10-11% increase in body weight, as well as bone ash (Figure 2).

In the presence of enteritis or a malabsorption malady, this pressure for proper nutrient absorption is only increased. Vitamin D3 and 25-OH D3 were evauated for absorption in day 8 broiler straight-run birds that were induced to have malabsorption syndrome (MAS) by "seeder" birds in the same pen (Trouw Nutrition, Spain). Treatments included diets with only vitamin D3 (2200 and 3700 IU/kg) or the same levels of vitamin D3 plus 25-OH D3 (37.5 ug/kg). In birds infected with MAS, plasma levels of 25-OH D3 were

higher (P<.05) when 25-OH D3 was added to the diet (Figure 3). Mortality was decreased (P<.05) with the addition of 25-OH D3 in the control and the MAS diets. Hence, in cases where malabsorption can occur, 25-OH D3 can be superior to vitamin D3.

> The absorption of 25-OH D3 occurs irrespective of fat absorption (Sitrin et al., 1987; Maislos et al., 1981), thus making 25-OH D3 an obvious consideration in starter diets for chicks and poults at a time when pancreatic lipase might be limited for cholecalciferol absorption. Hence, as opposed to vitamin D3, 25-OH D3 conceivably would bypass this initial insufficiency in fat digestibility at a time when skeletal changes are rapidly occurring, and bone ash percent is being maximized.

Hydroxylation of Vitamin D3.

Upon absorption, vitamin D metabolites are bound to one of several vitamin D binding proteins. A large excess of these proteins exists (Haddad and Walgate, 1976), presumably to act as storage capacity during shortfalls in the diet, or to act as a buffer during times of excessive vitamin D intake. Of the active vitamin D forms for poultry, the relative binding affinity of these proteins shows a distinct preference for 25-OH D3 over either 1, 25-di OH D3 or vitamin D3 (Soares et al., 1995).

Vitamin D3 is transported to the liver where most of its initial hydroxylation to 25-OH vitamin D3 occurs (Figure 4); some hydroxylation to 25-OH D3 can also exist in the chick intestine and kidney (Tucker et al., 1973). An age-related decline in hydroxylation efficiency has been reported (Soares et al., 1976), but research on this topic is limited.

> In a study involving 32 field outbreaks of leg disorders over a 4-year period, turkey poults with rickets had plasma 25-OH D3 levels of less than 50% relative to poults without rickets (from 19.4 to 8.1 ng/ml; Bar et al., 1987), while tibia ash levels declined by about 20% (Table 1). Most incidences occurred with poults through the initial 21 days of age. The commercial feeds were found to be adequate in vitamin D3, Ca and P in all cases. It was theorized that an insufficiency of blood levels of 25-OH D3 was due to inadequate hydroxylation of vitamin D3 to 25-OH D3.

The administration of 25-OH D3 to poults with field rickets resulted in a rapid mineralization of the bones (Hurwitz and Bar, 1981). *Vitamin D3 did not have this same effect.* Similarly, studies at Roslin Institute and Auburn University found that 25-OH D3 effectively decreased defective bone developments in broilers. Hence, in some cases of apparent vitamin D3 deficiency when vitamin D3 is determined to be adequate, 25-OH D3 corrects a deficiency that vitamin D3 itself does not.

Other studies have been completed which clearly show that higher levels of vitamin D3 do not substitute for the same response as 25-OH D3 (Calabotta, 1999). Vitamin D3 of 2, 4, 8 and 10 times reported commercial levels of vitamin D3 (Ward, 1993; recently updated), in this study, were clearly not as effective as was 25-OH D3 for body weight and F/G improvements.

Hydroxylation of 25-OH vitamin D3. The 25-OH D3 is transported to the kidney where it is hydroxylated in the mitochondria by 1-hydroxylase to form 1, 25-diOH vitamin D3 and 24, 25-diOH vitamin D3. This second hydroxylation of 25-OH D3 is under strict control, and dependent on the vitamin D, calcium, or phosphorus status of the animal,

either directly or indirectly, avian or mammalian. A number of hormones also exert control measures on this subsequent hydroxylation step.

Even when chicks are given high levels of vitamin D3 or 25-OH D3, the level of 1, 25-diOH D3 remains virtually unchanged (Yarger et al., 1995), attesting to the strict control under which this metabolite exists. Thus, the calcification of soft tissues during times of vitamin D3 toxicity indicates that 25-OH D3 or another metabolite can also influence Ca absorption. In humans, a modest role for 25-OH D3 has been suggested. Due to the much greater concentration and half-life of 25-OH D3 than of 1, 25-diOH D3, the 25-OH D3 may have more constant and long lasting effects (Bell et al., 1988).

The function of 24, 25-diOH vitamin D3 in poultry remains somewhat elusive, although it does seem to have some biological activity for hatchability (Henry and Norman, 1978). Some studies in mammalian species (humans) suggest that a *ratio* of 25-OH D3 and 24, 25-diOH may have more significance than 24, 25-diOH D3 by itself.

Physiological levels of 25-OH D3. As much as 80% of the circulating vitamin D activity in serum is associated with 25-OH vitamin D3 in humans (Ovesen et al., 2003). In healthy women, in an investigation to understand factors that affect Ca absorption, 25-OH D3 was determined to outweigh the significance of 1, 25-diOH D3 for Ca absorption (Barger-Lux et al., 1995). Similarly, in chicks, 25-OH D3 is also recognized as the major vitamin D metabolite in the blood (Haussler and Rasmussen, 1972). Tissue levels of 25-OH D3 may eventually become recognized with greater importance when considering its vitamin D functions and other potential metabolic roles (Ovesen et al., 2003), as well as possible markers for identifying causes of various skeletal deformations.

In one study, chicks were found to contain 10 to 30 ng 25-OH D3/ml serum when fed no 25-OH D3. Those fed 69 ug HyD/kg feed had levels of about 55 to 80 ng 25-OH D3/ml serum. Yarger et al. (1995) reported 1, 25-dihydroxy vitamin D3 to decline ($P<.05$) as dietary and blood levels of 25-OH D3 increased from 69 to 690 ug/kg feed. Tissue concentrations of 25-OH D3 were lowest in birds fed vitamin D3, but increased several-fold when 25-OH D3 was fed, being highest in skin, leg and breast tissues, resp. Circulating and tissue levels were highly associated with dietary levels of 25-OH D3, at least within the levels fed.

Similar data and trends have also been reported for turkeys (Lanenga et al., 1999) and laying hens (Terry et al., 1999).

> Recently, DSM developed a new and improved method that couples high performance liquid chromatography with mass spectrometry. This technology permits an accurate determination of 25-OH D3 in vitamin premixes, commercial feeds and plasma samples through a multi-step extraction process. The variation between duplicate tissue samples tends to range from 3-7%, and higher for feed samples. In addition, the analysis of 25-OH D3 can be conducted by procedures involving radioisotopes, or by commercial kits based on radio-immunoassay or ELISA. However, these tend to be less accurate with more variation between duplicate samples.

Hatchability of fertile eggs. It has been known for sometime that vitamin D is essential for the hatchability of eggs. A deficiency of this vitamin exerts itself by causing embryos

to have a shortened mandible and other skeletal deformities, with death occurring after day 18 of incubation. Maximum values for fresh weight and calcium content of embryo tibiae occur by day 19 of incubation (Kubota et al., 1981) 1, 25-diOH D3 is not transferred into the egg, and does not support hatchability any better than the absence of vitamin D supplementation in hen diets (Abdulrahim et al., 1979; Sunde et al., 1978). Conversely, 25-OH D3 fed to hens is known to result in optimal hatchability (Sunde et., 1982; Hart et al., 1986) relative to any other known vitamin D metabolite.

Avian embryos assimilate large amounts of Ca in their bones in a short amount of time, and being that the yolk contains insufficient amounts of Ca, this Ca must be derived from the eggshell. 25-OH D3 is easily transferred into the chicken and turkey egg. This metabolite is then converted to 1, 25-diOH D3 by the embryonic kidney after day 8 to support the transfer of Ca from the eggshell, and assimilation into the embryonic skeleton.

Hargis (2000) reported a large-scale field study involving 3 million breeders in which the inclusion of 25-OH D3 increased hatchability of fertile eggs from 79.5 to 82.5%. 25-OH D3 was fed from 26 to 65 weeks of age. In this case, 25-OH D3 was in addition to vitamin D3 in the diet, thus indicating that vitamin D3 supplementation under field conditions may not be sufficient to optimize hatchability in broiler breeders, in such cases outlined by Hargis (2000). Data prior to, and subsequent to the Hargis study bears out a potential benefit from 25-OH D3 for the hatchability of fertile eggs.

Penalva (unreported) conducted a replicated broiler breeder study in which control birds were fed 3.5 MIU vitamin D3/kg feed, compared to 2.0 MIU/kg plus the addition of 25-OH D3 (69 mg/MT). Thus, there were two treatments, each replicated 10 times, and taken from 25 to 55 weeks of age. Amongst the results (Table 2), 25-OH D3 resulted in more chicks hatched/hen-housed (125.8 versus 119.0, $P<.05$) and more hatched eggs (151.6 versus 145.8, $P<.05$).

In addition, in two separate field trials this year involving over two (2) million breeders, Penalva (unreported) noted an improvement in the hatchability of fertile eggs. In one trial, this improvement with 25-OH D3 was 94.85 vs 93.26%; in trial #2, 25-OH D3 increased hatch of fertile from 94.16 to 96.85%. Other important variables were also increased with the use of 25-OH D3 in both studies, and 25-OH D3 and vitamin D3 were fed as in the replicated study.

In turkeys, data are limited. Manley et al. (1977), however, similarly noted an improvement in hatchability of eggs from hens fed 25-OH D3.

The mechanism behind the improvement in hatchability is not clear but could be related to an improved transfer of 25-OH D3 into the egg. The 25-OH D3 1-hydroxylase (to convert 25-OH D3 to 1, 25-diOH D3) attains maximal activity in the chick embryo by day 17 (Kubota et al., 1981), and eventually the transfer of Ca into bone. Insufficient 25-OH D3 in the egg would hinder this sequence of events, thus limiting Ca use from the eggshell for skeletal development and survival. Noted earlier (Kubota et al., 1981), a vitamin D deficiency results in dead embryos by day 18 or immediately thereafter.

In addition, eggshell quality may have been sufficiently improved to increase hatchability in a number of studies (Soares et al., 1995). Calabotta (1997) notes that eggshell "percent cracks" was decreased from 5.38% to 3.76% in laying hens fed 25-OH D3 in two large-scale field trials. There have been a good number of studies in which eggshell quality or percentage cracks with positively affected by 25-OH D3, with shell thickness often being the variable affected (Charles and Ernst, 1974; McLaughlin et al., 1976; Marrett et al., 1975 and others).

Thus, in essence, in spite of there being no studies that have elucidated the mode of action by which 25-OH D3 can improve hatchability, the preponderance of data indicate that this metabolite has a place in breeder programs.

25-Hydroxy D3 and Tibial Dyschondroplasia (TD)

The effect of 25-OH D3 on reducing TD (Sunde, 1975) or increasing bone ash (Applegate et al., 2003) has been well documented.

Studies from the Roslin Institute (Rennie and Whitehead, 1996; Figure 5) showed 25-OH D3 (75 ug/kg feed) to decrease the percent abnormal tibial growth plates. The percent normal growth plates in birds fed 25-OH D3 was 88%, while an equivalent amount vitamin D3 resulted in 35% having normal growth plates.

Work at Auburn University likewise showed a definitive ($P<.05$) reduction in TD due to feeding 25-OH D3 up to 70 ug/kg feed (Zhang et al., 1997; Figure 5). This reduction in TD was more pronounced in the low-TD birds, which had a rate more closely associated with commercial flocks. As well, Mireles et al. (1996) has completed a number of broiler studies with 25-OH D3, with positive response in TD and improvements in body weight and F/G.

These, and other studies, have led to the conclusion that reductions in TD pose as the reason for the body weight and F/G improvements often reported for 25-OH D3. However, to be sure, a reduction in TD by 25-OH D3 does not completely explain such responses.

25-Hydroxy D3 and Broiler Trials

The initial research for the commercialization of 25-OH D3 began with the determination of the optimal feeding level (Yarger et al., 1995). Figure 6 shows the results for body weight and feed conversion from one of the trials. From this and other studies, the recommendation for broilers became 69 ug/kg feed. This remains as the current recommendation for broilers.

A large number of broiler studies had been completed to evaluate 25-OH D3 on the live performance characteristics by the mid1990s (Ward, 1995). Today, this compilation consists of 22 studies, although others have been conducted and reported in the literature. These all were floor pen studies designed to be similar to commercial conditions regarding diets, placement density, type of litter, etc. In most cases, these were straight-run birds grown on used litter in floor pens.

Noteworthy is the average improvement in body weights of almost 2%, while F/G was improved by almost 4 points (Figures 7, 8, 9). Mortality was improved slightly more than 8% across these 22 trials. Thus, these trials provide ample evidence of the potential improvements in performance of broilers fed 25-OH D3.

> University of Arkansas researchers concluded that 25-OH D3 provided a greater safety margin under commercial stress-like conditions (Fritts and Waldroup, 2003). Here, several levels of vitamin D3 were compared with equivalent amounts of 25-OH D3 in two similarly conducted floor pen trials. At 21 and 42 days of age the body weight and tibia ash of birds fed 25-OH D3 were superior (P<.05) to those of birds fed equivalent levels of vitamin D3 at the lower levels of vitamin D supplementation. At 21 and 42 days, main effects for body weights, tibia ash, TD incidence and TD severity were most favorable (P<.05) for 25-OH D3. F/G was improved (P<.05) with 25-OH D3 at 0 to 42 days of age. At 42 days of age, the 50 and 100 ug/kg 25-OH D3 gave the best results for TD incidence.

Not all studies have shown 25-OH D3 to elicit an improvement in live performance with 25-OH D3. Bar et al. (2003) reported that 25 OH D3 and vitamin D3 performed similarly for body weight, bone ash and TD. In diets with moderate P restriction, 25-OH D3 provided improvements in body weight and bone ash.

The exact nature or mechanism for the improved body weights and/or F/G in an overwhelming number of studies is not completely understood. It is likely that, in part, the improvement in body and F/G due to 25-OH D3 is derived from the reduction in TD associated with feeding 25-OH D3, since TD can lead to lowered live performance. But there have been reports whereby virtually no change has occurred in TD, or TD was not at a measurable level, and yet the feeding of 25-OH D3 led to body weight and/or feed conversion improvements.

25-Hydroxy D3 and Turkey Trials

The recommendation for turkeys was also developed several years ago, and remains the same today. Early studies indicated that the optimal response for body weight, F/G and mortality was 99 ug/kg (Figure 10).

Although data with turkeys are fairly limited, 25-OH D3 can effectively improve body weights and F/G. In one of the earliest trials, Nicholas toms experienced an improved body weight (33 points; P<.06) and F/G (5.3 points; P<.20) up through the 130 day feeding period.

Another trial with Nicholas toms was conducted with 8 replicates per treatment, and the birds were fed through 18 weeks of age. In this case three treatments were imposed: vitamin D3 (2.67 MIUkg); vitamin D3 plus 25-OH D3 (1.33 MIU/kg and 33.4 ug/kg); 25-OH D3 (66.75 ug/kg). The best result was with 25-OH D3 alone. At 18 weeks, body weight for best (P<.04) at 34.16 lbs for the 25-OH D3 group, while the vitamin D3 and combination groups were 33.19 and 33.58 lbs, resp (Figure 11). F/G was also improved (P<.0.02) with the 25-OH D3 group alone at 2.44, compared to 2.50 and 2.46 for the vitamin D3 and combination groups, resp.

In another trial, toms and hens were fed separately, for 101 and 133 days, resp., during which three treatments were fed: 2.7 MIU/kg vitamin D3; 1.35 MIU D3 plus 49.5 ug/kg 25-OH D3; or 99 ug/kg 25-OH D3. The 25-OH D3 provided body weight increases over vitamin D3 alone for both hens and toms (0.62 and 0.69 lbs/bird, resp.). In addition, improvements in F/G of 8.6 points (hens) and 12.7 points (toms) were determined. No difference in mortality was reported. See Figure 12.

To the contrary, however, Roberson (2002) reports no additional benefit to adding 25-OH D3 to turkey diets.

It would seem that 25-OH D3 would offer its greatest benefits up through 9 to 12 weeks of age, taken with that being the peak during which TD occurs in turkeys (Poulos, 1978). But in effect, data with turkeys show 25-OH D3 to be an efficacious product for improving live performance in turkeys.

Phosphorus sparing effect of 25-OH D3.

Work by Dr. R.A. Angel at the University of Maryland and Dr. T.A. Applegate at Purdue University in a number of studies finds 25-OH D3 to have a phosphorus sparing effect of about 0.04% in broilers and turkeys. Depending on P source and the digestibility used for P, this could amount to 4 to 6 lbs of P in a commercial diet.

They suggest different potential mechanisms by which this occurs (Applegate and Angel, 2002; Applegate et al., 2003). The rapid (tanscaltachia) and slow (via calcium-binding proteins) phases of calcium uptake in the small intestine might be improved with 25-OH D3. This would decrease the amount of calcium that binds to phytic acid (phytase is less capable of breaking down the calcium-phytate).

In addition, some phytases are inhibited by high levels of P (Wodzinski and Ullah, 1996), and the improved P uptake into the blood due to vitamin D3 (25-OH D3) would decrease the amount of P in the intestinal tract that might act to impair phytase activity.

To date, there has been little discussion on this effect of 25-OH D3, but taken with the potential feed-cost advantage and effect on P excretion, more attention should be given to this aspect of 25-OH D3.

Conclusions

The vitamin D metabolite, 25-OH D3, has shown a variety of commercial advantages in live performance for poultry that exceeds vitamin D3, in line with suggestions in humans that 25-OH D3 serves functions that may go well beyond that of commonly known for vitamin D3. Some of the basic modes of action have not been resolved, but research continues to probe this aspect.

For poultry raised under commercial stress, 25-OH D3 shows tremendous promise for improving economics of production through body weight gains, F/G efficiency and hatchability.

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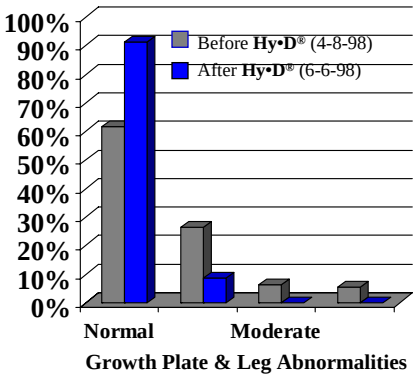
Figure 1. Effect of 25-OH vitamin D3 Starter Feeds Only (69 ug/kg)

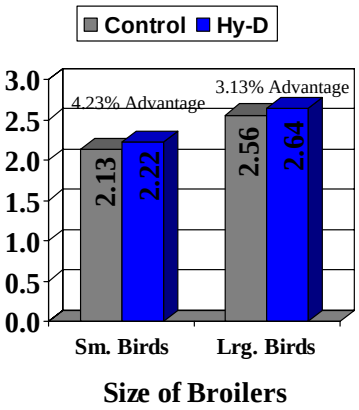
DSM

Leg Abnormalities



USA East Coast Customer Field Observations
Sample size of 110 birds (average age 16-18 days)

Weight Gain (kg.)

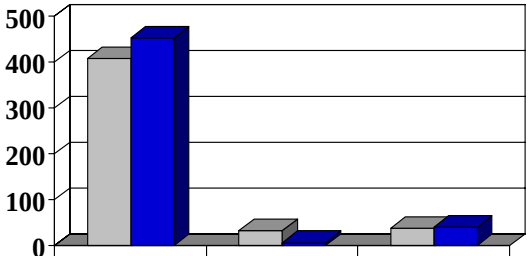


USA East Coast Customer Field Observations
(total sample size of 4 million birds)

Figure 2. Effect of 25-OH vitamin D in Starter Feed Only (69 ug/kg)

DSM

Cobb Broiler Chickens 1-14 days (mixed sex)



	Body Wt. Grams	GP Lesions %	Tibia Ash%
Control	407.9	33.50	39.4
Hy-D Diet	451.9	7.30	40.6

Queensland Poultry Science Symposium-2001, Dr. G. Parkinson and Dr. P. Cransberg, University of Queensland

Figure 3. Effect of Malabsorption on Absorption of Vitamin D3 and 25-OH D3

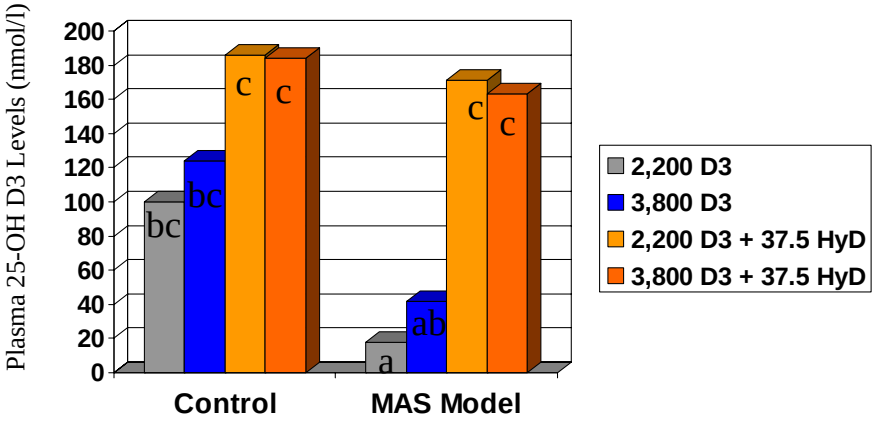


Figure 4. Vitamin D Metabolism Review

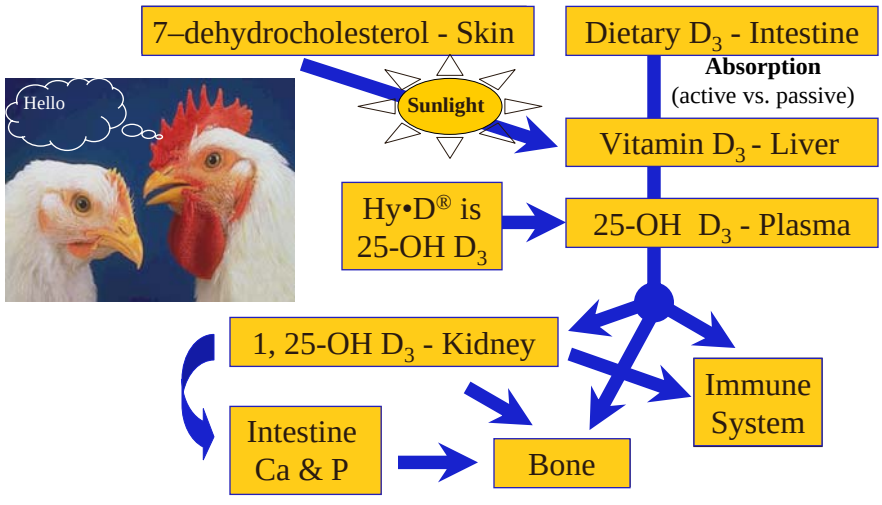
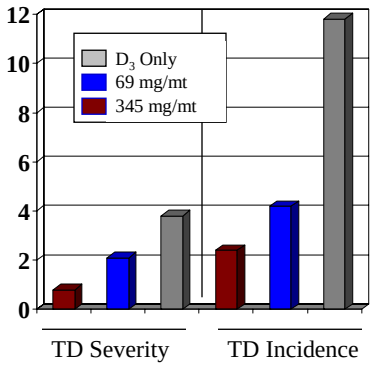


Figure 5. Effect of 25-OH D3 on Tibial Dyschondroplasia

Rennie and Whitehead, 1996

(Diet Induced)	Control D_3 68 mg/mt	**Hy•D®** 68 mg/mt
Percent Normal Tibial Growth Plates	35.0%	88.0%
Percent Abnormal Tibial Growth Plates	%	%
Serverity 0	25.0	2.0
Serverity 1	12.5	2.0
Serverity 2	16.7	6.0
Serverity 3	10.4	2.0
	100.0	100.0

Zhang et al., 1997



Commercial type broiler (% of flock)

Table 1. Comparison of variables in poults with field rickets

Variable	*Field rickets*	*Normal*	*Vitamin D-deficient*
Bone ash, % of DM	33.1	40.8	29.6
Plasma Ca, mg/dl	9.1	11.0	9.3
Plasma, P, mg/dl	4.7	7.5	4.3
Plasma 25-OH D3, ng/ml	8.1	19.4	1.6
Duodenal CaBP, ug/g	0.5	2.6	0.1

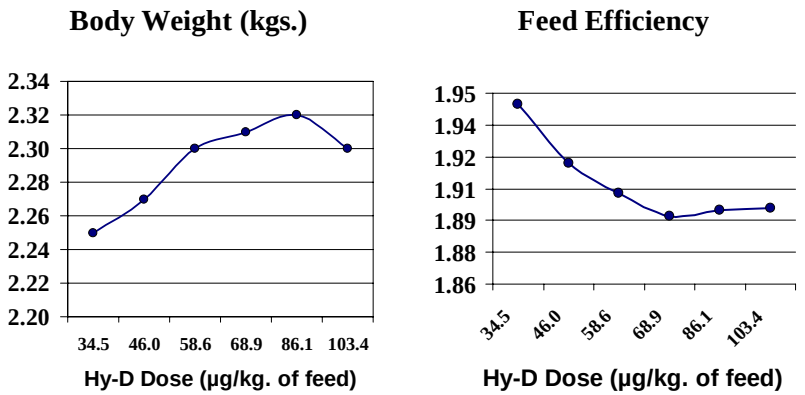
Bar et al., 1987

Table 2. Effect of 25-OH vitamin D on egg production, hatchability and hatched chicks in broiler breeders

	Vitamin D3	25-OH D3	P value
Egg/hen-housed	154.6	159.7	<.05
Hatchability (eggs/hen)	145.8	151.6	<.05
Chicks/hen-housed	119.0	125.8	<.05

Penalva, unreported

Figure 6. Dose Response For 25-OH Vitamin D3 (Yarger et al., 1995)



Recommended Level of 69 mg/mt

Figure 7. Feed Conversion-Weight Gain of Broilers in 22 Studies

DSM

Unadjusted Feed Conversion & Body Weight Gain (kg.)

Trial	Location	25-OH D3	D3	Diff. Pts.	Conf.	25-OH D3	D3	Diff. %	Conf.
1	PARC 90-11	1.906	1.926	2.00	82	2.10	2.07	1.35	95
2	CQR AM-1-91	1.896	1.937	4.10	>99	2.59	2.59	-0.14	15
3	CQR AM-1-92	1.913	1.951	3.80	95	2.54	2.51	1.30	>99
4	CQR AM-2-92	2.053	2.088	3.50	72	2.52	2.49	1.31	99
5	CQR AM-1-93	1.981	2.059	7.80	97	2.51	2.42	3.60	>99
6	PARC AMO-07B	1.980	2.043	6.30	92	2.06	2.02	2.06	96
7	PARC AMO-08B	1.907	1.943	3.60	95	2.09	2.06	1.36	96
8	PARC AMO-09B	1.824	1.848	2.40	94	2.06	2.03	1.38	98
9	PARC AMO-10B	1.938	2.005	6.70	>99	2.39	2.30	3.58	>99
10	CQR AM-3-93	2.112	2.088	-2.80	24	2.75	2.69	2.06	>99
11	PARC AMO-14B	1.891	1.942	5.10	>95	2.09	2.08	0.47	<95
12	PARC AMO-14B	1.885	1.942	5.70	>95	2.12	2.08	2.00	>95
13	PARC AMO-13B	1.929	1.959	3.00	>95	2.09	2.05	1.81	>95
14	PARC AMO-13B	1.902	1.935	3.30	>95	2.08	2.03	2.49	>95
15	CQR AM-4-94	1.977	2.030	5.30	>95	2.45	2.44	0.41	<95
16	CQR AM-5-94	2.083	2.175	9.20	<95	2.45	2.39	2.31	>90
17	CQR AM-5-94	2.121	2.175	5.40	<95	2.45	2.39	2.31	>90
18	CQR AM-95-1	1.933	1.961	2.80	83	2.54	2.48	2.60	98
19	CQR AM-95-1	1.946	1.961	1.50	73	2.51	2.47	1.69	95
20	HMS	2.000	1.958	-4.20		2.48	2.43	1.90	98
21	HMS	1.966	1.958	-0.80		2.48	2.43	2.09	99
22	Kasetsart	1.768	1.857	8.90	95	1.52	1.44	5.70	95
Average		**1.944**	**1.984**	**3.96**		**2.31**	**2.27**	**1.92**	

DSM

Figure 8. Weight Gain-22 Broiler Trials

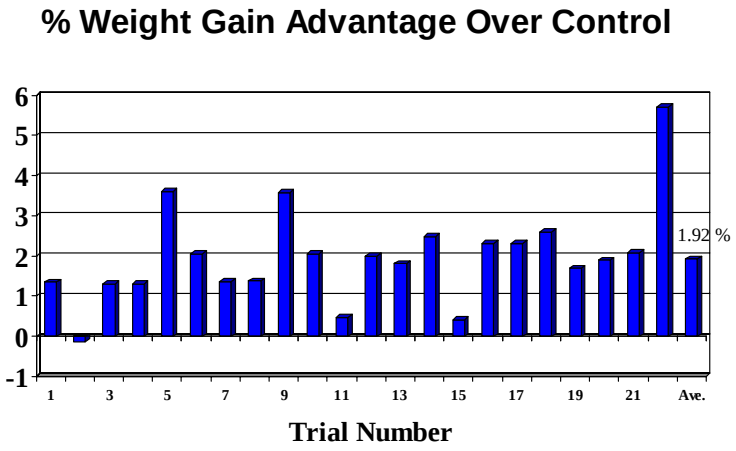


Figure 9. Feed Conversion- 22 Broiler Trials

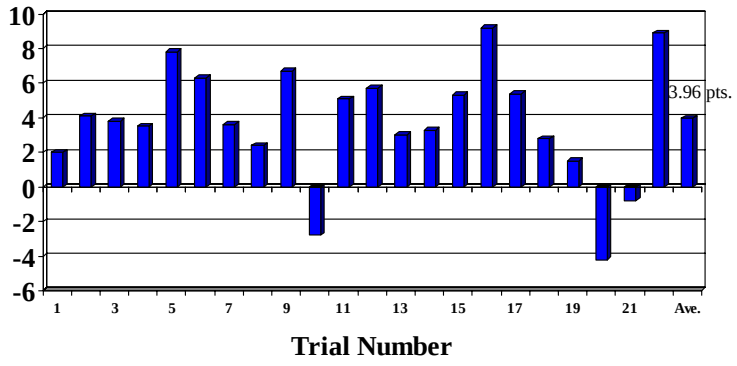
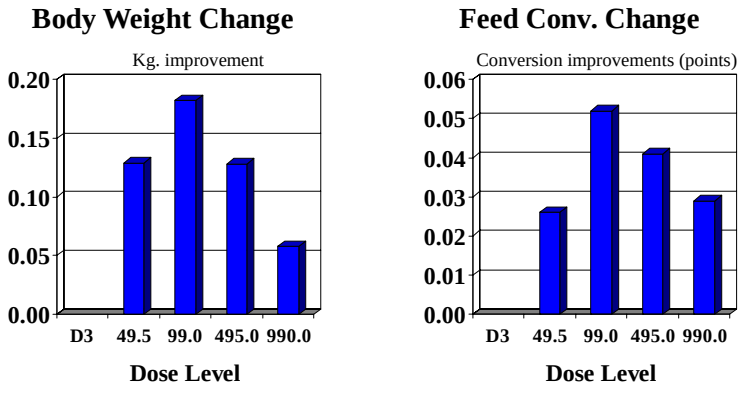


Figure 10. Dose Response for 25-OH D3 in Turkeys

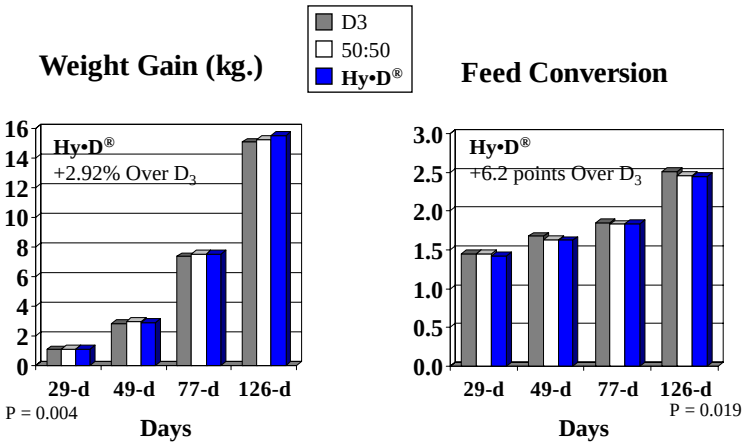


Recommended level for turkeys of 90-100 mg/mt

Study: 97-ISO-03T Dose level is mg/mt feed

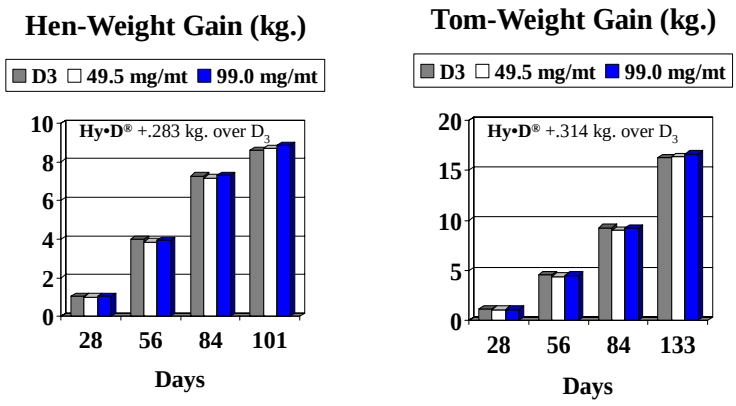
(from 0-112 days of age; 126 males & 150 females per treatment)

Figure 11. Effect of 25-OH D3 with and without Supplemental Vitamin D3



(Study # ISO-T896) 24 Pens, 8 Reps., 110 Nicholas Toms per Pen

Figure 12. Effect of Vitamin D3, Combination of D3 and 25-OH D3, and 25-OH D3 Alone for Toms and Hens



CQR Turkey Trial (ISO-98-1 completed 7-23-98) 3 treatments, 13 pens per treatment (208 hens and 195 toms per treatment).