Effect of Dietary Fat-soluble Vitamins on Growth Performance and Nutrient Digestibility in Growing Pigs

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ABSTRACT : Two experiments were conducted to compare the effect of various vitamins on performance and digestibility in growing pigs. In experiment 1, a total of 54 pigs (L×Y×D, 42.73±2.40 kg) were assigned to three treatments in a randomized complete block design with three replicates (6 pigs/pen) for 40 days. The three dietary treatments were: 100% fat-soluble vitamins (FSV) and water-soluble vitamins (WSV); 150% FSV and 100% WSV of NRC (1998); and 100% FSV and 150% WSV of NRC (1998). In experiment 2, a total of 180 pigs (L×Y×D, 28.20±3.05 kg) were assigned to four treatments in a completely randomized design with three replicates for four weeks (15 pigs/pen). The four dietary treatments were, 150% vitamin A and 100% other vitamins, 150% vitamin D and 100% other vitamins, 150% vitamin E and 100% other vitamins, and 150% vitamin K and 100% other vitamins. In experiment 1, there were significant differences in growth performance and digestibility of nutrients among the treatments. The ADG, ADFI and FCR of pigs fed 150% FSV diet were better ($p<0.05$) than those fed the control diet. However, there were no differences ($p>0.05$) in ADG, ADFI and FCR between pigs fed the control and 150% WSV diets. Digestibilities of dry matter, gross energy and calcium were improved in 150% FSV treatment group compared with control ($p<0.05$). However, the improvement was similar when compared with 150% WSV except for Ca. In experiment 2, there were no differences ($p>0.05$) in ADG, ADFI and FCR and nutrient digestibility between the fat-soluble vitamin treatments when fed at the 150% level. In conclusion, growing pigs were more responsive to additional fat-soluble vitamin supplements over the requirements suggested by NRC (1998) than to water-soluble vitamin supplements as measured by growth performance and digestibility of nutrients. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 4 : 563-567)***

Key Words : Vitamin A, Vitamin D, Vitamin E, Vitamin K, Growth, Pigs, Digestibility

INTRODUCTION

The concentrations of most of the essential vitamins in feed ingredients are not sufficient enough to meet requirements of pigs and hence supplementation of vitamin as premixes in the feed is normally followed around the globe (Chae, 2000). The requirements of fat-soluble vitamins as suggested by NRC (1998) are considered to be lower and especially vitamin A, D and E are being supplemented at levels approximately 3.5 to 7 times to that of NRC (1998) requirements in the feed formulations (Ching et al., 2002). This is normally practiced because of various indigenous and environmental factors present on many commercial farms that might cause the animal to have a higher requirement or factors that could cause deterioration of dietary vitamins (Coehlo, 2000; Lohakare et al., 2005). There do exist reports that B-vitamin levels suggested by NRC (1988) are inadequate for maximal performance of weaned pigs (Wilson et al., 1993) and high-lean growing pigs (Stahly et al., 1995). A trend of improvement in ADG in growing pigs fed 5 times NRC (1988) levels of supplemented B-vitamins (Stahly et al., 1995) and fed vitamins A, E and C from 25 to 425% of NRC has also been reported (Stahly et al., 1997).

As a series of experiments, the experiment one was an attempt to study the effect of higher level of fat-soluble and water-soluble vitamins on growth performance and nutrient digestibility of growing pigs and the objective of experiment two was to ascertain, which fat-soluble vitamin was more beneficial in improving performance in growing pigs when supplemented at higher level.

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MATERIALS AND METHODS

Animals, management and feeding

Two experiments were conducted separately to explore the efficacy of dietary vitamin levels on growth performance and nutrients digestibility. In experiment 1, fifty-four pigs (L×Y×D, 42.73±2.40 kg average body weight) were assigned to three dietary treatments with three replicates comprising 6 pigs per replicate employed in a completely randomized block design for 40 days. They were fed the treatment diets as: 100% of fat-soluble vitamin (FSV) and water-soluble vitamin (WSV) levels of NRC, 1998 (diet 1); 150% FSV and 100% WSV of NRC, 1998 (diet 2); and 100% FSV and 150% WSV of NRC, 1998 (diet 3).

In experiment 2, a total of 180 pigs (L×Y×D, 28.20±3.05 kg average body weight) were allotted to four dietary treatments for four weeks with three replicates containing 15 pigs each in a randomized complete block design. The dietary treatments were: 150% vitamin A and 100% other vitamins as suggested by NRC (1998), 150%

Table 1. Ingredient and chemical composition of experimental diets used in the feeding trial (expt. 1)

	% of NRC (1998)		
Fat-soluble vitamin	100	150	100
Water-soluble vitamin	100	100	150
Ingredients (%)			
Corn[1]	72.85	72.80	72.80
Soybean meal (44%)	21.49	21.49	21.49
Animal fat	2.33	2.33	2.33
Fish meal	0.88	0.88	0.88
Tricalcium phosphate	1.77	1.77	1.77
Salt	0.20	0.20	0.20
DL-Met (50%)	0.01	0.01	0.01
L-Lysine HCL	0.17	0.17	0.17
Trace min. mix[2]	0.10	0.10	0.10
Chlortetracycline (100 g/kg)	0.10	0.10	0.10
Vit. mix[3]	0.10	0.10	0.10
Fat-soluble vitamin[4]	-	0.05	-
Water-soluble vitamin[5]	-	-	0.05
Total	100.00	100.00	100.00
Calculated composition (%)			
ME (kcal/kg)	3,197	3,197	3,197
Crude protein	16.00	16.00	16.00
Lysine	0.95	0.95	0.95
Met+cys	0.54	0.54	0.54
Calcium	0.80	0.80	0.80
Phosphorus	0.68	0.68	0.68

[1] Corn was replaced by vitamin premix in treatment diets.
[2, 3] 0.1% in the diet provided 100% of NRC (1998) requirement.
[4, 5] 0.05% in diet provided 50% of NRC (1998) requirement.

Table 2. Ingredient and chemical composition of experimental diets used in the feeding trial (expt. 2)

	150% of NRC (1998)			
	Vit. A	Vit. D	Vit. E	Vit. K
Ingredients (%)				
Corn[1]	60.95	60.95	60.95	60.95
Wheat (11%)	5.00	5.00	5.00	5.00
Soybean meal (44%)	28.12	28.12	28.12	28.12
Animal fat	3.29	3.29	3.29	3.29
Tricalcium phosphate	1.86	1.86	1.86	1.86
Salt	0.20	0.20	0.20	0.20
DL-met (50%)	0.03	0.03	0.03	0.03
L-lysine-HCL	0.20	0.20	0.20	0.20
Trace min. mix[2]	0.10	0.10	0.10	0.10
Chlortetracycline (100 g/kg)	0.10	0.10	0.10	0.10
Vit. mix[3]	0.10	0.10	0.10	0.10
Vit. A[4]	0.05	-	-	-
Vit. D[5]	-	0.05	-	-
Vit. E[6]	-	-	0.05	-
Vit. K[7]	-	-	-	0.05
Total	100.00	100.00	100.00	100.00
Calculated composition (%)				
ME (kcal/kg)	3,310	3,310	3,310	3,310
Crude protein	18.00	18.00	18.00	18.00
Lysine	1.10	1.10	1.10	1.10
Met+cys	0.65	0.65	0.65	0.65
Calcium	0.80	0.80	0.80	0.80
Phosphorus	0.70	0.70	0.70	0.70

[1] Corn was replaced by vitamin premix in treatment diets.
[2, 3] 0.1% in the diet provided 100% of NRC (1998) requirement.
[4, 5, 6, 7] 0.05% in diet provided 50% of NRC (1998) requirement for each vitamin.

vitamin D and 100% other vitamins, 150% vitamin E and 100% other vitamin; and lastly 150% vitamin K and 100% other vitamins. The dietary formulations for each diet fed during experiment 1 and 2 are shown in Tables 1 and 2, respectively. Vitamin premixes were prepared separately to meet the NRC (1998) requirements at the inclusion level of 0.1% in the diet. For experiment 1, separate vitamin premixes were prepared for additional fat-soluble vitamins and water-soluble vitamins so that it could be added at 0.05% level. Similarly for experiment 2, vitamin premixes were prepared for individual fat-soluble vitamin that could be added at 0.05% level in the diet.

All pigs were allotted on the basis of sex (50:50) and weight to dietary treatments for both experiments in a completely randomized block design. Experiment 1 was conducted at the Kangwon National University experimental pig farm. The pigs were housed in a 3.0 m×2.8 m pens with concrete floors. Experiment 2 was conducted at Kangnim Farm, Wonju, Korea. The pigs were housed in a 4.0 m×2.8 m pens with half slatted floors. Feed and water were offered for *ad libitum* consumption in both experiments. The temperature range in both the farms varied from 15- 32°C.

For nutrient digestibility, at the end of each experimental feeding, feeds including 0.25% chromic oxide as an indigestible marker were given for both experiments. A grab of sample of feces was taken from several pigs in each pen and pooled by pen on the 5th day after feeding the marked diets. Feces were dried in a forced-air drying oven at 60°C for 72 h and then used for chemical analysis.

Chemical and statistical analysis

Proximate analyses of the feeds and feces were made according to the methods of AOAC (1990) and gross energy was measured with an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Chromium was measured with a spectrophotometer (Control 942, Italy).

Data were analyzed using the General Linear Model (GLM) procedure of SAS (1985). The pen was the experimental unit for each analysis. The statistical model was that appropriate for a randomized complete block design. When significant differences were found, the means were compared by Duncan's multiple range tests and the statement of significant probability were based on $p<0.05$.

RESULTS AND DISCUSSION

The average daily gain (ADG) during initial twenty days was higher ($p<0.05$) in FSV supplemented diet than the control diet (Table 3). The average daily feed intake

Table 3. Effect of diets containing high level of fat-soluble and water-soluble vitamins on growth performance in growing pigs

	% of NRC (1998)			SE[1]
Fat-soluble	100	150	100	
Water-soluble	100	100	150	
0-20 d				
ADG (g)	812[b]	858[a]	838[ab]	26.13
ADFI (g)	1,948[a]	1,757[b]	1,867[ab]	42.69
FCR	2.40[a]	2.06[b]	2.25[b]	0.06
20-40 d				
ADG (g)	830[b]	898[a]	855[b]	38.11
ADFI (g)	2,160[ab]	2,069[b]	2,180[a]	37.13
FCR	2.62[a]	2.33[b]	2.57[a]	0.08
0-40 d				
ADG (g)	821[b]	878[a]	846[b]	31.84
ADFI (g)	2,054[a]	1,913[b]	2,024[ab]	38.73
FCR	2.51[a]	2.20[b]	2.41[a]	0.07

[a, b] Values with different subscripts in the same row differ significantly ($p<0.05$).
[1] Pooled standard error.

Table 4. Effect of diets containing high level of vitamin A, D, E and K on growth performance in growing pigs

Treatment	150% of NRC (1998)				SE[1]
	Vit. A	Vit. D	Vit. E	Vit. K	
0-2 week					
ADG (g)	587	609	596	652	18.06
ADFI (g)	1,414	1,470	1,480	1,514	51.32
FCR (g)	2.41	2.11	2.47	2.33	0.08
2-4 week					
ADG (g)	656	639	661	610	21.75
ADFI (g)	1,616	1,717	1,632	1,637	43.95
FCR	2.46	2.84	2.47	2.71	0.09
0-4 week					
ADG (g)	621	624	627	631	14.92
ADFI (g)	1,515	1,593	1,556	1,575	44.99
FCR	2.44	2.55	2.48	2.50	0.06

[1] Pooled standard error.

(ADFI) was lower ($p<0.05$) in FSV supplemented diet that terminated into improved feed conversion ratio (FCR) in these animals over that of non-added diet. The ADG, ADFI and FCR in FSV diet was not different from that of WSV fed group during 0-20 day measurements. Similar trend of increased ADG and improved FCR in FSV fed pigs than control diet was noticed during 20~40 d and the overall period (0-40 d). But unlike initial measurements, at 20-40 d and overall study showed higher ($p<0.05$) ADG and improved FCR in FSV group than WSV diet. This showed that the requirement of FSV as suggested by NRC (1998) were not sufficient to meet the requirements and supplementation of FSV especially during growing stages was beneficial for improving performance of the pigs. Our previous study (Chae et al., 2000a) also showed improved weight gain in growing pigs by 150-250% vitamin-trace mineral premix supplementation of NRC (1998) requirement. Our study is also in agreement with the results of Stahly et al. (1995, 1997). They reported that additional feeding of B-vitamins or vitamins A, E and C over NRC (1988) requirements improved ADG of growing pigs. The improvement in FCR in WSV fed group as compared with control was observed only during 0-20 d in the present study and no further benefit was noticed by supplementing WSV, although numerically higher ADG was noticed as compared to control in this particular group at all measurements. Vitamin availability is normally low in feed ingredients, because most of them present in feedstuffs exist as precursor compounds or coenzymes that are often bound or complexed in some manner (Baker, 1995). Contrary to the present study, some researchers (Patience and Gillis, 1995, 1996; Mavromichalis et al., 1999) observed no effect on growth performance and carcass characteristics of pigs when vitamin and (or) trace mineral premixes were omitted during the last 3 to 5 weeks before market. It seems highly possible that the improvement in growth rate with increasing vitamins in the diet depend on the inclusion level and feeding duration in the pig (Chae et al., 2000a; 2000b).

The objective of experiment two to ascertain, which fat-soluble vitamin was more beneficial in improving performance in growing pigs when supplemented at higher level. The NRC (1998) requirements of vitamin A (1,300 IU), vitamin D_3 (150 IU), vitamin E (11 IU) and vitamin K_3 (0.50 mg) could be sufficient enough for the growth of the pigs and higher level of individual FSV was not beneficial for growth or improving the FCR over the other in the present study (Table 4). The results from the experiment 1 and 2 suggest that the FSV are more beneficial cumulatively rather than their individual supplementation, which pinpoints the inter-relationships among the fat-soluble vitamins. With the minimal requirement of vitamins, responses of animals cannot be maximized because there are many factors affecting vitamin needs under practical conditions as suggested by Cunha (1977). These factors include genetic potential, nutrient inter-relationships, environmental conditions, antimetabolites, stress, disease and toxins in feeds. As mentioned earlier, at practical commercial conditions, vitamin A, D and E are being supplemented at levels approximately 3.5 to 7 times to that of NRC (1998) requirements in the feed formulations (Ching et al., 2002). There were no differences in the growth performance of pigs among different fat-soluble vitamins at 150% higher levels than NRC (1998) requirements, at all phases of study. Hence we feel the level of individual fat-soluble vitamin used in experiment 2 were either low or may be ineffective to improve the growth performance of growing pigs optimally and the improved performances result we get by supplementing FSV in experiment 1 could be the cumulative effect of all FSV, rather than individual vitamin.

The nutrient digestibility studies conducted at the end of experiment 1 showed higher ($p<0.05$) digestibility of dry

Table 5. Effect of diets containing high level of fat-soluble and water-soluble vitamins on nutrient digestibility (%) in growing pigs

	% of NRC (1998)			SE[1]
Fat-soluble	100	150	100	
Water-soluble	100	100	150	
Dry matter	78.47[b]	80.70[a]	80.41[a]	0.39
Gross energy	75.34[b]	78.02[a]	76.96[ab]	0.46
Crude protein	74.11	73.42	71.80	0.68
Crude fat	65.76	67.19	69.65	1.66
Calcium	52.98[b]	57.33[a]	52.79[b]	0.91
Phosphorus	41.55	50.53	41.45	2.62

[a, b] Values with different subscripts in the same row differ significantly ($p<0.05$).
[1] Pooled standard error.

matter, gross energy and calcium in FSV fed diets as compared with control (Table 5). Except dry matter, the digestibility of all other nutrients in WSV fed diet was similar to that of control diet. The crude protein, crude fat and phosphorus digestibility were not affected by the dietary treatments. The increased digestibility of some of the nutrients in FSV supplemented diet might have improved the weight gains in this group. In our earlier studies, increasing dietary vitamin-trace mineral premix had a linear effect ($p<0.05$) on digestibility of calcium and phosphorus and there were no differences in the digestibility of energy, crude protein and fat among dietary treatments (Chae et al., 2000a; 2000b). Although phosphorus digestibility is not improved in the present study, but the causes for increasing the digestibility of some nutrients remained obscure. One of the possible explanations would be interaction among nutrients. It is well known that vitamin D and some trace minerals are related to the metabolisms of calcium and phosphorus in the manner of interaction or antagonism. Vitamin D is a companion nutrient to Ca and P. Active vitamin D_3 stimulates Ca absorption (Peo, 1991) and improves phosphorus digestibility (Soares, 1995). Also, Soares (1995) reported that adding 5 to 10 µg of dihydroxy cholecalciferol to a vitamin D-adequate diet increased phytate phosphorus bioavailability by 50%.

The digestibility of dry matter, gross energy, crude protein, crude fat, Ca and P were not different among the treatments when vitamins A, D, E and K were fed at 150% higher level than NRC (1998) requirements (Table 6). There exists possibility that the levels of individual fat-soluble vitamin we used were still low to show any significant differences in nutrients digestibility when compared among themselves, and this might be one of the reasons that the ADG was also not improved in the present study. In experiment 1, we found improved digestibility of some of the nutrients when all the FSV were given at 150% level of NRC, but their individual supplementation failed to do so. There might be the cumulative effect rather than individual vitamin effect. The reasons for such results are far from clear and hence we recommend carrying out further studies especially on individual vitamins role in nutrients digestibility at different levels.

Table 6. Effect of diets containing high level of vitamin A, D, E and K on nutrient digestibility (%) in growing pigs

	150% of NRC (1998)				SE[1]
	Vit. A	Vit. D	Vit. E	Vit. K	
Dry matter	77.83	78.59	77.75	78.10	0.66
Gross energy	79.52	80.26	79.91	79.99	0.59
Crude protein	74.99	75.75	76.23	75.83	0.75
Crude fat	55.81	57.74	57.03	58.85	1.39
Calcium	48.59	50.06	49.19	49.62	1.88
Phosphorus	42.72	50.42	46.12	47.08	2.01

[1] Pooled standard error.

In conclusion, we found that increasing the dietary fat-soluble vitamins in growing pigs improved growth performance and nutrient digestibility; and there were no differences in performance when individual fat-soluble vitamin was supplemented at 150% higher level than NRC (1998) recommendations. Hence, further studies needed to determine the optimal inclusion level of each vitamin for modern genotype growing pigs.

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