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The effects of orally supplemented vitamin D3 on serum 25(OH)D3 concentrations and growth of pre-weaning and nursery pigs

Abstract

A total of 270 pigs from 29 litters (PIC 327 Ã— 1050, initially 2 d of age) were used in a 52-d study to determine the effects of oral vitamin D3 supplementation on growth performance, serum 25(OH)D3 concentrations, and bone mineralization of pre- and postweaning pigs. Vitamin D plays an essential role in maintaining proper Ca and P homeostasis within the body of mammals. Because most swine production occurs in environmentally controlled facilities, direct sunlight is no longer a source of vitamin D for the neonatal pig, which could impact bone growth and muscle function. Experimental treatments consisted of 3 oral dosage treatments: (1) control (1 mL peanut oil), (2) 40,000 IU vitamin D3 delivered in 1 mL peanut oil, or (3) 80,000 IU vitamin D3 delivered in 1 mL peanut oil. Pigs were initially weighed over 2 differ- ent days (d 0 or 2), allowing pigs to be placed on test 1 or 2 d after birth. Within a litter, pigs were assigned to similar-weight matched sets of 3 and were allotted to 1 of the 3 oral dosage treatments. Blood samples were collected from pigs of 29 matched sets (87 pigs total) prior to dosing, then the same matched set pigs were bled periodi- cally throughout the trial to measure 25(OH)D3 serum concentrations. All pigs were weighed again on d 10 and 20. On d 20, pigs were weaned and allotted to the nursery portion of the trial and all pigs were fed common diets from d 20 to 52 of age. Pigs were also randomly selected for necropsy on d 19 and d 35. Eighteen pigs were necropsied on d 19 (6 matched sets for a total of 6 pigs per treatment) and 12 pigs were necropsied on d 35 (6 control pigs and 6 pigs previously dosed with 80,000 IU vitamin D3). Bone and tissue samples were collected. All bone samples were analyzed for ash content and histopathology.; Swine Day, Manhattan, KS, November 17, 2011

Keywords

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The Effects of Orally Supplemented Vitamin D_3 on Serum 25(OH)D_3 Concentrations and Growth of Pre-Weaning and Nursery Pigs

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Summary

A total of 270 pigs from 29 litters (PIC 327 × 1050, initially 2 d of age) were used in a 52-d study to determine the effects of oral vitamin D_3 supplementation on growth performance, serum 25(OH)D_3 concentrations, and bone mineralization of pre- and postweaning pigs. Vitamin D plays an essential role in maintaining proper Ca and P homeostasis within the body of mammals. Because most swine production occurs in environmentally controlled facilities, direct sunlight is no longer a source of vitamin D for the neonatal pig, which could impact bone growth and muscle function.

Experimental treatments consisted of 3 oral dosage treatments: (1) control (1 mL peanut oil), (2) 40,000 IU vitamin D_3 delivered in 1 mL peanut oil, or (3) 80,000 IU vitamin D_3 delivered in 1 mL peanut oil. Pigs were initially weighed over 2 different days (d 0 or 2), allowing pigs to be placed on test 1 or 2 d after birth. Within a litter, pigs were assigned to similar-weight matched sets of 3 and were allotted to 1 of the 3 oral dosage treatments. Blood samples were collected from pigs of 29 matched sets (87 pigs total) prior to dosing, then the same matched set pigs were bled periodically throughout the trial to measure 25(OH)D_3 serum concentrations. All pigs were weighed again on d 10 and 20. On d 20, pigs were weaned and allotted to the nursery portion of the trial and all pigs were fed common diets from d 20 to 52 of age. Pigs were also randomly selected for necropsy on d 19 and d 35. Eighteen pigs were necropsied on d 19 (6 matched sets for a total of 6 pigs per treatment) and 12 pigs were necropsied on d 35 (6 control pigs and 6 pigs previously dosed with 80,000 IU vitamin D_3). Bone and tissue samples were collected. All bone samples were analyzed for ash content and histopathology.

Increasing oral vitamin D_3 increased serum 25(OH)D_3 concentrations on d 10 and 20 (quadratic, $P < 0.01$), and on d 30 (linear, $P < 0.01$). During lactation, no differences were observed in ADG across treatments, but at weaning, pigs previously dosed with vitamin D_3 were 0.3 lb heavier than control pigs. Throughout the nursery study (d 20 to 52), no significant differences were observed in ADG, ADFI, or F/G; however, on d 52, pigs previously dosed with vitamin D_3 were 0.5 lb heavier than control pigs. Vitamin D_3 supplementation had no effect on bone ash concentration of either the femur

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or 2nd rib. Pathologic lesions were not identified by microscopic evaluation of bone, regardless of vitamin D_3 treatment. Oral vitamin D_3 did not influence growth performance or bone measurements in this study, but more research may be needed to test the response under field conditions with more health challenges.

Key words: nursery pig, vitamin D, 25(OH)D_3

Introduction

Vitamin D is a group of fat-soluble secosteriods. The two major physiologically relevant forms of vitamin D are vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol). Although humans utilize both sources, pigs discriminate in their metabolism and more readily utilize cholecalciferol. Cholecalciferol is produced in the photochemical conversion of 7-dehydrocholesterol within the skin of animals when exposed to sunlight or a synthetic UVb light source. One IU of vitamin D is defined as .025 μg of cholecalciferol. Both vitamin D_2 and vitamin D_3 are hydroxylated in the liver to the 25-hydroxy forms (25(OH)D_2 and 25(OH)D_3). This metabolite of vitamin D is the main circulating form in the blood and acts as a clinically useful marker for vitamin D status. 25(OH)D_3 is then hydroxylated again in the renal tubules within the kidney to 1,25$(OH)_2D_3$ by the 25(OH)D 1α-hydroxylase enzyme or to 24,25$(OH)_2D_3$ by the 24α-hydroxylase enzyme. The 1,25$(OH)_2D_3$ form is the most potent metabolite that is used in the regulation of Ca and P absorption across the intestinal wall. The vitamin D receptor (VDR) transcription factor acts as the major mediator between the metabolite 1,25$(OH)_2D_3$ and its target cell. Research shows that both the 1,25 and the 24,25 metabolites are important for proper bone formation. Additionally, the presence of VDRs has been reported within macrophages and activated T and B lymphocytes, insinuating a relationship between vitamin D and immune function. Also, the hydroxylated D_3 metabolites are viewed as hormones because they act according to established criteria for hormones, which includes acting on mucosal cells of the small intestine to cause the formation of calcium-binding proteins. These proteins facilitate Ca and Mg absorption and influence P absorption. Together with a parathyroid hormone and calcitonin, they maintain a Ca and P homeostasis in the body.

Relatively little information is available on the normal concentration of cholecalciferol or its metabolite 25(OH)D_3 in weanling pigs. Results of recent analyses from serum samples collected by Abilene Animal Hospital (Abilene, KS) and Iowa State University and assayed at Heartland Assays Inc. (Ames, IA) indicate that pigs have lower than expected concentrations of vitamin D at weaning. These concentrations are considered inadequate for bone mineralization and overall health in young pigs. Bone microfractures have been documented in cohorts of these pigs sampled for serum analysis. These microfractures could represent a subclinical form of rickets. We hypothesized that microfractures could result in slowed growth of piglets during the farrowing and nursery phase; furthermore, low-serum vitamin D concentrations may also affect muscle function and the immune system. A prior pilot study has verified that oral dosing of vitamin D_3 to pigs shortly after birth can increase serum 25(OH)D_3 at weaning, but growth performance was not measured. Therefore, this trial was conducted to determine the effects of oral vitamin D_3 dosage on growth performance, serum 25(OH)D_3, and bone ash of pre- and postweaning pigs.

Procedures

The protocol in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was performed at the K-State Swine Teaching and Research Center in Manhattan, KS.

A total of 270 pigs (PIC 327 × 1050; initially 2 d of age) from 29 litters were used in a 52-d study to determine the effects of oral vitamin D_3 dosage on subsequent pre- and postweaning pig performance, serum 25(OH)D_3, and bone ash concentrations. Pigs were allotted to treatments in a randomized complete block design with litter and matched set within litter functioning as the blocks. Sow gestation and lactation diets were corn-soybean meal-based with 40% DDGS in gestation and 20% DDGS in lactation and contained 625 IU vitamin D_3 per lb (Table 1).

Shortly after farrowing, pigs were allotted to 1 of 3 oral vitamin D_3 treatments: (1) a control treatment with 1 mL of a peanut oil- and ethanol-based liquid carrier without vitamin D_3, (2) 1 mL with 40,000 IU vitamin D_3 in a peanut oil- and ethanol-based liquid carrier, or (3) 1 mL with 80,000 IU vitamin D_3 in a peanut oil- and ethanol-based liquid carrier. Pigs were allotted to treatments on 2 different days (d 0 or 2 of the trial) during the week of farrowing. This allowed pigs to be placed on test at either 1 or 2 d after farrowing. To perform the allotment, pigs were weighed on their own respective allotment days and 3 pigs closest in weight within a litter were considered a matched set. The numbers of matched sets per litter were variable depending on the number of pigs born and weight variation; however, gender was balanced across treatments. Within each litter, 1 matched set closest to the average litter weight was then bled by jugular venipuncture to determine initial 25(OH)D_3 levels. Each pig was ear-tagged for identification, and pigs within each matched set were randomly allotted and dosed with 1 of the 3 oral treatments. No cross-fostering was performed on treatment pigs. Necropsies were performed on the majority of pigs that died during the lactation period. Neither creep feed nor other supplements were provided except the respective vitamin D_3 dosage. Management of all pigs, including processing methods, was similar throughout the trial and consistent with standard farm procedures.

After the initial 2 allotment days, all pigs were individually weighed on single days, which were 10, 18, and 20 d after the first pigs were placed on test (d 0). On d 10, pigs were weighed, and the same matched set of pigs bled previously within each litter were bled again for 25(OH)D_3 concentrations via jugular venipuncture. On d 18, pigs were again weighed, and based on this weight a total of 6 matched sets were selected for a necropsy on d 19. On d 20, remaining pigs were weighed and weaned into a nursery facility. After pigs were placed in their respective nursery pens, blood was again collected from those pigs previously sampled for serum 25(OH)D_3 concentrations.

For the nursery phase (d 20 to 52), pigs were penned by treatment. Sets of pens were blocked to minimize the effect of location. Pigs were assigned to a set of pens, maintaining the integrity of the initial matched sets within a pen set. There were 6 or 7 pigs per pen and a total of 12 pens for the control treatment and the 40,000 IU treatment and 11 pens for the 80,000 IU treatment. All pigs that were allotted on d 0 and alive at d 20 were evaluated in the nursery phase. Pens contained a 4-hole, dry self-feeder and nipple waterer to allow for ad libitum access to feed and water. All pigs were fed a common

3-phase dietary program. Phase 1 diets (SEW and transition diets) were fed from d 20 to 25 and were fed in pelleted form. Phase 2 and 3 diets were fed from d 25 to 39 and d 39 to 52, respectively, and were fed in meal form (Table 2).

During the nursery phase, pig weights were recorded on d 20, 25, 32, 39, 46, and 52. Feed disappearance was recorded during the nursery stage and used with pig weights to determine ADG, ADFI, and F/G. Pigs selected for serum 25(OH)D_3 concentrations were bled again on d 30 and 52. On d 35, 12 pigs were selected (6 from the control treatment and 6 from the 80,000 IU vitamin D_3 treatment) for necropsy.

Necropsies were conducted at the K-State College of Veterinary Medicine. All necropsies performed were in compliance with the college's standard operating procedures. On d 19, pigs were bled via jugular venipuncture and were euthanized with an intravenous overdose of sodium pentobarbital (Fatal Plus, Deerborn, MI). Both femurs and the 2nd and 3rd ribs on both sides were removed to determine bone ash content. The 4th ribs and tibias were removed for histopathology examination. On d 35, 12 more pigs were selected for necropsy with 6 chosen from both the control and 80,000 IU vitamin D_3 treatment groups. Tissue collection procedures were similar to those performed on d 19.

Blood samples were collected on prior to dosing and on d 10, 20, 30, and 52 (along with the blood samples from the necropsy pigs on d 19 and 35). All samples were collected in serum separator tubes and were refrigerated for at least 6 h after collection. Blood was centrifuged at 2,800 rpm for 25 min. Serum was extracted and stored in 2-mL vials and frozen in a freezer at -20°C. All 25(OH)D_3 testing was performed by Heartland Assays Inc.

Statistical analysis conducted for each portion of the study was performed using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC). For the preweaning period, the growth data were analyzed as a randomized complete block design. Individual pig was the experimental unit and litter and matched sets within litter were included as blocking factors in the statistical model. Only pigs that completed the full lactation period (d 0 to 20) were used in this analysis. Nursery growth performance data were analyzed as a randomized complete block using pen as the experimental unit and pen set as a blocking factor. Bone ash results were analyzed using the PROC MIXED procedure of SAS with individual pig as the experimental unit. Serum 25(OH)D_3 results were analyzed using the repeated measures function of SAS to determine the effect of treatment on serum concentrations over time and the treatment × time interactions. Linear and quadratic effects were also evaluated for increasing vitamin D_3 dosage.

Results and Discussion

In the lactation phase (d 0 to 20), no significant differences were observed ($P > 0.14$) for ADG (Table 3), but d 20 BW was numerically increased by 0.3 lb/pig for pigs previously given oral vitamin D_3. During the nursery phase (d 20 to 52), previous oral vitamin D_3 dosage did not affect ($P > 0.29$) ADG, ADFI, or F/G (Table 4); however, similar to the lactation phase, pigs previously dosed with either 40,000 or 80,000 IU vitamin D_3 were numerically heavier (0.5 lb/pig) at the end of the nursery phase.

Prior to vitamin D_3 supplementation, initial serum 25(OH)D_3 concentrations were similar ($P = 0.99$) among all pigs (Table 5). A vitamin D_3 dose × day interaction ($P < 0.01$) was observed for serum 25(OH)D_3. The interaction was the result of serum 25(OH)D_3 increasing (quadratic, $P < 0.01$) over time with the greatest values observed on d 10 for pigs dosed with vitamin D_3 (Figure 1). Pigs orally dosed with vitamin D_3 had greater serum 25(OH)D_3 on d 10 (quadratic, $P < 0.01$), 20 (quadratic, $P < 0.01$), and 30 (linear, $P < 0.01$) with concentrations similar to control values on d 52 ($P > 0.36$).

Bone ash from femurs of pigs euthanized on d 19 (Table 6) showed no effect ($P > 0.46$) of vitamin D_3 dosage, but 2nd rib ash content tended (linear $P < 0.09$) to decrease as oral vitamin D_3 dosage increased. No differences were found in bone mineralization of femurs or the 2nd rib collected on d 35 ($P > 0.47$).

Histopathologic analysis revealed all ribs from both collection days were similar in progression of chondrocytes through the normal maturation zones. The zones had a normal even, abrupt transition to primary spongiosa, which undergoes remodeling to form the secondary spongiosa and trabecular bone. The growth plates were uniform in width across their length except one rib that was collected from a pig dosed with 40,000 IU vitamin D_3. For this pig, the physis was uneven and there were irregular, somewhat rectangular plugs of hypertrophied zone cartilage extending into the metaphysis. On the metaphyseal surface, and lateral to the plugs, there was normal formation of primary spongiosa that was remodeled to secondary spongiosa. The tibial physis of this pig also was uneven with a few V-shaped plugs of cartilage extending toward the metaphysis. One potential explanation for this phenomenon is trauma that may have occurred during lactation. This pig also showed swelling in its right hip and, upon visual evaluation during necropsy, abnormal mineralization of its right femur (not ashed). The presentation of this pig is consistent with injury by the sow during lactation. All tibias collected for histopathologic analysis were categorized as having normal maturation zones and growth plates as well as typical primary spongiosa formation.

In summary, pigs in this study initially started with similar concentrations of 25(OH)D_3 prior to dosing. On d 10, 20, and 30, serum concentrations were dependent on the dosage of supplemental vitamin D_3; however, by d 52, serum concentrations had returned to values similar to that of control pigs. This might suggest that the standard addition of 625 IU vitamin D_3/lb of vitamin premix supports circulating 25(OH)D_3 concentrations of approximately 15 ng/mL in the nursery pig.

Oral vitamin D_3 dosage had no significant effect on growth performance throughout the duration of the study. Yet pigs dosed with either 40,000 IU or 80,000 IU vitamin D_3 weighed numerically more than that of their control contemporaries at weaning (d 20) and again at the end of the study (d 52). Also, no differences were observed for percentage bone ash or histopathologic analysis of bone samples collected on d 19 or 35. But it should be pointed out that percentage ash values, regardless of treatment, were much lower than the expected range of values (approximately 56%)[6] for mineral content as a percentage of dry fat-free bone. Perhaps this is because of the young age of the pigs on trial and the fact that most reference sources on the topic have been sampled

[6] Lewis and Southern. 2002. Swine Nutrition. 2nd ed. CRC Press, Boca Raton, FL.

from older pigs. Even so, oral vitamin D_3 at d 2 postfarrowing failed to increase percentage of ash in the nursery pig.

Although no growth performance differences were observed in this study, more research should be conducted with varying genotypes and herd health statuses to determine other possible links related to vitamin D responses. More work also should be completed in the area of Ca, P, and vitamin D interactions to determine optimal concentrations of these nutrients in feed for optimal mineralization of bone tissue, muscle function, and performance of growing swine.

Table 1. Composition of sow diets (as-fed basis)

Item	Gestation	Lactation
Corn	51.98	51.96
Soybean meal (46.5% CP)	4.14	24.24
Dried distillers grains with solubles	40.00	20.00
Limestone	1.75	1.45
Monocalcium P (21% P)	0.70	1.00
Salt	0.50	0.50
Trace mineral premix	0.15	0.15
Sow add pack	0.25	0.25
Vitamin premix	0.25	0.25
L-Lysine HCl	0.18	0.10
Phytase[1]	0.10	0.10
Total	100	100
Calculate analysis		
ME, kcal/lb	1,494	1,490
CP, %	17.4	21.2
Total lysine, %	0.71	1.10
Standardized ileal digestible amino acids, %		
Lysine	0.55	0.94
Isoleucine:lysine	93	79
Leucine:lysine	303	191
Methionine:lysine	52	34
Met & Cys:lysine	106	69
Threonine:lysine	89	71
Tryptophan:lysine	20	21
Valine:lysine	120	92
Ca, %	0.84	0.84
P, %	0.61	0.66
Available P, %[2]	0.50	0.49
Ca:P	1.38	1.26

continued

Table 1. Composition of sow diets (as-fed basis)

Item	Gestation	Lactation
Added vitamins		
VitaminA, IU/ton	10,000,000	10,000,000
Vitamin D, IU/ton[3]	1,250,000	1,250,000
Vitamin E, IU/ton	60,000	60,000
Vitamin K (menadione), mg/ton	4,000	4,000
Vitamin B12, mg/ton	35	35
Niacin, mg/ton	45,000	45,000
Pantothenic acid, mg/ton	25,000	25,000
Riboflavin, mg/ton	7,500	7,500
Biotin, mg/ton	200	200
Folic acid, mg/ton	1,500	1,500
Pyridoxine, mg/ton	4,500	4,500
Choline, mg/ton	500,000	500,000
Carnitine, mg/ton	45,000	45,000

[1] Natuphos 600, BASF, Florham Park, NJ. Provided 272 phytase units per pound of diet.
[2] Phytase provided 0.11% available P to both gestation and lactation diets.
[3] Provided 625 IU vitamin D per pound of diet.

Table 2. Composition of nursery diets (as-fed basis)

	Phase 1[1]			
Item	SEW	Transition	Phase 2	Phase 3
Ingredient, %				
Corn	36.10	38.23	57.06	65.80
Soybean meal (46.5% CP)	12.44	19.98	25.90	30.67
Spray-dried whey	25.00	25.00	10.00	---
Spray-dried animal plasma	6.70	2.50	---	---
Select menhaden fish meal	6.00	5.00	4.50	---
Spray-dried blood cells	1.65	1.25	---	---
Lactose	5.00	---	---	---
Choice white grease	5.00	5.00	---	---
Monocalcium P (21% P)	---	0.70	0.38	1.02
Limestone	0.45	0.45	0.58	0.98
Salt	0.25	0.30	0.30	0.35
Zinc oxide	0.375	0.375	0.25	---
Vitamin premix with phytase	0.25	0.25	---	---
Trace mineral premix	0.15	0.15	0.15	0.15
Vitamin premix	---	---	0.25	0.25
L-Lysine HCl	0.15	0.26	0.25	0.36
DL-Methionine	0.15	0.18	0.125	0.13
L-Threonine	0.08	0.125	0.105	0.13
Phytase[2]	---	---	0.165	0.165
Acidifier[3]	0.2	0.2	---	---
Vitamin E, 20,000 IU	0.05	0.05	---	---
Total	100	100	100	100
Calculated analysis				
ME, kcal/lb	1,611	1,590	1,505	1,504
CP, %	22.7	22.3	21.3	20.4
Total lysine, %	1.70	1.65	1.43	1.38
Standardized ileal digestible amino acids, %				
Lysine	1.56	1.51	1.30	1.25
Isoleucine:lysine	49	52	61	60
Methionine:lysine	30	33	35	33
Met & Cys:lysine	55	56	59	58
Threonine:lysine	64	63	63	62
Tryptophan:lysine	17	17	17	17
Ca, %	0.79	0.83	0.70	0.68
P, %	0.73	0.77	0.63	0.61
Available P, %	0.68	0.68	0.47	0.42
Ca:P	1.08	1.08	1.12	1.12

continued

Table 2. Composition of nursery diets (as-fed basis)

Item	Phase 1[1]		Phase 2	Phase 3
	SEW	Transition		
Vitamins (added levels)				
Vit A, IU/ton	10,000,000	10,000,000	10,000,000	10,000,000
Vit D, IU/ton[4]	1,250,000	1,250,000	1,250,000	1,250,000
Vit E, IU/ton	40,000	40,000	40,000	40,000
Vit K (menadione), mg/ton	4,000	4,000	4,000	4,000
Vit B12, mg/ton	35	35	35	35
Niacin, mg/ton	45,000	45,000	45,000	45,000
Pantothenic acid, mg/ton	25,000	25,000	25,000	25,000
Riboflavin, mg/ton	7,500	7,500	7,500	75,00

[1] During Phase 1 (d 20 to 25) in the nursery, SEW and transition diets were allotted at 1 and 3 lb/pig, respectively (4 lb total per pig).
[2] Natuphos 600, BASF, Florham Park, NJ. Provided 449 phytase units per pound of diet in Phase 2 and 3 rations.
[3] Ken Gest, Kemin Industries Inc., Des Moines, IA.
[4] Provided 625 IU vitamin D per pound of diet.

Table 3. Effects of oral vitamin D_3 dose on preweaning growth performance growth[1,2]

		Vitamin D3			*P*-values	
	Control	40,000 IU	80,000 IU	SEM	Quadratic	Linear
Number of pigs						
Initial[3]	90	90	90			
d 10	87	88	85			
d 18	86	86	83			
d 20[4]	79	78	77			
BW						
Initial	3.77	3.75	3.77	0.08	0.41	0.92
d 10	8.01	8.10	8.04	0.23	0.66	0.89
d 18	12.17	12.37	12.47	0.36	0.86	0.41
d 20	13.00	13.28	13.30	0.39	0.69	0.44
ADG						
d 0 to 10	0.45	0.46	0.45	0.02	0.60	0.90
d 10 to 18	0.52	0.53	0.55	0.02	0.86	0.14
d 18 to 20	0.41	0.45	0.42	0.03	0.17	0.90
d 2 to 20	0.48	0.49	0.49	0.02	0.69	0.42

[1] A total of 270 pigs from 29 litters (PIC 327 × 1050) were used in a 20-d preweaning study to determine the effects of oral vitamin D_3 dose at 2 d of age on growth performance.
[2] Data were analyzed using performance records from pigs that survived through weaning, d 20.
[3] Initial refers to pigs placed on test on both d 0 and d 2 of the trial. Pigs were placed on test at 1 or 2 d postfarrowing. Pig days were adjusted to account for differences in trial starting day for calculating ADG from d 0 to 10.
[4] Six pigs per treatment (6 matched sets) were removed on d 19 for necropsy.

Table 4. Effects of oral vitamin D_3 dose on nursery pig growth[1]

		Vitamin D_3			*P*-values	
Item	Control	40,000 IU	80,000 IU	SEM	Linear	Quadratic
d 20 to 25						
ADG, lb	0.52	0.53	0.52	0.03	0.99	0.86
ADFI, lb	0.51	0.53	0.52	0.02	0.89	0.48
F/G	1.01	1.01	1.00	0.04	0.91	0.89
d 25 to 39						
ADG, lb	0.66	0.66	0.69	0.02	0.35	0.65
ADFI, lb	0.97	0.98	0.99	0.03	0.56	0.93
F/G	1.47	1.48	1.44	0.04	0.64	0.59
d 39 to 52						
ADG, lb	1.06	1.10	1.07	0.02	0.83	0.29
ADFI, lb	1.68	1.74	1.70	0.04	0.65	0.33
F/G	1.58	1.59	1.60	0.03	0.72	0.95
d 20 to 52						
ADG, lb	0.79	0.82	0.81	0.02	0.47	0.50
ADFI, lb	1.17	1.21	1.19	0.03	0.52	0.30
F/G	1.47	1.49	1.47	0.02	0.93	0.60
BW, lb						
d 20	13.0	13.4	13.3	0.28	0.46	0.60
d 25	15.9	16.0	16.0	0.36	0.96	0.87
d 39	25.4	25.4	25.8	0.58	0.63	0.83
d 52	39.2	39.7	39.7	0.75	0.65	0.79

[1] A total of 235 weaned pigs (PIC 327 × 1050) initially 21 d of age were used in a 32-d nursery study to determine the effects of oral vitamin D_3 dose at 2 d of age on nursery pig growth and performance.

Table 5. Effects of oral vitamin D_3 dose on serum 25(OH)D_3 levels, ng/ml[1,2]

		Vitamin D_3			*P*-values	
Day of collection	Control	40,000 IU	80,000 IU	SEM	Linear	Quadratic
Initial[3]	3.6	3.5	3.6	1.1	0.99	0.99
10	14.7	57.3	68.5	1.2	<0.01	<0.01
20	8.0	28.1	35.8	1.2	<0.01	<0.01
30	10.4	17.8	22.5	1.2	<0.01	0.36
52	13.9	15.0	15.4	1.2	0.36	0.82

[1] A total of 87 pigs or 29 pigs per treatment (1 matched set per litter) were bled prior to dosing (initial: includes pigs placed on test on both d 0 and 2) and 10 later in lactation and d 20, 30, and 52 in the nursery to determine serum 25(OH)D_3 concentrations.
[2] Vitamin D_3 treatment × day effect ($P < 0.01$).
[3] Initial refers to pigs placed on test on both d 0 and d 2 of the trial. Pigs were placed on test at 1 or 2 d postfarrowing. Pig days were adjusted to account for differences in trial starting day for calculating ADG from d 0 to 10.

Table 6. Effects of oral vitamin D_3 dose on bone ash, %[1]

		Vitamin D_3			*P*-values	
Item	Control	40,000 IU	80,000 IU	SEM	Linear	Quadratic
d 19						
left femur	42.0	42.7	40.5	0.02	0.54	0.46
left 2nd rib	35.5	32.6	30.8	0.02	0.09	0.82
d 35						
right femur	39.0	---	39.7	0.02	0.47	---
right 2nd rib	31.5	---	33.0	0.02	0.55	---

[1] A total of 18 pigs, 6 per treatment (6 matched sets), were necropsied and bone samples were collected on d 19; 12 pigs (6 control pigs and 6 pigs from the 80,000 IU vitamin D_3 treatment) were necropsied on d 35.

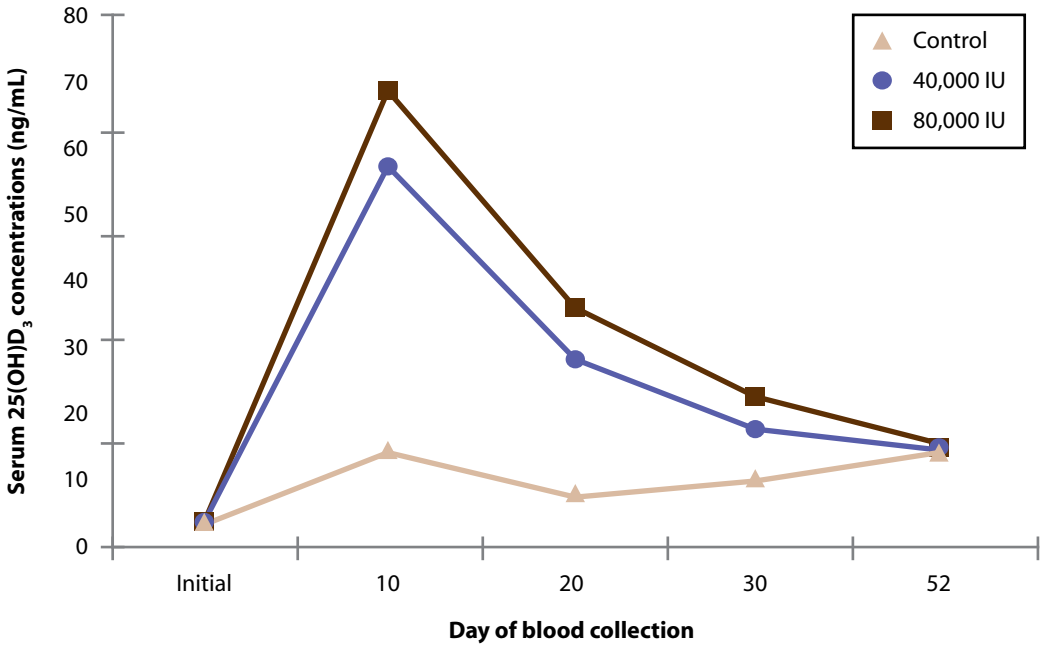

Figure 1. Effect of oral vitamin D_3 on serum 25(OH)D_3 concentrations.[1,2]

[1] A total of 87 pigs or 29 pigs per treatment (1 matched set per litter) were bled on d 2 and 10 in lactation and d 20, 30, and 52 in the nursery to determine serum 25(OH)D_3 concentrations.

[2] Initial refers to pigs placed on test on both d 0 and d 2 of the trial. Pigs were placed on test at 1 or 2 d postfarrowing. Pig days were adjusted to account for differences in trial starting day for calculating ADG from d 0 to 10.