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An Evaluation of Supplemental Vitamin D_3 on Growth Performance of Pigs Pre- and Postweaning, Nursery Feed Preference, and Serum $25(OH)D_3$[1]

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Summary

Three experiments were conducted to evaluate the effects of supplementing different concentrations and sources of vitamin D_3 on pig performance, feed preference, and serum $25(OH)D_3$.

In Exp. 1, a total of 398 barrows from 80 litters (PIC 1050, initially 7 d of age) were used in a 38-d study in a 2 × 2 factorial to determine the effects of vitamin D_3 supplementation from either a single oral dose or from high levels of vitamin D_3 in early nursery diets on pig performance and serum $25(OH)D_3$. On d 7 after birth, matched sets of pigs within litters were allotted to 1 of 2 oral dosages (none or 40,000 IU vitamin D_3) in a randomized complete block design. Pigs were weighed at d 7 and at weaning (d 21). Following weaning, a subset of 300 barrows were used from d 21 to 45 to determine the effects of the previously administered oral vitamin D_3 and 2 levels of dietary vitamin D_3 (625 or 6,250 IU/lb; 0.80% Ca and 0.63% available P) from weaning to d 31 on pig growth and serum $25(OH)D_3$. A common diet containing 625 IU/lb of vitamin D_3 (0.70% Ca and 0.47% available P) was fed from 31 to 45 d of age. No dose × diet interactions ($P > 0.09$) were observed. Serum $25(OH)D_3$ increased ($P < 0.01$) on d 21 and tended to increase on d 31 after dosing pigs with oral vitamin D_3 prior to weaning. On d 31, serum concentrations increased with increasing dietary vitamin D_3 levels ($P < 0.01$). Weaning weight was not influenced ($P > 0.17$) by the oral dose of vitamin D_3. Supplementing vitamin D_3 by either dose or diet did not influence ($P > 0.23$) nursery performance.

In Exp. 2, a total of 864 pigs (PIC TR4 × FAST ADN, initially 21 d of age) were used in a 30-d study to determine the effects of water supplementation of vitamin D_3 on nursery growth performance and serum $25(OH)D_3$. Upon arrival to the nursery (d 0), pigs were allocated to pens and pens were randomly allotted to 1 of 2 water vitamin D_3

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[4] Innovative Swine Solutions, Carthage, IL.
[5] New Fashion Pork Inc., Jackson, MN.
[6] Hubbard Feeds, Mankato, MN.

supplementation treatments (none or 4,000,000 IU/gal). There were 24 pigs/pen and 18 pens/treatment. Pigs were provided the water supplementation treatments from d 0 to 10. From d 10 to 30, pigs were administered water with no supplemental vitamin D_3. Common diets were fed throughout the study and were formulated to contain 1,000 IU/lb added vitamin D_3. Twelve pigs per treatment were randomly selected to be bled on d 0, 10, 20, and 30 to determine serum 25(OH)D_3 concentrations. Water supplementation of vitamin D_3 increased ($P < 0.01$) serum 25(OH)D_3 concentrations on d 10, 20, and 30 of the study but did not affect ($P > 0.15$) nursery growth performance.

In Exp. 3, 72 pigs (PIC 327 × 1050, initially 28 d of age) were used in 2 14-d feed preference comparisons to determine whether pigs discriminate in their choice of feeds containing different concentrations of vitamin D_3. On d 0, pigs were weighed and allotted to pens based on BW with 6 pigs/pen and 6 pens per feed comparison. The first preference comparison was between diets containing either 625 (control) or 6,250 IU/lb vitamin D_3, and the second comparison was between diets containing 625 (control) or 20,000 IU/lb vitamin D_3. Total pen feed intake was measured, and intake of each diet was expressed as a percentage of total intake. The percentage of feed intake did not differ ($P > 0.14$) between the control diet and the diet containing 6,250 IU/lb, but pigs chose to consume a greater percentage ($P < 0.01$) of the control diet (77%) than the diet containing 20,000 IU/lb of vitamin D_3.

These experiments demonstrated that providing high levels of vitamin D_3 in an oral dosage, in the water, or in feed increased serum 25(OH)D_3; however, preweaning and nursery pig growth performance was not influenced by elevating vitamin D_3 above normal dietary levels.

Key words: nursery pig, vitamin D

Introduction

Vitamin D is a fat-soluble steroid known for its role in the absorption and homeostasis of Ca and P in the body. The two main forms of vitamin D are vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol). Previous research has shown that pigs discriminate in the metabolism of these two forms and more readily convert vitamin D_3 to its circulating metabolite 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. In recent years, more focus has been placed on vitamin D because of documented cases where it has been absent from premixes fed to pigs. In these cases, large percentages of pigs have reportedly developed metabolic bone disease, which is categorized as disturbances related to bone formation and remodeling and can lead to bone breakages and clinical symptoms of rickets. Previous work conducted at Kansas State University (Flohr et al., 2011[7]) has shown that supplementation of vitamin D_3 (40,000 or 80,000 IU) given in a single oral dose after birth can increase serum 25(OH)D_3 concentrations of pigs up to 10 d after weaning, but no benefit in growth performance or bone mineralization was observed. Further research is needed to determine whether pig performance can be influenced by oral supplementation of high levels of vitamin D_3.

[7] Flohr et al., Swine Day 2011. Report of Progress 1056. pp. 34–45.

These experiments were designed to: (1) evaluate the effects of supplementing vitamin D_3 in a single oral dose on growth performance of suckling pigs in a commercial facility, (2) evaluate the effect of supplementing additional vitamin D_3 in early nursery diets or by water supplementation on pig growth performance and serum 25(OH)D_3 concentrations in the nursery, and (3) determine any potential preferences of young pigs to consume diets with different concentrations of supplemental vitamin D_3.

Procedures

The protocols in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee. The preweaning portion of Exp. 1 was conducted at Innovative Swine Solutions in Carthage, IL, and the nursery portion was performed at the K-State Segregated Early Weaning Facility in Manhattan, KS. Experiment 2 was conducted at New Fashion Pork in Buffalo Center, IN. Experiment 3 was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS.

For Exp. 1, a total of 398 barrows from 80 litters (PIC 1050, initially 7 d of age) were used in a 38-d study in a 2 × 2 factorial to determine the effects of supplementing vitamin D_3 from either a single oral dose or from high concentrations in early nursery diets on pig growth performance and serum 25(OH)D_3. On d 7 after birth, matched pairs of pigs within litters were allotted to 1 of 2 oral dosage treatments (none or 40,000 IU vitamin D_3) in a randomized complete block design. Pigs were weighed on d 7 and at weaning (d 21). Following weaning, a subset of 300 barrows were used from d 21 to 45 to determine the effects of the previously administered vitamin D_3 dose and 2 levels of dietary vitamin D_3 (625 or 6,250 IU/lb vitamin D_3, 0.80% Ca, and 0.63% available P; Table 1) from weaning through d 31 on pig performance and serum 25(OH)D_3. Common diets (625 IU/lb vitamin D_3, 0.70% Ca, and 0.47% available P) were fed from d 31 to 45. Barrows were allotted to pens based on their previously administered oral vitamin D_3 dose, then pens were randomly assigned to dietary treatments. All pens contained a 4-hole dry self-feeder and a cup waterer to allow for ad libitum access to feed and water.

Pigs and feeders were weighed on d 21, 26, 31, 38, and 45 to determine ADG, ADFI, and F/G. Serum was collected from 12 pigs per treatment via jugular venipuncture at weaning (d 21), d 31, and d 45. To select pigs bled for serum, the average weight pig from each of 12 pens/treatment were used. All blood samples were collected in serum separator tubes and were refrigerated for at least 6 h after collection. Blood was centrifuged at 1,600 × g for 25 min. Serum was extracted and stored in 2-mL vials and frozen in a freezer at -4°F. All 25(OH)D_3 testing was performed by Heartland Assays Inc. (Ames, IA). Additionally, barrows were vaccinated for porcine circovirus type 2 (PCV2) and Mycoplasma hyopnuemoniae (M. hyo). A 1-dose product, Ingelvac CircoFLEX (CircoFLEX; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO) was given for PCV2. For the *Mycoplasma hyopneumoniae* (*M. hyo*) vaccine, Respisure (Pfizer Animal Health, New York, NY), a 2-dose product was used. Serum samples collected at weaning and on d 64 (5 wk postvaccination) were analyzed for PCV antibody titers to distinguish potential effects of supplemental vitamin D_3 on acquired immunity. Serum was analyzed at the K-State Veterinary Diagnostic Laboratory using indirect fluorescent assays (IFA). Titration endpoints were calculated as the reciprocal of the last serum dilution that gave a positive fluorescence result. Prior to analysis, all IFA titers were

log_2-transformed to approximate a normal distribution of titers. Log_2-transformed antibody titers were used to quantify the change in antibody titers from weaning (d 21) through d 64 based on supplemental vitamin D_3 treatments.

In Exp. 2, 864 pigs (PIC TR4 × FAST ADN; initially 21 d of age) were used in a 30-d nursery study to determine the effects of water supplementation of vitamin D_3 on nursery pig growth performance and serum 25(OH)D_3 concentrations. Pigs were placed in pens upon arrival in the nursery facility with 24 pigs/pen. Pens were randomly allotted to 1 of 2 water vitamin D_3 supplementation treatments (none or 4,000,000 IU/gal). The 4,000,000 IU dose was provided by mixing Hi-D 2X (Alpharma, Inc.) at 2 oz/gal. Each treatment comprised 18 pens. Pens contained a 5-hole dry self-feeder and nipple waterer to allow for ad libitum access to feed and water. Pigs and feeders were weighed on d 0, 10, 20, and 30 to determine ADG, ADFI, and F/G. Twelve pigs/treatment were bled via jugular venipuncture on d 0, 10, 20, and 30 to determine 25(OH)D_3 concentrations. All blood samples were collected in serum separator tubes and refrigerated for at least 6 h after collection. Blood was centrifuged at 1,600 × g for 25 min. Serum was extracted and stored in 2-mL vials and frozen in a freezer at -4°F. All 25(OH)D_3 testing was performed by Heartland Assays Inc. (Ames, IA).

In Exp. 3, 72 pigs (PIC 327 × 1050, initially 28 d of age) were used in 2 14-d feed preference comparisons to evaluate if pigs differentiate between feeds containing different levels of vitamin D_3. All pigs received a common Phase 1 diet for 7 d prior to the start of the study. On d 0 (7 d postweaning), pigs were weighed and allotted to pens based on BW. There were 6 pigs/pen and 6 pens per treatment, and pens were randomly assigned to 1 of the 2 feed comparisons between Phase 2 nursery diets (Table 1). The first preference comparison was between diets containing 625 (control) or 6,250 IU/lb vitamin D_3, and the second comparison was between diets containing 625 (control) or 20,000 IU/lb vitamin D_3. Pens contained two 4-hole dry self-feeders and a nipple waterer to allow for ad libitum access to feed and water. Diets were placed in the separate feeders and feeders were positioned adjacent to each other. Every morning, feeders were weighed and switched in pen location to discourage any location bias by the pig. Total pen feed intake was calculated, and intake of each diet for both comparisons was expressed as a percentage of total intake.

Vitamin premixes and feed samples used in Exp. 1 and 3 were collected and sent to DSM Nutritional Products Laboratory, Inc. (Parsippany, NJ) for vitamin D_3 analysis (Table 2). Accepted analytical errors associated with complete feed vitamin D_3 assays is ± 25% of target level. All diets were within ±25% of their formulated level.

Statistical analysis conducted for each experiment was performed using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). In Exp. 1, for the preweaning period, the growth data were analyzed as a randomized complete block design. Individual pig was the experimental unit, initial weight on the day of dosing was used as a covariate, and sow was used as a random effect. Only pigs that completed the full lactation period (d 7 to 21) were used in this analysis. Nursery growth performance data were analyzed as a completely randomized design using pen as the experimental unit and barn as a random effect. Serum 25(OH)D_3 and PCV antibody titer results were analyzed using the repeated measures function to determine the effect of dosage or diet on response criteria over time and the treatment × time interactions. For Exp. 2, pen was the experimental unit, and initial BW on d 0 was used as a covariate. Serum 25(OH)D_3 was analyzed using the repeated measures function to determine the effect of water vitamin D_3 supplementation on serum over time and the treatment × time interactions. For Exp. 3, pen was again the experimental unit, and differences associated with the main effect of diet on the percentage of total feed intake were determined in both comparisons. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

Results and Discussion

In Exp. 1, no differences were observed ($P > 0.17$) for weaning weight (Table 3), but weaning weights were 0.2 lb/pig numerically heavier for pigs supplemented with the oral dosage of 40,000 IU of vitamin D_3. During the nursery phase (d 21 to 45), neither previously administered oral vitamin D_3 dose nor dietary level of vitamin D_3 in the diet affected ($P > 0.23$) ADG, ADFI, or F/G (Table 4). No dose × diet interactions were observed for any criteria in Exp. 1 except for a tendency ($P = 0.06$) for F/G from d 21 to 31. Here, F/G worsened with increasing dietary vitamin D_3 for pigs initially dosed on d 7 with 40,000 IU, but for pigs not orally dosed with vitamin D_3, F/G improved with increasing dietary vitamin D_3.

At weaning (d 21), serum 25(OH)D_3 concentrations (Table 5) increased ($P < 0.01$) in pigs that received an oral dose of 40,000 IU vitamin D_3. On d 31, a tendency ($P = 0.08$) for an increase in serum 25(OH)D_3 was observed for pigs dosed with vitamin D_3 prior to weaning. Also on d 31, increased serum 25(OH)D_3 concentrations were observed ($P < 0.01$) in pigs fed increased levels of vitamin D_3 (Figure 1).

PCV antibody titer results showed no dose × diet interaction ($P = 0.74$; Table 6) and no main effects of either dose or diet ($P > 0.59$) associated with the change in $\log_2$ reciprocal dilutions from d 21 to d 64.

In Exp. 2, supplementation of vitamin D_3 through the water did not affect ($P > 0.15$) overall ADG, ADFI, or F/G (Table 7), but F/G improved ($P = 0.05$) during the first phase (d 0 through 10) in pigs supplemented with 4,000,000 IU/ gallon of vitamin D_3. On the other hand, from d 10 to 30, ADG decreased significantly ($P = 0.03$) and F/G worsened ($P = 0.05$) in pigs supplemented 4,000,000 IU vitamin D_3 during the first phase.

For serum 25(OH)D_3 concentrations (Table 8), supplementing 4,000,000 IU vitamin D_3/gallon from d 0 to 10 increased ($P < 0.01$) serum 25(OH)D_3 concentrations in pigs on d 10, 20, and 30 (Figure 2).

In Exp. 3, there was no difference in preference between diets containing 625 or 6,250 IU of vitamin D_3 (Table 9), but when pigs were offered a choice between diets containing 625 and 20,000 IU of vitamin D_3, they consumed a greater portion ($P < 0.01$) of the diet containing 625 IU of vitamin D_3.

Results from Exp. 1 and Exp. 2 agree with our previous research (Flohr et al., 2011). Supplementation of vitamin D_3 appeared to significantly increase serum 25(OH)D_3 concentrations in the weaned pig but did not lead to increases in growth performance.

These studies clearly demonstrate that increasing supplementation of vitamin D_3 through an oral dose, diet, or water can increase serum $25(OH)D_3$.

Porcine circovirus type 2 antibody titer results from Exp. 1 suggest that vitamin D_3 supplementation has no effect on acquired immunity of the nursery pig, but to truly quantify vitamin D's role in immune function, disease challenge or studies with additional vaccines should be conducted.

In Exp. 3, the studies suggest that young pigs have a truly wide range of acceptance for different dietary vitamin D_3 concentrations; however, when diets contain extremely high concentrations (20,000 IU/lb) of vitamin D_3, pigs will reduce intake of the diet, which could potentially have negative effects on growth performance. If additional supplementation of vitamin D_3 is utilized in an operation, dietary levels should be monitored to reduce the risk of negative effects in growth performance or potential for vitamin D toxicity.

Multiple studies conducted at K-State associated with the supplementation of additional vitamin D_3 to the nursery pig have consistently shown that serum $25(OH)D_3$ concentrations can be increased without influence on growth performance of pigs pre- or postweaning. Future research needs to better quantify the relationship of circulating $25(OH)D_3$ to proper bone mineralization and ideal Ca and P absorption to determine optimal circulating concentrations of $25(OH)D_3$. More information is needed to determine whether another metabolite or other related protein may better quantify vitamin D status.

Table 1. Diet composition (as-fed basis)[1]

	Exp. 1[2]		Exp. 3[3]		
	Phase 1 diets		Phase 2 diets		
Ingredient,% vitamin D_3, IU/lb:	625	6,250	625	6,250	20,000
Corn	39.57	39.47	56.58	56.58	56.58
Soybean meal (46.5% CP)	17.34	17.34	26.30	26.30	26.30
Select menhaden fish meal	---	---	4.50	4.50	4.50
Dried distillers grains with solubles	5.00	5.00	---	---	---
Spray-dried porcine plasma	5.00	5.00	---	---	---
Spray-dried blood cells	1.25	1.25	---	---	---
Spray-dried whey	25.00	25.00	10.00	10.00	10.00
Soybean oil	3.00	3.00	---	---	---
Vitamins and minerals	2.64	2.64	1.66	1.66	1.66
Zinc oxide	0.39	0.39	0.25	0.25	0.25
Vitamin D premix[4]	---	0.10	0.05	0.05	0.05
Amino acids	0.48	0.48	0.49	0.49	0.49
Phytase[5]	0.13	0.13	0.17	0.17	0.17
Acidifier[6]	0.20	0.20	---	---	---
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
ME, kcal/lb	1,548	1,548	1,504	1,504	1,504
Total lysine, %	1.50	1.50	1.44	1.44	1.44
CP, %	21.2	21.2	21.5	21.5	21.5
Standardized ileal digestible amino acids, %					
Lysine	1.35	1.35	1.31	1.31	1.31
Isoleucine:lysine	61	61	61	61	61
Methionine:lysine	29	29	35	35	35
Met & Cys:lysine	58	58	59	59	59
Threonine:lysine	64	64	63	63	63
Tryptophan:lysine	18	18	17	17	17
Valine:lysine	72	72	68	68	68
Ca, %	0.80	0.80	0.71	0.71	0.71
P, %	0.71	0.71	0.63	0.63	0.63
Available P, %	0.63	0.63	0.47	0.47	0.47
Ca:P	1.13	1.13	1.12	1.12	1.12

continued

Table 1. Diet composition (as-fed basis)[1]

	Exp. 1[2]		Exp. 3[3]		
	Phase 1 diets		Phase 2 diets		
Ingredient,% vitamin D_3, IU/lb:	625	6,250	625	6,250	20,000
Vitamins (added levels)					
Vit A, IU/ton	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Vit D, IU/ton	1,250,000	12,500,000	1,250,000	12,500,000	40,000,000
Vit E, IU/ton	40,000	40,000	40,000	40,000	40,000
Vit K (menadione), mg/ton	4,000	4,000	4,000	4,000	4,000
Vit B_{12}, mg/ton	35	35	35	35	35
Niacin, mg/ton	45,000	45,000	45,000	45,000	45,000
Pantothenic acid, mg/ton	25,000	25,000	25,000	25,000	25,000
Riboflavin, mg/ton	7,500	7,500	7,500	7,500	7,500

[1] Diets from Exp. 2 were not included because experimental vitamin D_3 levels were achieved by water supplementation.
[2] A total of 300 barrows (PIC 1050, initially 21 d of age) were used for 24 d as part of a 38-d study evaluating the effects of supplemental vitamin D_3 by an oral dose or in early nursery diets on nursery growth performance and serum 25(OH)D_3 concentrations. Phase 1 experimental diets were fed from weaning (d 21) to d 31, then a common Phase 2 diet was fed from d 31 to 45.
[3] A total of 72 pigs (PIC 327 × 1050 initially 28 d of age) were used in two 14-d feed preference comparisons to evaluate if pigs differentiate between feeds containing different levels of vitamin D_3.
[4] Vitamin D premix was made by mixing rice hulls with Rovimix D_3 (DSM Nutritional Products, Parsippany, NJ) to achieve desired dietary vitamin D_3 concentration.
[5] Natuphos 600, BASF, Florham Park, NJ. Provided 354 and 463 phytase units (FTU) per pound of diet for Phase 1 and Phase 2 diets, respectively.
[6] KemGest, Kemin Industries Inc., Des Moines, IA.

Table 2. Analyzed dietary vitamin D_3 content of experimental rations (Exp. 1 and 3)[1,2]

	Exp. 1		Exp. 3		
Formulated level, IU/lb	625	6,250	625	6,250	20,000
Analyzed level, IU/lb	576	4,703	776	7,055	22,500
Analytical error[3]	± 25%	± 20%	± 25%	± 20%	± 15%

[1] Diets from Exp. 2 were not included because supplemental vitamin D_3 levels were achieved by water supplementation.
[2] All dietary vitamin D_3 analyses were conducted by DSM Nutritional Products Laboratory Inc. (Parsippany, NJ).
[3] Laboratory assay variability associated with vitamin D_3 content.

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

Item Oral vitamin D_3:	None	40,000 IU	SEM	Probability, *P*<
No. of pigs weaned	200	198	---	---
Weaning weight, lb	11.40	11.58	0.134	0.17
Weight gain, lb	7.07	7.25	0.134	0.17

[1] A total of 398 barrows from 80 litters (PIC 1050, initially 7 d of age) were used in a 14-d preweaning study to determine the effect of supplementing a single oral dose of vitamin D_3 on preweaning growth performance.
[2] Initial BW (d 7) was used as a covariate and sow was included in the statistical model as a random effect.

Table 4. Effects of supplemental vitamin D_3 by an oral dose or in early nursery diets on nursery pig growth performance (Exp. 1)[1]

						Probability, *P*<		
Oral dosage[2]:	None		40,000 IU D_3					
Dietary D_3, IU/lb[3]:	625	6,250	625	6,250	SEM	Dose × diet interaction	Dosage	Diet
d 21 to 31								
ADG, lb	0.35	0.36	0.37	0.33	0.021	0.15	0.80	0.46
ADFI, lb	0.34	0.34	0.35	0.34	0.028	0.84	0.51	0.56
F/G	0.99	0.95	0.97	1.04	0.035	0.06	0.25	0.66
d 31 to 45								
ADG, lb	0.93	0.90	0.89	0.93	0.023	0.17	0.85	0.95
ADFI, lb	1.22	1.19	1.19	1.22	0.024	0.14	0.97	0.99
F/G	1.32	1.33	1.33	1.32	0.021	0.64	0.89	0.94
d 21 to 45								
ADG, lb	0.68	0.67	0.67	0.68	0.017	0.59	0.83	0.92
ADFI, lb	0.85	0.83	0.84	0.86	0.020	0.28	0.83	0.99
F/G	1.25	1.24	1.25	1.26	0.020	0.62	0.67	0.85

[1] A total of 300 barrows were used from d 21 to 45 of age to determine the effects of supplemental vitamin D_3 on nursery growth performance from either a single oral dose or in early nursery diets. There were 5 barrows per pen and 15 pens per treatment.
[2] Oral dosage treatments were administered at d 7 of age.
[3] Dietary vitamin D_3 levels were fed in Phase 1 diets (d 21 to 31), then pigs were fed common diets containing 625 IU/lb vitamin D_3 from d 31 to 45.

Table 5. Effects of supplemental vitamin D_3 from either an oral dose or in early nursery diets on serum 25(OH) D_3 concentrations (Exp. 1)[1,2]

Dosage:	No vitamin D_3		40,000 IU D_3			Probability, $P<$		
Dietary D_3, IU/lb:	625	6,250	625	6,250	SEM	Dose × diet interaction	Dosage	Diet
25(OH)D_3, ng/mL								
d 21	7.8	7.9	26.8	21.6	2.59	0.30	0.01	0.32
d 31	21.3	33.5	28.6	35.6	2.59	0.33	0.08	0.01
d 45	10.1	14.3	15.6	13.7	2.59	0.25	0.35	0.66

[1] Twelve pigs/treatment were bled on d 21 (weaning), 31, and 45 to determine serum 25(OH)D_3 concentrations.
[2] Dose × diet × day interaction ($P = 0.99$), day main effect ($P < 0.01$).

Table 6. Effects of supplemental vitamin D_3 by an oral dose or in early nursery diets on PCV2 antibody titers[1,2]

Oral dosage:	No Vitamin D_3		40,000 IU D_3			*Probability, $P<$*		
Dietary D_3, IU/lb:	625	6,250	625	6,250	SEM	Dose × diet interaction	Dosage	Diet
PCV2 antibody titer, log_2								
d 21 (weaning)	6.6	7.6	6.6	6.6	0.41	0.16	0.14	0.21
d 64 (5 w postvaccination)	8.4	9.4	7.5	8.2	1.02	0.84	0.23	0.35
Change (d 64 to d 21)	1.8	1.8	0.9	1.6	1.13	0.74	0.59	0.70

[1] Serum collected on d 21 (weaning) and 5 wk postvaccination (d 64) was sent to the K-State Veterinary Diagnostic Laboratory for indirect fluorescent assays. There were 12 samples/treatment.
[2] Endpoint antibody titers determined by indirect fluorescent antibody (IFA) assay were log_2-transformed.

Table 7. Effects of water supplemented vitamin D_3 on nursery growth performance (Exp. 2)[1,2]

	Water supplemented D_3, IU/gal			
	None	4,000,000[3]	SEM	Probability, P<
d 0 to 10[4]				
ADG, lb	0.56	0.57	0.014	0.63
ADFI, lb	0.57	0.56	0.012	0.75
F/G	1.01	0.98	0.013	0.05
d 10 to 30				
ADG, lb	1.27	1.24	0.011	0.03
ADFI, lb	1.66	1.63	0.017	0.30
F/G	1.30	1.32	0.007	0.05
d 0 to 30				
ADG, lb	1.04	1.01	0.010	0.15
ADFI, lb	1.29	1.27	0.014	0.31
F/G	1.25	1.25	0.004	0.28

[1] A total of 864 pigs (PIC TR4 × FAST AND; initially 21 d of age) were used in a 30-d nursery study to determine the effects of water supplementation of vitamin D_3 on growth performance.
[2] Common diets formulated to contain 1,000 IU/lb of vitamin D_3 were provided throughout the trial.
[3] Hi-D 2X (Alpharma, Inc.) was included in water source at a rate of 2 oz/gal to achieve the desired experimental treatment level.
[4] Experimental water treatments were administered from d 0 to 10; from d 10 to 30, pigs were provided a control water source with no supplemental vitamin D_3

Table 8. Effects of water supplemented vitamin D_3 on serum 25(OH)D_3 (Exp. 2)[1,2]

	Water supplemented D_3, IU/gal:			
	None	4,000,000[2]	SEM	Probability, P<
Serum 25(OH)D_3, ng/mL				
d 0	11.6	16.0	2.79	0.27
d 10	27.4	90.2	2.79	< 0.01
d 20	17.8	47.7	2.79	< 0.01
d 30	21.0	32.6	2.79	< 0.01

[1] A total of 12 pigs/treatment were bled via jugular venipuncture to determine serum 25(OH)D_3 concentrations.
[2] Day × treatment interaction (P < 0.01), day main effect (P < 0.01).

Table 9. Evaluation of nursery pig feed preference for diets formulated to varying levels of vitamin D_3 (Exp. 3)[1]

Feed comparison:[2]	1				2			
Dietary vitamin D_3, IU/lb:	625	6,250	SEM	*Probability, P<*	625	20,000	SEM	Probability, *P*<
Feed intake, %								
d 0 to 7	54.5	45.5	4.2	0.14	77.7	22.3	4.20	< 0.01
d 7 to 14	46.4	53.6	6.7	0.46	61.4	38.6	6.74	0.03
d 0 to 14	49.3	50.7	5.2	0.85	66.9	33.1	5.20	< 0.01

[1] A total of 72 pigs (PIC 327 × 1050; initially 28 d of age) were used in a 14-d feed comparison to evaluate nursery pig preference to diets containing varying levels of vitamin D_3.
[2] There were 6 pigs/pen and 6 pens/feed comparison.

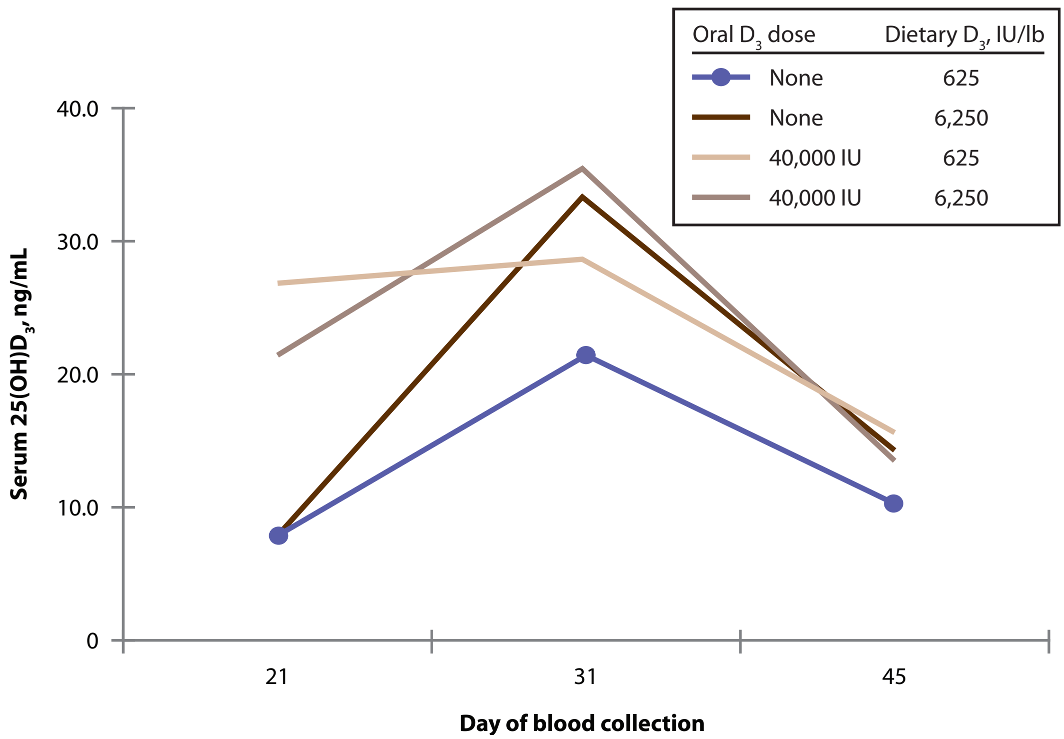

Figure 1. Effects of supplemental vitamin D_3 by either an oral dose or in early nursery diets on serum 25(OH) D_3 concentrations as determined by jugular venipuncture of 12 pigs/treatment on d 21 (weaning), 31, and 45 (Exp. 1).

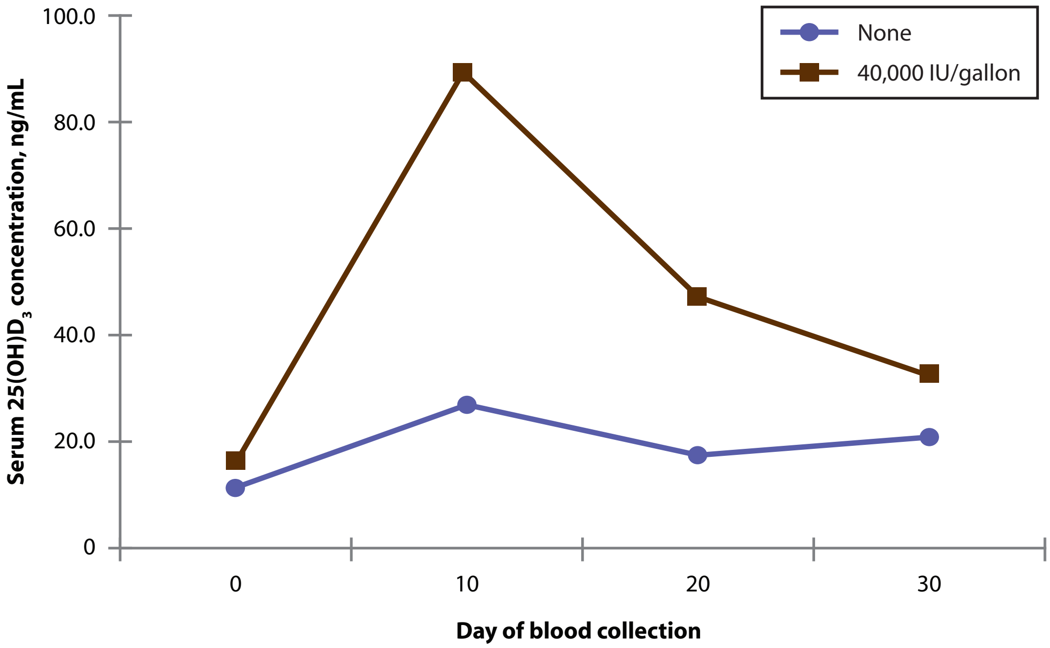

Figure 2. Effects of water supplementation of vitamin D_3 on serum 25(OH) D_3 concentrations as determined by jugular venipuncture of 12 pigs/treatment on d 0 (weaning), 10, 20, and 30 (Exp. 2).