Effects of Inclusion Levels of Dietary Vitamins and Trace Minerals on Growth Performance and Pork Stability in Finishing Pigs[a]

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ABSTRACT : A total of one hundred twenty pigs (L×Y×D, 50±0.78 kg) were employed for a 7-week feeding trial to determine the effect of inclusion levels of vitamin and mineral (VTM) premixes on growth performance, nutrient digestibility and pork stability in finishing pigs. Treatments were 100% (Control), 150%, 200%, and 250% of NRC (1998) requirements. Increasing dietary VTM premixes in finishing pigs had a linear ($p<0.05$) effect on ADG. It also had a linear effect ($p<0.05$) on the digestibility of calcium and a linear and quadratic effect ($p<0.05$) on the digestibility of phosphorus. As dietary VTM levels were increased from 100 to 250% NRC (1998), TBARS values of pork samples were linearly ($p<0.05$) lowered when stored at 1℃ for 2 or 3 weeks. There was also a trend reducing POV of pig meat as dietary VTM level was increased. In conclusion, it would appear that inclusion of VTM premixes at the level of 200-250% of NRC (1998) requirements gave positive effects on growth performance and pork stability in finishing pigs. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1445-1449*)

Key Words : Vitamin and Mineral Premix, Growth, Pork Stability

INTRODUCTION

As micronutrients, vitamins and trace minerals are important in various metabolic processes in animals. Most pigs are now raised in confinement, without access to soil and forage; this rearing environment may increase the needs for vitamins and minerals (NRC, 1998).

NRC (1998) published minimum requirements of the nutrients, but some researchers reported that vitamins amounts listed in NRC (1988) are inadequate for maximal performance of growing pigs (Wilson et al., 1993; Stahly et al., 1995; Stahly et al., 1997). Recent reports also demonstrated that additional levels of vitamins and trace minerals improved growth performance of growing (Chae et al., 2000) and finishing pigs (Edmond and Arentson, 1999).

On the other hand, some researchers (Patience and Gillis, 1995, 1996; Mavromichalis et al., 1999) observed 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 5 weeks before market. Mavromichalis et al. (1999) reported that removing vitamin and trace mineral premixes from diets during late finishing had no effect on rate and efficiency of growth and pork quality in terms of color, marbling and firmness. However, Edmond and Arentson (1999) demonstrated that deleting vitamins and trace minerals during the finishing period reduced growth performance and markedly lowered the nutritional quality (vitamin content) of pork.

Around the world, nowadays, pork quality is one of the main issues of concern for the swine industry, and the oxidative stability of the meat is of particular importance in cases where meat is further processed (Heugten, 1999). Of vitamins, E has an antioxidant effect (Davies, 1988). 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).

Although vitamins and trace minerals supplied by a corn-soybean meal based diet can support optimum performance of pigs during late finishing (Mavromichalis et al., 1999), pork stability may be of concern during storage. Therefore, this experiment was designed to determine the effects of dietary vitamins and trace minerals on pork stability as well as growth performance in finishing pigs.

MATERIALS AND METHODS

Animals and feeding

A total of one hundred twenty pigs (L×Y×D, average initial body weight of 50±0.78 kg) were employed for a 7-week feeding trial to determine the effect of inclusion levels of vitamin and mineral (VTM) premixes on growth performance, nutrient digestibility and pork stability in finishing pigs. VTM premixes were separately made to meet the NRC (1998) requirements at the inclusion level of 0.1% in the diet. Treatments were 100% (Control), 150%,

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200%, and 250% of NRC (1998) requirements.

Experimental diets for feeding trials were formulated to contain 3,197 kcal ME/kg and 16% crude protein (table 1). All pigs were alloted on the basis of sex and weight to four treatments in a completely randomized block design. 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. At the end of the experiment, twelve barrows (three/treatment), average body weight of 88.3 ±1.53 kg, were sacrificed to evaluate carcass characteristics. Also, pork samples (M. *trapezius cevicalis*) from the carcasses were taken and separately sealed with vinyl and stored in a refrigerator at 1℃ for the analyses of thiobarbituric acid reactive substance (TBARS) and peroxide values (POV).

For nutrient digestibility, on the 4th week of the feeding trial, feeds including 0.25% chromic oxide as an indigestible marker were given. 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 an air forced drying oven at 60℃ for 72 hours for chemical analysis.

Table 1. Fomula and chemical composition of experimental diets for feeding trial

Item	% of NRC (1998)			
	100	150	200	250
Ingredient (%)				
Corn[1]	72.95	72.90	72.85	72.80
SBM (44%)	21.49	21.49	21.49	21.49
Fat, animal	2.33	2.33	2.33	2.33
Fish meal	0.88	0.88	0.88	0.88
TCP	1.77	1.77	1.77	1.77
Salt	0.20	0.20	0.20	0.20
DL-Met (50%)	0.01	0.01	0.01	0.01
L-Lys-HCl	0.17	0.17	0.17	0.17
Vit. mix[2]	0.10	0.15	0.20	0.25
Trace min. mix[2]	0.10	0.15	0.20	0.25
CTC	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated composition (%)				
Crude protein	16.0	16.0	16.0	16.0
Lysine	0.95	0.95	0.95	0.95
Methionine	0.29	0.29	0.29	0.29
Threonine	0.66	0.66	0.66	0.66
Tryptophan	0.21	0.21	0.21	0.21
ME, kcal/kg	3,197	3,197	3,197	3,197
Ca	0.80	0.80	0.80	0.80
P	0.68	0.68	0.68	0.68

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

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

Chemical and statistical analyses

Proximate anlayses of the feeds and feces were make 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).

Thiobarbituric acid reactive substance (TBARS) as mg of malonaldehyde (MDA)/kg was determined by the method of Sinnhubber and Yu (1977) and peroxide values (POV) by Shantha and Decker (1994) in the pork samples. These values were analyzed weekly during the four weeks after slaughter.

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 and nutrient digestibility

Growth performances of pigs fed different levels of dietary vitamin and trace minerals are presented in table 2. Increasing dietary VTM premix in finishing pigs had a linear ($p<0.05$) effect on ADG. Adding 200% VTM of NRC (1998) showed improved ($p<0.05$) ADG as compared to 100-150%. There was a quadratic ($p<0.05$) effect on daily feed intake, with decreased feed intake when 250% VTM of NRC (1998) was added in the diets as compared to other treatments. Feed conversion ratio was better ($p<0.05$) in groups fed 200 and 250% VTM of NRC (1998) than 100 and 150% 200 and 250% VTM of NRC (1998) in the diet.

Generally, it seems that the requirements of vitamins and trace minerals listed by NRC (1998) are too low to optimize growth performance of pigs under too practical conditions. This is 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. Our previous study (Chae et al., 2000) also showed improved weight gain in growing pigs by 150-250% VTM supplementation of NRC (1998) requirement.

However, this result is not in agreement with the results of Patience and Gillis (1995, 1996) and Mavromichalis et al. (1999), who 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. There are two differences (feeding period and growth stage) between this study and Mavromichalis et al. (1999): 50-88 kg vs 86-116 kg of body weight and 49 d vs 30 d of feeding period. Pigs are able to store

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

	% of NRC (1998)				SE
	100	150	200	250	
Growth performance					
Initial weight (kg)	50.20	49.70	50.03	50.15	0.78
Final weight (kg)	87.33	86.94	89.47	88.22	1.57
ADG (g)[1]	758[b]	760[b]	805[a]	777[ab]	25.79
ADFI (g)[2]	2,083[a]	2,075[a]	2,019[a]	1,881[b]	94.42
FCR	2.75[a]	2.73[a]	2.51[b]	2.42[b]	0.17
Carcass characteristics					
Backfat thick (last rib, mm)	21.05	21.85	22.20	20.70	1.07
Dressing percent (%)	72.30	74.90	72.84	73.19	2.49

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

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

[2] Quadratic effect ($p<0.05$).

some vitamins (i.e., vitamin A) in the body, which makes the vitamin available during periods of low intake (NRC, 1998). However, it is suggested that pigs need additional vitamins and trace minerals over NRC (1998) requirements to maintain growth rate for extended period. Edmond and Arentson (1999) reported that deleting VTM premix in the diet for 12 weeks before market tended to reduce growth performance in finishing pigs.

In fact, the total amounts of most B-vitamins and some trace minerals in corn-soybean meal based diets appear to meet the requirements listed by NRC (1998) for growing pigs (Chae et al., 2000), but additional vitamins and trace minerals are needed due to low availability in the plant source of feedstuffs (Baker, 1995; Baker and Ammerman, 1995) and environmental stresses such as disease (Stahley et al., 1997).

Digestibilities of Ca and P, but not energy, crude protein and fat, were affected by feeding different levels of dietary vitamin and trace minerals (table 3). Increasing dietary VTM premix in growing pigs had a linear effect ($p<0.05$) on the digestibility of calcium and a linear and quadratic effect ($p<0.05$) on phosphorus. Calcium digestibility was improved ($p<0.05$) up to 200% VTM of NRC (1998), and phosphorus digestibility was improved at 250% VTM of NRC (1998) requirement as compared to 100% VTM of NRC (1998).

This result is in agreement with our previous study (Chae et al., 2000). Additional feeding of vitamins and trace minerals over NRC (1998) improved ($p<0.05$) calcium and phosphorus digestibilities in growing pigs. 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. As discussed in our previous study, additional vitamin D might improve the utilization of Ca and P in the manner of interaction as explained by Soares (1995) and Peo (1991).

Table 3. Nutrient digestibility as affected by the addition levels of vitamin and mineral mixtures in growing-finishing pigs

	% of NRC (1998)				SE
	100	150	200	250	
Dry matter	74.35	74.35	74.40	74.55	0.11
Gross energy	73.33	72.45	73.01	72.40	0.46
Crude protein	70.02	69.63	69.16	69.73	0.53
Crude fat	67.74	68.56	68.19	70.71	1.96
Ca[1]	64.75[c]	70.33[b]	79.82[a]	80.39[a]	5.21
P[2]	61.64[b]	62.55[b]	62.73[b]	67.02[a]	4.47

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

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

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

Pork stability

Pork stability in terms of TBARS and POV values as affected by supplementation of VTM premix is presented in table 4. In terms of TBARS (mg malonaldehyde/kg sample), data analyzed on the 3rd day after slaughter showed significant differences ($p<0.05$) among treatments, resulting in reduced TBARS in meat from pigs fed 250% VTM as compared to 100 or 200% VTM of NRC (1998) requirements. As dietary VTM levels were increased from 100 to 250% NRC (1998), TBARS values of pork samples were linearly ($p<0.05$) lowered when stored at 1℃ for 2 or 3 weeks.

There was also a trend of reducing POV in pig meat as dietary VTM level was increased. From 1 week after storage at 1℃, POV was significantly ($p<0.05$) higher in pork samples from pigs fed 100% or 150% VTM than those from pigs fed 250% VTM NRC (1998) requirements.

Generally, TBARS or POVs in pork samples

Table 4. Effects of feeding dietary vitamin mineral levels on pork stability in growing pigs[1]

	% NRC (1998)				SE
	100	150	200	250	
TBARS (mg/kg)					
Wk: 0	3.17[a]	2.72[ab]	3.18[a]	2.43[b]	0.43
1	4.38	3.99	3.38	2.79	2.27
2[2]	5.45[a]	3.90[b]	3.02[b]	3.45[b]	1.18
3[2]	7.10[a]	5.06[b]	4.99[b]	4.59[b]	1.20
4	10.35[a]	7.70[b]	8.40[b]	6.97[b]	1.47
SE[2]	2.77	2.30	2.31	1.88	
POV (meq/kg)					
Wk: 0	0.031[ab]	0.032[a]	0.026[c]	0.027[bc]	0.003
1	0.042[a]	0.039[ab]	0.037[b]	0.035[b]	0.003
2	0.070[a]	0.061[b]	0.065[ab]	0.052[c]	0.007
3	0.083[a]	0.787[ab]	0.077[ab]	0.075[b]	0.004
4	0.111[a]	0.102[ab]	0.097[b]	0.092[b]	0.009
SE[2]	0.030	0.027	0.027	0.025	

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

[1] The 1st analysis of TBARS and POV was the 3rd d after slaughter; subsequent analyses were made weekly.

[2] Linear effect ($p<0.05$).

($p<0.01$) increased linearly regardless of the dietary levels of VTM in this study. However, the increments in the pork samples were small as dietary VTM levels were increased from 100% to 250% NRC (1998) requirement. Data are very limited concerning pork stability when pigs are fed different levels, or without, VTM premixes in the diet. Mavromichalis et al. (1999) 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), but they did not determine pork stability during storage. However, Edmond and Arentson (1999) reported that deleting vitamins and trace minerals during the finishing period markedly lowered vitamin E content in the ham muscle.

Jensen et al. (1997) recently reported that an increase in dietary vitamin E from 100 to 700 mg/kg (50-90 kg pigs) linearly increased vitamin E level in the tissue (*Longissimus dorsi*), thus improving pork stability (TBARS). It is known that the antioxidant defensive system may be weakened by dietary deficiences in retinol, vitamins C and E, and carotenoids. 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 by erythrocyte fragility. They also reported that vitamin E inhibited the activity of phospholipase A_2 in mitochondria, which causes the hydrolysis of phospholipids, resulting in destabilizing of the mitochondrial membranes.

It is also known that the rate and extent of lipid oxidation in meats are dependent on the α-tocopherol concentration in the tissue (Buckley and Morrissey, 1992; Jensen et al., 1997). The autocatalytic peroxidation process begins immediately after slaughter (Buckly et al., 1995). In this study, a significant difference was found in TBARS values of pork samples between 100-150% and 250% NRC (1998) VTM level in the diets. It was reported that a level of approximately 1.0 mg expressed as MDA per kg tissue has been suggested as the threshold level in which rancidity or warmed-over flavor could be detected by taste (Gray and Pearson, 1987). In the present study, the addition level of vitamin E in the 250% NRC (1998) VTM group was 27.5 mg/kg in the diet, and the TBARS value in the tissue (*M. trapezius cevicalis*) was 2.43 mg MDA/kg, which was higher than the threshold level.

Se, like vitamin E, is 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). In the present study, it is difficult to explain if the iron and copper levels in the 250% VTM of NRC (1998) group could affect lipid oxidation of pork at the amounts of 125 and 8.75 mg/kg, respectively. The use of $CuSO_4$ to ensure maximum growth of animals may decrease pork stability (Jensen et al., 1998). On the contrary, Lauridsen et al. (1999) reported that the addition of copper (up to 175 mg/kg) with vitamin E reduced the oxidation rate of the liver in pigs.

Even though Mavromichalis et al. (1999) demonstrated no effect on carcass quality in pigs when vitamin and(or) trace mineral premixes were omitted during the late finishing period before market, additional VTM in the diet, or at least the vitamins typically involved in pork stability, might be needed to improve pork stability during storage.

IMPLICATIONS

Increasing dietary vitamins and trace minerals linearly improved daily gain of pigs and pork stability in terms of TBARS and POV values during storage at 1℃ for 2 or 3 weeks after slaughter. So, the additional vitamins and trace minerals, or at least those vitamins typically involved in pork stability, might be needed to maximize growth of finishing pigs and to improve pork stability during storage.

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