Oral and injectable fat-soluble vitamin programs for sows, newborn and weaned pigs

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Introduction

Current swine feeding and management practices have amplified the need for optimum supplementation of fat-soluble vitamins A, D and E. Confinement feeding with lack of access to sunlight for vitamin D synthesis, different feed ingredients, increased litter size, genetic potential and reduction in weaning age are some of the factors that have escalated the need for adequate fat-soluble vitamin supplementation during all phases of present-day swine production. Besides recognized physiological functions, optimal levels of fat-soluble vitamins have been shown to enhance both cell-mediated and humoral immunity.[1,2] Pigs with serum alpha-tocopherol levels above 3 µg/mL have been shown to have improved immune function compared to pigs with serum tocopherol levels below 3 µg/mL.[3]

Although all are fat-soluble, these three vitamins are metabolized and stored differently in swine. Vitamin D (cholecalciferol), unlike vitamins A and E, can be synthesized by animals with adequate exposure to UV light. The rank of placental transfer of the vitamins is vitamins D > vitamin A > vitamin E to fetuses in utero. After birth, the rank of colostral/milk transfer is vitamin E > vitamin A > vitamin D.[4] Weanling pigs are typically adequate in vitamins A and E, but have low vitamin D status. This is primarily due to a lack of mammary transfer and lack of adequate sunlight (UV light) for systemic production of vitamin D by the sow and nursing pig.[5]

Storage of these vitamins is also different. Vitamin A is stored in the liver as retinyl palmitate and the biologically active form of vitamin A is retinol. Serum retinol is the measure of vitamin A status. Vitamin D (cholecalciferol) can be synthesized in the skin with adequate UV irradiation or orally consumed. Cholecalciferol is converted to 25-hydroxy-cholecalciferol (25-OH-D) in the liver and stored in fat cells. The biologically active form of vitamin D is 1,25-dihydroxy-cholecalciferol that is formed in kidneys from 25-OH-D.[6] Due to the short half-life of 1–25-OH D, serum 25-OH-D is the measure of vitamin D status. Vitamin E (alpha-tocopherol) is transported to various tissues via tocopherol transfer protein. Although vitamin E may be found in fat cells, vitamin E deficiency can occur since there is no mechanism to transfer vitamin E from fat cells to deficient tissues, hence no true storage of vitamin E.[7] Serum alpha-tocopherol is the measure of vitamin E status. Table 1 shows the ranges of vitamin levels in serum and liver of various classes of swine.

At weaning, serum vitamin E status in pigs is usually adequate but within one week post-weaning, serum levels decline dramatically regardless of level of vitamin E acetate in the diet.[8,9] The pig appears to be unable to metabolize vitamin E acetate during the first two to three weeks post-weaning, while they are able to utilize the alcohol form of vitamin E (alpha-tocopherol).[10] Unlike vitamin E status, vitamin A and vitamin D status does not dramatically decline after weaning. Growing-finishing pigs diets are routinely supplemented with fat-soluble vitamins and typically do not require additional fat-soluble vitamin supplementation. Gilts and sows can benefit from additional fat-soluble vitamins prior to breeding and parturition.[11,12]

In addition to supplementing complete feeds, water-supplementation, oral gavage and/or injections of fat-soluble vitamins A, D, and E have been shown to optimize vitamin status during critical production periods. The purpose of this paper is to review the results from various injectable and oral supplementation programs for newborn pigs and sows.

Materials and methods

In order to determine appropriate supplementation programs for sows and pigs, three studies were conducted to measure the effects of either injectable or oral administration of vitamins A, D and E on serum status of newborn and weaned pigs and gestating sows. In one study, tissue levels were determined in weaned pigs 14 days post-weaning. In all studies sows and pigs were not exhibiting deficiency symptoms of any of the fat-soluble vitamins.

Injectable or oral vitamin products for newborn pigs (Exp. 1)

To determine how newborn pigs responded to either oral or injectable fat-soluble vitamins, a total of 24 pigs (Yorkshire × Duroc) were used from 4 litters of pigs. Within each litter, 2

Table 1: Effect of vitamin administration to pigs on serum 25-OH D, retinol, and α-tocopherol concentration (Exp. 1)

	Treatments					*P*-value
Criteria	Sow	Control	Oral vit. AD_3E	Inj. vit. AD_3E	SEM[1]	Trt
25-OH D, ηg/mL						
Birth	21.23	2.60	2.65	2.67	0.11	0.741
d 10		9.24[c]	37.71[b]	81.86[a]	4.81	< 0.0001
Weaning	31.60	5.97[b]	9.99[b]	30.72a	3.57	0.0004
Retinol, µg/mL						
Birth		0.16	0.14	0.13	0.01	0.081
d 10		0.37	0.27	0.37	0.05	0.470
Weaning		0.35	0.19	0.20	0.05	0.186
alpha-tocopherol, µg /mL						
Birth		2.25	1.83	1.83	0.32	0.662
d 10		6.85[b]	3.76[b]	15.20[a]	1.66	0.007
Weaning		3.93	3.74	5.93	0.82	0.288

[1] Standard error of mean.

[a-c] Means without a common superscript differ ($P < 0.01$).

pigs were assigned to one of 3 treatments. Treatments were: 1) control, no supplemental vitamins, 2) oral administration of 400 I.U. vitamin E, 40,000 I.U. vitamin A and 40,000 I.U. vitamin D_3 (0.8 mL EMCELLE Newborn EAD, Stuart Products, Inc.), and 3) intramuscular injection of 400 I.U. vitamin E, 40,000 I.U. vitamin A and 40,000 I.U. vitamin D_3 (0.8 mL VITAL E-Newborn, Stuart Products, Inc.). Products were administered during processing at one-day of age. Serum was obtained on d0, d10 and weaning (d21) and analyzed for 25-OH-D, and alpha-tocopherol. Although not treated, sows were bled at farrowing and at weaning and serum analyzed for 25 OH-D and alpha-tocopherol. Body weights were obtained for sows and pigs during the study.

Injectable or oral vitamin products at birth (Exp 2)

This study was conducted to determine if a vitamin interfered with absorption of the other vitamins. Pigs (Yorkshire × Duroc) were used from 4 litters. Within each litter, pigs were assigned to one of six treatments; and following the initial assignment of pigs, any remaining pigs in each litter were assigned to Treatments 1 or 2. Treatments were: 1) control: no supplemental vitamins, 2) intramuscular injection of 1.0 mL vitamins E, A, and D, (contained 500 I.U. vitamin E, and 50,000 I.U. vitamins A and D. per mL. VITAL E-Newborn, Stuart Products, Inc.). 3) oral administration of 0.60 mL of vitamin D3 (EMCELLE D_3 LIQUID contained 84,500 I.U. vitamin D3 per mL). 4) oral administration of 1.66 mL vitamin E and D combination (EMCELLE ED_3 LIQUID contained 500 I.U. vitamin E and 30,000 I.U. vitamin D per mL), 5) oral administration of 1.66 mL vitamin E (EMCELLE TOCOPHEROL contained 500 I.U. vitamin E per mL) and 6) oral administration of 1.00 mL of vitamin A, vitamin D and vitamin E containing the same levels of vitamins as treatment 2. All pigs receiving supplements with vitamin D received about 50,000 I.U. vitamin D.

Injectable vitamin A, D and E (VITAL E-Hi A+D) to sows pre-farrowing (Exp 3)

A total of 24 PIC sows (average parity-5.2) were used to determine the transfer of vitamins from sow to piglets. Treatments were: 1) control, no injection, and 2) intramuscular injection of 5 mL VITAL E-Hi A+D two weeks pre-partum (1,000,000 I.U. vitamin A, as retinyl palmitate; 500,000 I.U. vitamin D as cholecalciferol; and 1,500 I.U. vitamin E as d-alpha-tocopherol per injection). Sows were bled pre-injection, and at parturition. Two pigs were randomly selected from each litter for blood sampling at birth and again at weaning.

Results and discussion

Results for experiment 1 are presented in Table 1. At parturition, sows had an average serum 25-OH D level of 21.23 ηg/mL and 31.60 ηg/mL at weaning. The sows were supplemented with 6,600 I.U. vitamin A, 880 I.U. vitamin D and 44 I.U. vitamin E per kg diet. At birth, the average 25-OH-D level across all piglets was 2.64 ηg/mL. At day 10, serum 25-OH-D status was different among all treatments with injection having the highest serum level. At weaning, only pigs injected at birth had a higher serum 25-OH-D level (P < 0.001). Serum retinol was not different among treatments at day 10 and weaning, although retinol levels at weaning were higher than at birth due to colostrum and milk transfer. Average vitamin E status after colostrum intake was 1.97 µg/mL. At day 10, injected pigs alpha-tocopherol status was 15.20 µg/mL which was higher than either control or orally supplemented pigs (P < 0.007). At weaning, injected pigs had a higher serum vitamin E status, although not significant (P <.29).

This study demonstrated that injecting fat-soluble vitamins was more efficient than orally administering equal I.U's of vitamins. The decline in 25-OH-D from day 10 to weaning in control pigs demonstrates that sow milk may not always be an adequate source of vitamin D. Since milk is a better source for vitamins A and E than for vitamin D, serum retinol and serum a-tocopherol status increased (Table 1).

Results for experiment 2 are presented in Table 2. Responses in this study were similar to those in experiment 1. Sows were fed the same as in experiment 1. All pigs supplemented with products containing vitamin D had higher serum levels of 25-OH D at day 10 and weaning with those injected having the highest serum levels. Absorption of oral vitamin D was not reduced when administered alone or in combination with vitamins A and E (84.68 vs 77.17). Serum levels at weaning were lower for retinol and higher for α-tocopherol compared to pigs in experiment 1.

In experiment 3, injecting gestating sows with vitamins A, D and E (VITAL E-Hi A+D) two weeks pre-partum increased sow's serum 25-OH-D concentrations at farrowing (Table 3). Furthermore, vitamin D status was higher in pigs born to injected sows compared to pigs born to non-injected sows (6.15 vs 4.00, P < 0.0001). At weaning, pigs nursing injected sows still maintained a higher serum 25-OH-D status compared to control pigs (12.05 vs 9.67, P <.05). Injecting sows pre-partum may be less labor intensive than injecting individual pigs at birth.

Conclusions

These studies demonstrate that fat-soluble vitamin supplementation to either gestating sows or newborn pigs do improve vitamin status of newborn and nursing pigs. Injected vitamins appear to be more efficiently utilized than an equal I.U. level given orally to newborn pigs. Field demonstrations have shown that supplementing drinking water with vitamins E and D for 2 weeks post-weaning averts a dramatic decline in both vitamin E and vitamin D status after weaning. The most critical times for optimum fat-soluble vitamin supplementation of sows appear to be pre-farrowing and lactation. Injecting vitamins pre-farrowing enhances vitamin status of newborns. The rank of need for newborn pigs appears to be vitamin D > vitamin E > vitamin A; and for the post-weaned pig, the rank of need appears to be vitamin E > vitamin D > vitamin A.

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Table 2: Effect of vitamin administration to pigs on serum 25-OH D, retinol, and α-tocopherol (Exp. 2)

Criteria	Treatment						SEM[1]	*P*-value
	Sow	Control	Inj. AD_3E	Oral D_3E	Oral E	Oral AD_3E		Trt
25-OH D, ηg/mL								
Birth	26.45	4.41	4.47	5.45	5.10	4.40	0.80	0.954
d 10		8.25^{b}	110.74^{a}	84.68^{a}	6.47^{b}	77.17^{a}	16.21	< 0.001
Weaning	32.65	5.02^{c}	40.24^{a}	27.30^{ab}	5.10^{c}	26.10^{b}	5.02	< 0.001
Retinol, μg/mL								
Birth	0.16	0.04	0.07	0.08	0.10	0.11	0.02	0.132
d 10		0.23	0.25	0.21	0.28	0.25	0.05	0.588
Weaning	0.27	0.18	0.16	0.16	0.18	0.17	0.05	0.850
α-tocopherol, μg/mL								
Birth	1.23	3.24	2.86	4.30	1.43	3.68	1.49	0.952
d 10		4.78^{b}	11.26^{a}	6.93^{b}	5.80^{b}	5.37^{b}	1.54	0.001
Weaning	3.13	3.86^{b}	7.16^{a}	7.33^{a}	4.80^{ab}	5.93^{ab}	0.92	0.004

[1] Standard error of mean.

[a,b,c] Means without a common superscript differ ($P < 0.01$).

Table 3: Effect of vitamin injection (VITAL E-Hi A+D) to sows on serum 25-OH D concentration of sows and piglets (Exp. 3)

Criteria	Control		Vitamins EAD_3 Injection, 5 mL		SEM[1]	*P*-value
Sows, ηg/mL						
Initial[2]	42.07	(n = 11)	37.10	(n = 13)	2.612	0.1923
At farrowing	43.10	(n = 11)	58.60	(n = 13)	2.861	0.0009
Percent change (%)	+2.4		+57.9			
Piglets,ηg/mL						
At birth	4.00	(n = 22)	6.15	(n = 26)	0.357	0.0001
At weaning	9.67	(n = 11)	12.05	(n = 12)	0.807	0.0498
Percent change (%)	141.7		95.9	(n = 12)	0.798	0.9029

[1] Standard error of mean.

[2] Before injection at 2 week prepartum.