Impacts of Dietary Vitamins and Trace Minerals on Growth and Pork Quality in Finishing Pigs**

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ABSTRACT : Two feeding trials were conducted to determine the effect of inclusion levels or deletion of vitamin-trace mineral (VM) premixes on growth performance and pork quality in finishing pigs. In exp. 1, a total of ninety-six crossbred pigs (Landrace × Yorkshire × Duroc, 85.09±3.12 kg) were used for a 4-week feeding trial. Treatments were premix supplementation at the level of 50% (Control), 100%, 150%, and 200% of NRC (1998) requirements for vitamins and trace minerals. In exp. 2, a total of one hundred and eight crossbred pigs (Landrace × Yorkshire × Duroc, 84.76±0.58 kg) were used for a 4-week feeding trial. Treatments were premix supplementation at the level of 0% (Control), 200% VM, and 200% vitamin E and Se listed in NRC (1998) requirements. Average daily gain (ADG) and feed/gain (F/G) were the highest at 150% VM addition level (quadratic, $p<0.05$) among treatments. Dressing percentage and backfat thickness in pigs were not affected by different addition levels of VM premixes. Pork stability in terms of TBARS was linearly ($p<0.05$) improved as dietary VM premix was increased (exp. 1). ADG, F/G and pork stability (TBARS) were also reduced ($p<0.05$) when VM premixes were deleted. However, supplementation of vitamin E and Se improved ($p<0.05$) ADG and pork stability when pigs were fed diets without VM premixes (exp. 2). In conclusion, deleting dietary VM premixes gave negative effects on growth performance and pork quality for the last 4 weeks of finishing period. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 10 : 1444-1449)***

Key Words : Vitamin-mineral Premix, Growth, Pork Quality, Finishing Pig

INTRODUCTION

Mostly, diets are formulated to meet or exceed the estimated requirements for specific nutrients at all stages of the pig life cycle (McGlone, 2000). Among nutrients, vitamins and trace minerals are very important in various metabolisms in animals including pigs. Furthermore, supplementation levels of these nutrients are always higher than their requirements in practical conditions (Tian et al., 2001), because most pigs are now raised on confinement, without access to soil and forage; this rearing environment may increase the need for vitamins and minerals (NRC, 1998). Some researchers reported that vitamins listed in NRC (1988) are inadequate for maximal performance of pigs (Wilson et al., 1993; Stahly et al., 1995; Stahly et al., 1997).

In contrast, there are several researches (Mavromichalis et al., 1999; McGlone, 2000), demonstrating no adverse effect on growth performance and carcass characteristics of pigs when vitamin and (or) trace mineral premixes were omitted during the last 3 to 6 weeks before marketing. Mavromichalis et al. (1999) reported that removing vitamin and trace mineral premixes from diets during late finishing period had no effect on rate and efficiency of growth and pork quality in terms of color, marbling and firmness, while Edmond and Arentson (2001) demonstrated that deleting vitamins and trace minerals during the finishing period markedly lowered the nutritional quality (vitamin content) of pork. Our previous study (Chae et al., 2000) also demonstrated that additional levels of vitamins and trace minerals over NRC (1998) requirements improved the growth performance and pork stability in finishing pigs.

Deleting vitamin-mineral premixes in finishing pig diets can impair pork stability during storage, even though it may reduce diet cost and pollution problems from manure. It is also well known that vitamin E (Davies, 1988; Asghar et al., 1991; Jensen et al., 1997) and selenium (Halliwell and Gutteridge, 1986; Hsieh and Kinsella, 1989; Mahan and Kim, 1999) have antioxidant effects in the body and animal products. Increasing vitamin E in diets increased the vitamin and reduced thiobarbituric acid substance values in tissues of finishing pigs (Asghar et al., 1991; Jensen et al., 1997).

Therefore, this study was conducted to determine the impacts of dietary vitamin and mineral premixes on growth and pork quality in finishing pigs. Additional efforts were made to study the effects of supplementation of vitamin E and selenium on pork quality in finishing pigs fed a vitamin-mineral premix deleted diet.

MATERIALS AND METHODS

Experimental design, animals and feeding

Two feeding trials were conducted to determine the effects of feeding different inclusion levels of vitamin-

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mineral (VM) premixes, and supplementation of vitamin E and selenium in a VM deleted diet on growth performance and pork stability in finishing pigs.

In exp. 1, a total of ninety-six crossbred pigs (Landrace × Yorkshire × Duroc, 85.09±3.12 kg) were alloted for a 4-week feeding trial. Treatments were premix supplementation at the level of 50% (Control), 100%, 150%, and 200% of NRC (1998) requirements for vitamins and trace minerals.

In exp. 2, a total of one hundred and eight crossbred pigs (Landrace × Yorkshire × Duroc, 84.76±0.58 kg) were used for a 4-week feeding trial. Treatments were premix supplementation at the level of 0% VM (Control), 200% VM (T1), and 200% vitamin E (T2, 22 IU/kg as α-tocopherol) and Se (0.3 mg/kg as sodium selenite) listed in NRC (1998) requirements.

Experimental diets for feeding trials were formulated to contain 3,197 and 3,265 kcal ME/kg, and 0.89 and 0.75% total lysine for exp. 1 and 2, respectively (table 1). All pigs were alloted on the basis of sex and weight for four treatments in a randomized complete block design. The pigs were housed in 4.0 m×2.8 m pens with partially slotted floors. Feed and water were offered at in *ad libitum* consumption.

Blood samples were collected from four pigs per treatment on d 0 and 14 in exp. 1. Pigs were bled via venipuncture from the jugular vein, and blood samples were obtained into tubes treated with heparin as an anticoagulant.

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

At the end of the experiment, twelve barrows (three/treatment), average body weight of 108.39±3.20 kg were sacrificed in exp. 1, and twelve barrows (four/treatment), average body weight 101.83±2.30 kg, were also sacrificed to evaluate carcass characteristics in exp. 2. Dressing percentage and backfat thickness (last rib) were measured with carcasses. Pork samples (*M. longgissimus dorsi*) from the carcasses were also taken and separately sealed with polyethylene film and stored in a refrigerator at 1°C for the analyses of thiobarbituric acid reactive substance (TBARS) and peroxide values (POV). TBARS and POV were measured four times after slaghter by weekly basis in exp. 1, and TBARS was measured on d 0, 5 and 10 after slaughter in exp. 2.

Table 1. Formula and chemical compositions of basal diets

	Experiment	
	1	2
Ingredients (%)[1]		
Corn	76.05	42.84
Wheat	-	25.00
SBM (44%)	19.92	18.00
Rice bran	-	5.00
Molasses	-	4.00
Animal fat	1.67	3.00
Limestone	-	1.10
TCP	1.91	0.75
Salt	0.25	0.30
DL-Met. (50%)	0.01	-
L-Lys-HCl (78%)	0.19	0.01
Total	100.00	100.00
Chemical composition (%)		
ME (kcal/kg)	3,197	3,265
CP	15.00	15.00
Lys	0.89	0.75
Ca	0.80	0.70
Av. P	0.32	0.25

[1] Vitamin-trace mineral premixes based on NRC (1998) were additionally supplemented according to the experimental design.

Chemical and statistical analyses

Proximate anlayses of the feeds and feces were analyzed according to the methods of AOAC (1990) and gross energy was measured with an adiabetic bomb calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Chromium in feeds and feces was measured with a spectrophotometer (Contron 942, Italy). The concentrations of vitamin E in muscle (*M. longgissimus dorsi*) and serum were analyzed with HPLC (Waters, Model 486). Vitamin E was analyzed by the method of Miller et al. (1984). Blood samples were centrifuged (Rotina 48R, Hettich, Germany) at 3,000 rpm for 3 minutes, and serum was carefully removed into plastic vials and then stored at -20°C for the analysis of α-tocopherol. Trace minerals in bone (ribs) were analyzed with atomic absorption spectrophotometer (Hitachi 6000, Jn).

Pork color was measured with the color difference meter (Yasuda Seiko Co., CR 310, Minolta, Jn), and drip loss was measured by the procedure of Kim et al. (1997).

Thiobarbituric acid reactive substance (TBARS) as concentration (mg) of malonaldehyde (MDA)/kg, was determined by the method of Sinnhuber and Yu (1977) and peroxide values (POV) was measured by Shantha and Decker (1994) in the pork samples.

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

Growth performance and nutrient digestibility

Growth performance and nutrient digestibility in pigs fed experimental diets were presented in tables 2 and 3.

Table 2. Growth and nutrient digestibility of pigs in exp. 1

	Vitamin-trace mineral premix (% NRC, 1998)				SE
	50	100	150	200	
Growth performance					
ADG (g)[1]	679[b]	769[ab]	833[a]	788[ab]	68.92
ADFI (g)	2,249	2,324	2,276	2,348	160.88
FCR[2]	3.32[b]	3.03[ab]	2.73[a]	2.98[ab]	0.32
Nutrient digestibility (%)					
DM	74.96	75.78	75.57	76.90	2.24
CP	72.02	72.20	71.16	71.73	0.75
GE	74.54	74.89	75.01	74.10	1.09
EE	69.74	70.56	70.19	72.71	1.96
Ca	49.36	52.97	53.76	51.12	6.27
P	50.21	47.56	49.24	51.86	5.84

[a,b] Within a row, means without a common superscript letter differ ($p<0.05$).
[1] Linear and quadratic effect ($p<0.05$). [2] Linear ($p<0.05$).

As dietary VM premix was increased in finishing pigs, average daily gain (ADG) and feed/gain showed a quadratic response ($p<0.05$; table 2). Adding 150% VM of NRC (1998) resulted in improvement ($p<0.05$) of ADG compared to 50% of VM treatment. There was no difference ($p>0.05$) in daily feed intake among dietary treatments. Nutrient digestibility including dry matter, protein, energy, fat, calcium and phosphorus in experimental diets was not affected by feeding different dietary vitamin and trace mineral levels.

Pigs fed diets containing 200% of VM (T1) premix listed in NRC (1998) grew faster ($p<0.05$) than those fed diets without VM premix (Control) in finisher diets. However, there was no difference in ADG of pigs between T1 and 200% vitamin E and Se supplemented group (T2). A similar trend was found in feed conversion ratio, while no differences were found in feed intake and nutrient digestibility among dietary treatments as shown in table 3.

Carcass and pork quality

Carcass and pork traits as affected by dietary vitamins and trace minerals were presented in tables 4, 5 and 6.

In exp. 1, back fat thickness and dressing percentage were not affected ($p>0.05$) by dietary VM levels in finishing pigs. There were also no differences ($p>0.05$) in vitamin E levels in muscle and serum, but there was a trend towards increasing vitamin E levels as dietary VM levels were increased. Minerals such as Fe, Zn and Cu in bone were not different ($p>0.05$), but calcium content was increased ($p<0.05$) in 200% VM group over 50% VM group.

In exp. 2, dressing percentage and backfat thickness were not affected ($p>0.05$) by dietary treatments, and vitamin E content in muscle was increased by feeding 200% of NRC (1998) requirements, even though it was not significant. Drip loss showed higher ($p<0.05$) in pork from pigs fed VM deleted diets than in porks from pigs fed T1 or T2 diets, which were containing vitamin E and selenium.

Table 3. Growth and nutrient digestibility of pigs in exp. 2

	No vit-trace min.	200% of NRC (1998) Vit-trace min.	200% of NRC (1998) Vit. E + Se	SE
Growth performance				
ADG (g)	793[b]	840[a]	825[a]	38.52
ADFI (g)	2,935	2,838	2,969	98.93
F/G	3.70[a]	3.38[b]	3.60[b]	0.24
Nutrient digestibility (%)				
DM	83.24	82.33	83.42	0.52
CP	82.62	82.69	81.72	1.10
GE	83.39	83.42	82.80	0.42
EE	70.95	70.33	65.02	4.32
Ca	56.49	57.16	51.72	5.52
P	49.37	46.31	44.08	4.27

[a,b] Within a row, means without a common superscript letter differ ($p<0.05$).

During the storage of pork, color of the muscle was not affected ($p>0.05$) by dietary treatments.

The TBARS and POV values of pork were linearly ($p<0.05$) lowered as dietary VM levels were increased when tissues were stored at 1°C for 4 weeks in exp. 1. Also, TBARS in pork from pigs fed VM premix deleted diets, analyzed on d 5 and 10 after slaughter, showed higher ($p<0.05$) than pork from those fed diets containing VM premix, or vitamin E and selenium. However, there was no difference ($p>0.05$) in TBARS between T1 and T2.

DISCUSSION

In general, production traits in terms of ADG and feed

Table 4. Carcass traits, vitamin E concentrations in muscle and bone mineral contents in finishing pigs (exp. 1)

	Vitamin-trace mineral premix (% NRC, 1998)				SE
	50	100	150	200	
Carcass characteristics					
Backfat thick (mm)	30.54	30.29	30.49	31.98	0.50
Dressing percentage	68.71	68.87	69.03	68.37	3.25
Vitamin E					
Muscle (μg/g)	0.22	0.26	0.26	0.27	0.08
Serum (μg /ml)					
d 0	2.27	2.29	2.26	2.31	0.43
d 14	2.12	2.24	2.37	2.62	0.69
Bone mineral (DM)					
Ca (%)	14.04[b]	16.60[a]	15.95[ab]	18.31[a]	2.21
P (%)	8.09	8.10	8.20	8.42	0.41
Fe (mg/kg)	63.50	68.67	63.67	65.00	6.26
Zn (mg/kg)	114.50	112.3	116.50	118.00	16.40
Cu (mg/kg)	3.17	3.67	3.50	3.57	0.80

[a,b] Within a row, means without a common superscript letter differ ($p<0.05$).

Table 5. Effects of dietary vitamin-trace mineral levels on pork stability in finishing pigs[1]

	Vitamin-trace mineral premix (% NRC, 1998)				SE
	50	100	150	200	
TBARS (wk, mg/kg)					
1[2]	4.87[b]	4.44[b]	3.31[a]	2.72[a]	1.32
2[3]	5.90[c]	4.38[b]	3.78[a]	3.85[a]	1.11
3[2]	8.68[c]	6.71[b]	5.94[ab]	4.21[a]	1.86
4[2]	12.11[d]	10.64[c]	8.34[b]	6.71[a]	2.32
POV (wk, meq/kg)					
1[2]	0.049[b]	0.039[a]	0.038[a]	0.037[a]	0.006
2[2]	0.071[b]	0.064[b]	0.067[b]	0.048[a]	0.011
3	0.094[c]	0.079[b]	0.074[b]	0.065[a]	0.012
4	0.119[b]	0.113[b]	0.092[a]	0.089[a]	0.017

[1] The 1st analysis of TBARS and POV was the 2nd d after slaughter, followed by weekly basis.
[2] Linear ($p<0.05$).
[3] Linear and quadratic ($p<0.05$).
[a,b,c] Within a row, means without a common superscript letter differ ($p<0.05$).

Table 6. Carcass traits, and vitamin E concentration and drip loss in muscle in finishing pigs (exp. 2)

	No vit-trace min.	200% of NRC (1998) Vit-trace min.	Vit. E+ Se	SE
Carcass				
Dressing percentage	76.96	76.49	77.19	2.38
Backfat thickness (mm)	22.85	21.28	23.89	4.51
Muscle measurement				
Muscle vitamin E (μg/g)	0.18	0.26	0.22	0.08
Drip loss (%, d 5)	9.02[a]	6.35[b]	5.77[b]	1.74
TBARS (mg/kg)				
d 0	1.93	1.67	1.58	0.39
5	3.17[a]	1.84[b]	1.89[b]	0.81
10	4.06[a]	2.52[b]	2.34[b]	0.93
Color				
L^* d 0	63.35	60.62	62.59	2.68
5	57.07	56.00	60.54	3.53
10	56.17	54.81	56.09	2.13
a^*				
d 0	7.11	7.09	6.80	1.47
5	6.36	6.58	7.02	0.81
10	6.59	6.20	6.60	0.76
b^*				
d 0	12.72	11.99	12.99	1.83
5	7.64	7.84	8.96	1.24
10	7.38	7.18	7.57	1.01

[a,b] Within a row, means without a common superscript letter differ ($p<0.05$).

efficiency were lowered by reducing or deleting dietary VM premix during the finishing period. This result is not in agreement with several recent studies (Mavromichalis et al., 1999; McGlone, 2000; Edmonds and Arentson, 2001). They reported that deletion of VM premix for the last 3-6 weeks of finishing period had no effects on pig performance. However, our result is in agreement with the results of Stahly et al. (1995, 1997), who demonstrated that additional feeding of B-vitamins or vitamins A, E and C over NRC (1988) requirement improved ADG of growing pigs. Our previous study (Chae et al., 2000) also showed the increment of weight gain by supplementation of 150-250% VM listed in NRC (1998) requirement in finishing pigs.

One of the possible reasons for the differences between our results and others in growth performance of finishing pigs fed vitamin and (or) mineral premix deleted diets is experimental environments. We conducted these studies under practical condition (commercial farm), where environmental stresses were higher than university farm condition. Even though McGlone (2000) reported that pig performance was not affected by deleting dietary VM premix in the finishing period in a field trial, there are many stress factors which increase the requirements of these micronutrients in commercial farms. These include temperature of the farm, stock density, degree of contamination in swine farm (Cunha, 1997; Stahley et al., 1997).

Digestibilities of nutrients were not affected by increasing (exp. 1) or deleting (exp. 2) dietary VM premix in finisher diets. In the exp. 1, however, there was a trend to improve Ca digestibility as dietary VM premix was increased. This is partially in agreement with the results of our previous study (Chae et al., 2000) and Tian et al. (2001). They reported improved Ca digestibility due possibly to their interactions with vitamin D in the premix.

In contrast, there were no differences in dressing percentage and backfat thickness, which is in agreement with the reports of Mavromichalis et al. (1999) and Chae et al. (2000). The bone mineral contents including P, Fe, Zn and Cu were not affected by feeding different levels of VM premix, but Ca content in bone was significantly increased in 200% compared to 50% of NRC (1998) viatmain and trace mineral requirements. This may be related to improved Ca digestibility, and implies that some vitamins and (or) minerals (i. e., vitamin D) are able to affect bone mineralization, in that they have metabolic interactions, as explained by Peo (1991) and Soares (1995).

As dietary VM premix was increased, there was a trend towards increasing vitamin E content in muscle, which is directly related to pork stability. This result is well agreed with the report of Edmonds and Arentson (2001). They reported that deleting VM premix during the finishing stage markedly lowered the vitamin E content of pork muscle. The concentrations of vitamin E in serum in exp. 1 were similar in pigs at the beginning of the present study. However, vitamin E content in serum tended to increase on d 14 as dietary VM premix level was increased, although it

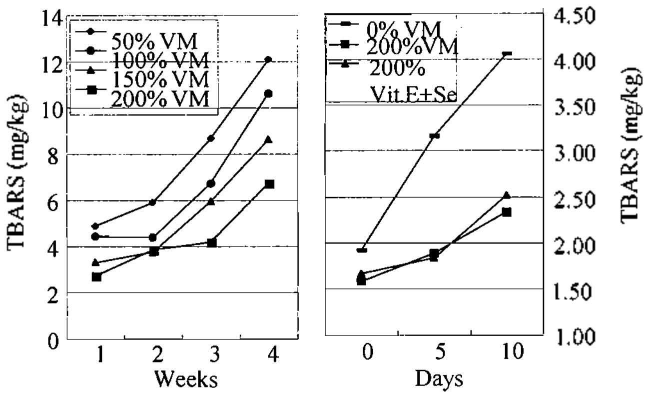

Figure 1. Thiobarbituric acid reactive substances (TBARS) of pork samples as affected by dietary vitamin-trace minerals (percentage of NRC (1998) requirements)

was not significantly different.

Pork stability in terms of TBARS and POV was decreased in pigs fed diets with reduced or deleted VM premixes as storage time passed (tables 5 and 6, and fig. 1). In exp. 2, growth performance and pork stability were improved when pigs were fed diets supplemented with adequate levels of vitamin E and Se compared to VM premix deleted diets in the finishing period. There were no differences in ADG, feed conversion ratio, and changes in TBARS value during storage between pigs fed diets containing 200% of all vitamins and trace minerals, and 200% of vitamin E and Se listed in NRC (1998) requirements. Jensen et al. (1997) reported that increase in dietary vitamin E from 100 to 700 mg/kg (50-90 kg pigs) linearly increased vitamin E level in the tissue, thus improving pork stability (TBARS).

The antioxidant defensive system may be weakened when retinol, vitamin C, E, and carotenoids are deficient in the diet. However, vitamin E is the primary lipid-soluble antioxidant in biological systems and breaks the chain of lipid peroxidation in cell membranes and prevents the formation of lipidhydroperoxides (Davies, 1988). Cheah et al. (1994) reported that improvement in pork quality by vitamin E is due to the ability of vitamin E to stabilize membranes as demonstrated with erythrocyte fragility.

Selenium is also an antioxidant in living organisms. But transition metal complexes such as iron and copper are known to enhance lipid oxidation in meats (Halliwell and Gutteridge, 1989). These metals may play a role in the propagation of lipid oxidation by catalyzing the breakdown of lipid hydroperoxides (Hsieh and Kinsella, 1989).

During storage (up to 10 days) after slaughter, pork color was not changed, but drip loss was higher in pork from pigs fed VM premix deleted diet than in pork from pigs fed VM premix supplemented diet. Mavromichalis et al. (1999) also reported that removing vitamin and trace mineral premixes from diets during late finishing had no effect on pork quality (i.e., color, marbling and firmness).

Presently, the oxidative stability of pork is of particular importance in cases where meat is further processed (Heuten, 1999). Even though pigs are able to store some vitamins and minerals in the body, which makes the nutrients available during periods of low intake (NRC, 1998), it is regarded that pigs need additional vitamins and trace minerals to optimize growth rate and maintain the nutrient levels in pork, which is related to pork stability. Conclusively, supplementation of VM premix (at least vitamin E and Se) would be desirable to improve growth performance, and to improve pork stability during storage as well.

IMPLICATIONS

Reducing or deleting dietary vitamin-trace mineral premix suggested by NRC (1998) gave negative effects on growth performance and pork quality for the last 4 weeks of finishing period. In addition, supplementation of vitamin E and selenium would improve growth performance and pork stability in finishing pigs fed diets without vitamin-trace mineral premixes.

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