Effects of Inclusion Levels of Dietary Vitamins and Trace Minerals on Growth Performance and Nutrient Digestibility in Growing Pigs[a]

B. J. Chae*, S. C. Choi, W. T. Cho[1], In K. Han[1] and K. S. Sohn[2]
Division of Animal Resources, Kangwon National University, Chunchon 200-701, Kangwon, Korea

ABSTRACT : Two feeding trials were conducted to evaluate the effects of inclusion levels of dietary vitamin and trace mineral (VTM) premixes on growth and nutrient digestibility in growing pigs. A total of 112 pigs (24.82±3.22 kg) were employed for 49 days (exp. 1), and 168 pigs (21.64±1.41 kg) for 40 days (exp. 2) in completely randomized block designs. Treatments were: 1) 100%, 2) 150%, 3) 200% and 4) 250% NRC (1998) requirement of VTM in exp. 1, and the ratio of vitamins to trace minerals at 1) 100:100%, 2) 100:150%, 3) 150:100% and 4) 150:150% of NRC (1998) requirement in exp. 2. Basal diets for feeding trials were formulated to contain 3,310 kcal ME/kg and 18% crude protein, and contained 0.25% chromic oxide as an indigestible marker for digestibility trials. Increasing dietary VTM premix in growing pigs had linear and quadratic effects ($p<0.05$) on ADG, and feed conversion ratio was also improved ($p<0.05$) as VTM premix was increased by 150-250% of NRC (1998) requirements in exp. 1. Adding vitamin to trace mineral premixes at 150% NRC (1998) over the control improved ($p<0.05$) ADG and feed efficiency in growing pigs, but performances were not improved by vitamin nor by trace mineral premixes alone ($p>0.15$) (exp. 2). There were no differences ($p>0.05$) in the digestibilities of energy, crude protein and fat among dietary treatments. However, increasing dietary VTM premix in growing pigs had a linear effect ($p<0.05$) on the digestibilities of calcium and phosphorus. The 200 or 250% fed group showed improved ($p<0.05$) calcium digestibility, and 250% fed group also showed improved ($p<0.05$) phosphorus digestibility as compared to 100% or 150% fed group (exp. 1). The digestibilities of Ca and P were higher ($p<0.05$) in 150% addition of vitamins than in 150% addition of trace minerals in the diet (exp. 2). *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1440-1444)*

Key Words : Vitamin and Trace Mineral Premix, Growth, Digestibility, Growing Pig

INTRODUCTION

Vitamins and trace minerals play important roles in pigs, and their requirements can be affected by many factors (Cunha, 1977). Optimal vitamin and trace mineral nutrition takes into account commercial practices which place stresses on the animals such as confinement, disease challenge and ambient temperature, and their bioavailability/stability (Anonymous, 1999). As pig genotype changes, so do these nutrients needs, in addition to the major ones, energy and amino acids. So, Patience et al. (1995) suggested that these trace elements may be increased by 10-20% for pigs with extremely high performance.

The recommendation levels of vitamins and trace minerals suggested by breeding companies, suppliers, or universities are substantially higher than the requirements reported by NRC (1988, 1998). As examples of experiments concerning dietary vitamin levels, some researchers reported that B-vitamins listed in NRC (1988) are inadequate for maximal performance of weaned pigs (Wilson et al., 1993) and high-lean growing pigs (Stahly et al., 1995). Stahly et al. (1997) also reported that daily gain of growing pigs improved with increasing supplementations of vitamins A, E and C from 25 to 425% of NRC (1988). In contrast, 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 is important to provide pigs with the expensive micronutrients they need optimally, although the problem is to figure out how much of which vitamins and trace minerals pigs need. As part of a series of experiments, the objectives of these were to determine 1) the effects of different inclusion levels of dietary vitamins and trace minerals, and 2) the effects of different levels of dietary vitamins or trace minerals on growth performance and nutrient digestibility in growing pigs.

MATERIALS AND METHODS

Animals and feeding

Two feeding trials were separately conducted to evaluate the effects of inclusion levels of dietary vitamin and trace mineral (VTM) premixes on growth

* Address reprint request to B. J. Chae. Tel: +82-33-250-8616, Fax: +82-33-244-4946, E-mail: bjchae@cc.kangwon.ac.kr.
[1] Department of Animal Science and Technology, Seoul National University, Suweon 441-744, Korea.
[2] Agribrands Purina Korea Inc., Seoul 135-280, Korea.
[a] This study was partially funded by the MAF-SGRP (Ministry of Agriculture and Forestry-Special Grants Research Program) in Korea.
Received February 2, 2000; Accepted March 16, 2000

and nutrient digestibility in growing pigs.

For feeding trials, a total of 112 pigs (24.82±3.22 kg) were employed for 49 days (exp. 1), and 168 pigs (21.64±1.41 kg) were used for 40 days (exp. 2). All pigs were 3-way crossed breeds (L×Y×D), and alloted on the basis of sex and weight to four treatments in a completely randomized block design. In exp. 1, treatments were: 1) 100%, 2) 150%, 3) 200% and 4) 250% NRC (1998) requirement of VTM. In exp. 2, the inclusion levels of vitamin and trace mineral premixes were different from exp. 1. Treatments were in the ratio of: 1) 100:100%, 2) 100:150%, 3) 150:100% and 4) 150:150% of NRC (1998) requirements for vitamins and trace minerals.

For nutrient digestibility, on the 4th week of each experiment, feeds including 0.25% chromic oxide as an indigestible marker were given. A grab sample of feces was taken from several pigs in each pen and pooled by the pen on the 5th day after feeding the marked diets. Feces were dried in an air forced drying oven at 60℃ for 72 hours for chemical analysis.

Experimental diets for feeding trials were formulated to contain 3,310 kcal ME/kg and 18% crude protein (table 1). The pigs were housed in 4.0 m ×2.8 m pens with half slatted floors. Feed and water were offered for *ad libitum* consumption.

Table 1. Fomula and chemical composition of basal diets for feeding trials

	% of NRC (1998) Exp. 1	% of NRC (1998) Exp. 2
Vitamin	100-250	100-150
Mineral	100-250	100-150
Ingredients (%)		
Corn[1]	61.00	60.95
Wheat (11%)	5.00	5.00
SBM (44%)	28.12	28.12
Fat, animal	3.29	3.29
TCP	1.86	1.86
Salt	0.20	0.20
DL-Met (50%)	0.03	0.03
L-Lys-HCl (78%)	0.20	0.20
Vit. & trace min. mix[2]	0.20	-
Vit. mix[3]	-	0.10
Trace min. mix[3]	-	0.10
Chlorotetracycline	0.10	0.10
Total	100.00	100.00
Calculated values (%)		
ME, kcal/kg	3,310	3,310
Crude protein	18.0	18.0
Lysine	1.10	1.10
Methionine	0.33	0.33
Threonine	0.71	0.71
Tryptophan	0.24	0.24
Ca	0.80	0.80
P	0.70	0.70

[1] Corn was replaced by vitamin and mineral premix by treatments.

[2,3] 0.2% and 0.1% in the diet provided 100% of NRC (1998) requirements.

Chemical and statistical analyses

Proximate nutrients of the feeds and feces were analyzed 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 (Contron 942, Italy). Data were analyzed using the General Linear Model (GLM) Procedure of SAS (1985). The statistical model was that appropriate for a randomized complete block design.

RESULTS AND DISCUSSION

Growth performance

Growth performance of pigs fed different levels of dietary vitamin and trace minerals is presented in tables 2 and 3. Increasing dietary VTM premixes in growing pigs had linear and quadratic effects ($p<0.05$) on ADG (table 2). Feed conversion ratio was also improved ($p<0.05$) as the VTM premix was increased by 150-250% of NRC (1998) requirements. However, feed intake was not affected by dietary treatments.

The trend was confirmed in exp. 2 (table 3). Adding VTM premixes at 150% NRC (1998) over the

Table 2. Growth performance as affected by dietary vitamin and mineral levels in growing pigs

	% of NRC (1998) 100	150	200	250	SE
Initial wt(kg)	24.75	24.83	24.78	24.90	3.22
Final wt(kg)	57.09	59.37	59.63	59.50	4.26
ADG(g)[1]	660[b]	705[a]	711[a]	706[a]	32.16
ADFI(g)	1,765	1,799	1,835	1,794	118.55
F/G	2.67[a]	2.55[b]	2.58[ab]	2.54[b]	0.11

[1] Linear and quadratic effect ($p<0.05$).

[a,b,c] Values on the same line without a common superscript differ ($p<0.05$).

Table 3. Growth performance as affected by dietary vitamin and mineral levels in growing pigs

	% of NRC (1998)				SE
Vitamin	100	100	150	150	
Mineral	100	150	100	150	
Initial BW(kg)	22.11	21.42	22.24	21.10	1.41
Final BW(kg)	48.36	48.32	49.16	49.66	2.33
ADG(g)	656[a]	672[ab]	673[ab]	714[b]	28.90
ADFI(g)	1,755	1,742	1,655	1,716	57.81
F/G	2.68[a]	2.59[ab]	2.46[ab]	2.40[b]	0.14

[a,b] Values on the same line without a common superscript differ ($p<0.05$).

Table 4. Calculated values of vitamins and trace minerals in experimental diets[1]

Item	NRC requirement (1998)	Calculated value			%[3]	Source
		Ingredient[2]	Premix	Total		
Vitamins						
A (IU)	1300.00	1.58	1300.00	1301.58	100.12	Vitamin A acetate
D3 (IU)	150.00	0.00	150.00	150.00	100.00	Vitamin D_3
E (IU)	11.00	0.01	11.00	11.01	100.08	Dl-α-tocopheryl acetate
K3 (mg)	0.50	0.00	0.50	0.50	100.00	Menadione sodium bisulfate
Biotin (mg)	0.05	0.12	0.05	0.17	336.05	D-biotin
Choline (g)	0.30	1.22	0.30	1.52	506.16	Choline chloride
Folacin (mg)	0.30	0.49	0.30	0.79	264.75	Folic acid
Niacin (mg)	10.00	26.60	10.00	36.60	366.01	Nicotinic acid
Pantothenate (mg)	8.00	8.65	8.00	16.65	208.18	Calcium D-pantothenate
Riboflavin (mg)	2.50	1.62	2.50	4.12	164.70	Riboflavin
Thiamin (mg)	1.00	3.63	1.00	4.63	462.54	Thiamine mononitrate
Vitamin B6 (mg)	1.00	4.85	1.00	5.85	584.72	Pyridoxone hydrochloride
Vitamin B12 (μg)	10.00	0.00	10.00	10.00	100.00	Cyanocobalamin
Trace minerals						
Copper (mg)	4.00	7.85	4.00	11.85	296.35	$CuSO_4 \cdot 5H_2O$
Iodine (mg)	0.14	0.00	0.14	0.14	100.00	$Ca(IO_3)_2$
Iron (mg)	60.00	76.09	60.00	136.09	226.82	$FeSO_4 \cdot H_2O$
Manganese (mg)	2.00	14.32	2.00	16.32	816.24	$MnSO_4 \cdot H_2O$
Selenium (mg)	0.15	0.15	0.15	0.30	200.00	Na_2SeO_3
Zinc (mg)	60.00	27.39	60.00	87.39	145.65	$ZnSO_4 \cdot H_2O$

[1] Control (100% of NRC) diet.

[2] The amounts in ingredients except animal fat were calculated by NRC (1998).

[3] Relative % to NRC (1998) requirement.

control improved ($p<0.05$) ADG and feed efficiency in growing pigs. We conducted exp. 2 in order to evaluate which premix (vitamins vs trace minerals) was more effective for growth performance of growing pigs. Neither vitamin nor trace mineral premix in the diet at the addition level of 150% of NRC (1998) improved ($p>0.15$) ADG or feed efficiency of pigs as compared to control (100% of NRC), even though there was a trend toward improving the production traits. It is concluded that vitamins and trace minerals work together for improving ADG and feed efficiency of pigs at the addition level of 150% of NRC (1998) requirement.

The improvements in growth rate with increasing vitamins in the diet depend probably on the inclusion level and feeding duration in the pig. Iowa State workers observed a trend toward improved 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 (1988) (Stahly et al., 1997). These addition levels of the vitamins are higher than those in the present study to optimize the growth performance of growing pigs.

Contrary to the results of Stahly et al. (1995, 1997), Patience and Gillis (1995, 1996) and 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, thus reducing both nutrient excesses that increased the cost of feeding and nutrients excreted in waste material. Pigs are able to store some vitamins (i.e., vitamin A) in the liver, which makes the vitamin available during periods of low intake (NRC, 1998). However, extended feeding (12 weeks before market) of diets deleting VTM premixes tended to reduce growth performance and lowered the nutritional quality (vitamin content) of pork (Edmond and Arentson, 1999). Data obtained in this study agreed with those of Edmond and Arentson (1999) in terms of growth performance.

With the calculated vitamins and trace minerals in the ingredients used in the present study, most water soluble vitamins except vitamins B_2 and B_{12} in the ingredients were enough to meet the NRC (1998) requirement, whereas fat soluble vitamins were not. Trace minerals were also enough to meet the requirements, except iodine and zinc (table 5).

Although the total amounts of vitamins and trace minerals in the feed ingredients used in the present study appear to meet the requirements of growing pigs, additional vitamins and minerals are needed due to their low availability in the plant source of feedstuffs. For an example in minerals, the copper of plant source feed ingredients is only about 50% as available as that in animal source feeds (Baker and Ammerman, 1995). Vitamin availability is also 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). Data concerning the availabilities of vitamins and trace minerals in plant feedstuffs are very limited.

Nutrient digestibility

Nutrient digestibility in pigs fed different levels of dietary vitamin and trace minerals is presented in table 5. There were no differences ($p>0.15$) in the digestibilities of energy, crude protein and fat among dietary treatments. However, increasing dietary VTM premix in growing pigs had a linear effect ($p<0.05$) on the digestibilities of calcium and phosphorus. The 200 or 250% fed group showed improved ($p<0.05$) calcium digestibility, and 250% groups also showed improved ($p<0.05$) phosphorus digestibility as compared to 100% or 150% fed group.

It is also clear that additional feeding of vitamins and trace minerals improved ($p<0.05$) calcium and phosphorus digestibilities in growing pigs in experiment 2 (table 6). But it is unclear, and not easy to explain the causes for improvements in calcium and phosphorus digestibilities in pigs when dietary vitamins and trace minerals were increased. One of the possible explanations would be interactions among nutrients. It is well known that vitamin D and some trace minerals are related to the metabolisms of Ca and P in the manner of interaction or antagonism. Vitamin D is a companion nutrient to Ca and P. Active vitamin D_3 stimulates Ca absoption (Peo, 1991) and improves phosphorus digestibility (Soares, 1995). Soares (1995) reported that adding 5 to 10 μg of dihydroxy-cholecalciferol to a vitamin D-adequate diet increased phytate phosphorus bioavailability by 50%.

Sulfur (primarily SO_4 salt) is an antagonistic to Ca, and Mn, Cu, Fe and Zn are antagonistics to P (Peo, 1991). In exp. 2, the digestibilities of Ca and P were higher ($p<0.05$) in 150% addition of vitamins than in 150% addition of trace minerals in the diet. It seems that additional vitamins are more effective to improve Ca and P digestibilities than trace minerals.

Table 5. Nutrient digestibilities as affected by the addition levels of vitamin and mineral mixtures in growing pigs

	% of NRC (1998)				SE
	100	150	200	250	
Dry matter	73.94	73.95	74.01	74.10	0.22
Gross energy	72.90	71.80	72.27	71.89	0.46
Crude protein	69.33	68.92	68.56	67.97	0.71
Crude fat	67.11	67.95	67.57	70.14	2.00
Ca[1]	62.51[c]	69.68[b]	84.46[a]	84.05[a]	9.86
P[1]	60.76[b]	61.71[b]	61.99[b]	69.57[a]	4.58

[1] Linear effect ($p<0.05$).
[a,b,c] Values on the same line without a common superscript differ ($p<0.05$).

Table 6. Nutrient digestibilities as affected by the addition levels of vitamin and mineral mixtures in growing pigs

	% of NRC (1998)				SE
Vitamin	100	100	150	150	
Mineral	100	150	100	150	
Dry matter	73.50[a]	73.64[a]	73.01[b]	73.06[b]	0.33
Gross energy	72.97	71.57	71.80	72.02	0.80
Crude protein	74.36	73.83	78.71	75.70	5.52
Crude fat	45.50	47.50	46.02	43.12	3.39
Ca	57.03[c]	62.28[bc]	71.72[a]	68.41[ab]	7.91
P	56.24[b]	60.96[b]	71.69[a]	72.63[a]	8.25

[a,b,c] Values on the same line without a common superscript differ ($p<0.05$).

IMPLICATIONS

Increasing dietary vitamins and trace minerals for growing pigs at rates of 150-200% of NRC (1998) improved their daily gain, feed efficiency and digestibilities of calcium and phosphorus as compared to 100% of NRC (1998). Further study is needed to determine the optimal inclusion level of each vitamin or trace mineral for modern genotype growing pigs.

REFERENCES

AOAC. 1990. Official Methods of Analysis (15th ed). Association of Official Analytical Chemists. Arlington, VA.

Anonymous. 1999. Optimum vitamin nutrition in feed focus. A bulletin of Roche Vitamins and Fine Chemicals. p. 1.

Baker, D. H. 1995. Vitamin bioavailability. In: Bioavailability of Nutrients for Animals- amino acids, minerals and vitamins (Ed. C. B. Ammerman, D. H. Baker and A. J. Lewis). Academic Press Inc. Sandiego, CA. pp. 399-431.

Baker, D. H. and C. L. Ammerman. 1995. Copper bioavailability. In: Bioavailability of Nutrients for Animals- amino acids, minerals and vitamins (Ed. C. B. Ammerman, D. H. Baker and A. J. Lewis). Academic Press Inc. Sandiego, CA. pp. 127-156.

Cunha, T. J. 1977. Swine Feeding and Nutrition. Academic Press, Inc. New York, NY.

Edmond, M. S. and B. E. Arentson. 1999. Effect of supplemental vitamins and trace minerals on performance and carcass quality in finishing pigs. J. Anim. Sci. 77 (Suppl. 1):129.

Mavromichalis, I., J. D. Hancock, I. H. Kim, B. W. Senne, D. H. Kropf, G. A. Kennedy, R. H. Hines and K. C. Behnke. 1999. Effects of omitting vitamin and trace mineral premixes and(or) reducing inorganic phosphorus additions on growth performance, carcass characteristics and muscle quality in finishing pigs. J. Anim. Sci. 77:2700-2708.

NRC. 1988. Nutrient Requirements of Swine (9th Ed.). National Academy Press, Washington, DC.

NRC. 1998. Nutrient Requirements of Swine (10th Ed.). National Academy Press, Washington, DC.

Patience, J. F. and D. Gillis. 1995. Removal of vitamins and trace minerals from finishing diets. Annu. Res. Rep. Prairie Swine Centre, Inc. Saskatchewan, Canada. pp. 29-31.

Patience, J. F. and D. Gillis. 1996. Impact of pre-slaughter withdrawal of vitamin supplements. Annu. Res. Rep. Prairie Swine Centre, Inc. Saskatchewan, Canada. pp. 29-32.

Patience, J. F., P. A. Thacker and C. F. M. de Lange. 1995. Swine nutrition guide. Prairie Swine Centre Inc. Saskatchewan, Canada.

Peo, Jr. E. R. 1991. Calcium, phosphorus and vitamin D in swine nutrition. In: Swine Nutrition (Ed. E. R. Miller, D. E. Ullrey and A. J. Lewis). Butterworth-Heinemann. Stoneham, MA. pp. 165-192.

SAS. 1985. SAS. User's Guide : Statistics, SAS Inst. Inc. Cary, NC.

Soares, J. H. 1995. Phosphorus bioavailability. In: Bioavailability of Nutrients for Animals- amino acids, minerals and vitamins (Ed. C. B. Ammerman, D. H. Baker and A. J. Lewis). Academic Press Inc. Sandiego, CA. pp. 257-294.

Stahly, T. S., D. R. Cook and R. C. Ewan. 1997. Dietary vitamin A, E, C needs of pigs experiencing a low or high level of antigen exposure. J. Anim. Sci. 75(Suppl. 1):194(Abstr.).

Stahly, T. S., N. H. Williams, S. G. Swenson and R. C. Ewan. 1995. Dietary B vitamin needs of high and moderate lean growth pigs fed from 9 to 28 kg body weight. J. Anim. Sci. 73(Suppl. 1):193.

Wilson, M. E., M. D. Tokach, R. W. Walker, J. L. Nelssen, R. D. Goodband and J. E. Pettigrew. 1993. Influence of high levels of individual B vitamins on starter pig performance. J. Anim. Sci. 71(Suppl. 1):56 (Abstr.).