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Effects of Deletion of Supplementary Vitamins and Trace Minerals on Performance, Muscle Vitamin E and Fecal Trace Mineral Contents in Finishing Pigs

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비육후기 사료에서 비타민-미량광물질 첨가제의 제거가 돼지의 성장 능력, 근육 내 비타민 E 및 분 중 미량광물질 함량에 미치는 영향

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ABSTRACT

Two experiments were conducted to determine the effects of deletion of vitamin and trace mineral premixes on growth, feed efficiency, backfat thickness, hemoglobin content, muscle vitamin E content, and fecal, serum and muscle trace mineral contents in finishing pigs raised under two different housing conditions. In Exp. 1, three pens (or experimental units) of five pigs each (average weight ± s.e., 70 ± 0.5 kg) were assigned to a control diet (with vitamin and trace mineral premixes) or diets with 50 or 100% of the premixes deleted. Pigs were fed to market weight under sub-optimal housing conditions with sawdust-covered concrete floor and no electrical ventilation. In Exp. 2, three pens of four pigs each (average weight ± s.e., 56 ± 1.1 kg) were assigned to a control (with vitamin and trace mineral premixes), Diet-P (100% of the premixes deleted) or Diet-P+E (Diet-P plus 100 mg α-tocopherol acetate/kg diet fed for the last 2 wk before slaughter). Pigs were fed to market weight under optimal housing conditions with 70%-slatted concrete floor, electrical ventilation and temperature control. No significant differences were found in average daily gain (ADG), average daily feed intake (ADFI), and gain/feed among treatments in both experiments, but in Exp. 2 done with younger pigs, ADG and ADFI tended to be higher in the control group than in pigs fed diet without premixes. Hemoglobin content, hematocrit and red blood cell count were not influenced by the deletion of premixes. Backfat thickness was not different among treatments. Fecal Mn (twofold) and Zn (threefold) contents were higher in the control than in pigs fed diets without the premixes. Serum trace mineral contents were not influenced by diets. α-Tocopherol content in *gluteus maxima* was decreased ($P < 0.01$) by deleting the dietary premixes, but increased to the level higher than the control by adding 100 mg α-tocopheryl acetate/kg diet fed for the last 2 wk before slaughter. Results indicate that: 1) supplementary vitamins and trace minerals may not be necessary for optimum growth in finishing pigs, and 2) deletion of the dietary premixes reduces muscle vitamin E content, but the reduced content can be reversed by adding α- tocopherol to diets fed for the last 2 wk before slaughter. The deletion may help to alleviate the environmental load of certain minerals from manure.

(**Key words** : Pigs, Growth, Vitamins, Trace minerals, Vitamin E)

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Ⅰ. INTRODUCTION

Formulating pig diets, today's feed manufacturers tend to ignore the amounts of vitamins and trace minerals present in feed ingredients, such as grains and oil meals, and also the amounts of vitamins contributed to by intestinal microflora, and rely on premixed supplements to meet requirements for vitamins and trace minerals. As a consequence, most commercially manufactured feeds may contain these micronutrients in excess of the requirements of pigs, increasing unnecessary feed costs and environmental load of some minerals.

Studies have shown that supplementary vitamins and trace minerals in diets for finishing pigs are not required (Patience and Gillis, 1995; Mavromichalis et al., 1999; McGlone, 2000; Shaw et al., 2002). These studies suggest that the amounts of vitamins and trace minerals supplied through other than premixed supplements are sufficient to support optimum performance of late finishing pigs. However, Edmonds and Arentson (2001) reported that supplemental vitamins and trace minerals should be provided in diets for finishing pigs, because deleting vitamin and trace mineral premixes from finishing diets lowered the vitamin E content in the pork.

We carried out studies to assess further the effect of deletion of supplementary vitamins and trace minerals from diets on growth, feed efficiency, backfat thickness, and muscle vitamin E and fecal trace mineral contents in finishing pigs raised under optimal or sub-optimal housing conditions. In addition, the effect of feeding a diet supplemented with α-tocopheryl acetate for the last 2 wk before slaughter on muscle vitamin E content was evaluated.

Ⅱ. MATERIALS AND METHODS

1. Animals and diets

Pigs were blocked by initial body weight and assigned to one of the pens. In Exp. 1, three pens (or experimental units) of five cross-bred barrows each (total 45 pigs of Yorkshire × Landrace × Duroc purchased from a local pig farm at 70 ± 0.5 kg of body weight (± s.e.)) were randomly assigned to a control diet with complete premixes that provided vitamins and trace minerals in excess of the NRC (1998) recommendations for finishing pigs, or diets with 50 or 100% of the premixes deleted (Table 1). Pigs were fed diets for 7 wk under sub-optimal housing conditions with concrete floors (6.25 m^2/pen) covered with sawdust and no electrical ventilation, and then slaughtered after 12-h fasting. The average body weight (± s.e.) at slaughter was 106.7 ± 1.1 kg.

Exp. 2 was conducted to confirm the result of Exp. 1 using younger pigs (Yorkshire) fed under optimal housing conditions and also to investigate the effect of deletion of the premixes from diets on trace mineral and vitamin E contents in the ham muscle (*gluteus maxima*) and fecal excretion of trace minerals. Three pens (or experimental units) of four Yorkshire barrows each (total 36 pigs with average weight ± s.e., 56 ± 1.1 kg) were randomly assigned to one of the following diets: control (with complete premixes), Diet-P (with 100% of the premixes deleted) or Diet-P+E (Diet-P plus 100 mg α-tocopherol acetate/kg diet fed for the last 2 wk before slaughter). Pigs were fed diets (Table 2) for 7 wk under optimal housing conditions with automatic ventilation, temperature control and 70% slatted concrete floor (16 m^2/pen), and then slaughtered after 12-h fasting. The average body weight (± s.e.) at slaughter was 101.7 ± 0.8 kg.

Table 1. Composition of experimental diets used for Exp. 1 (% as-fed basis)

Ingredient	Control	Premixes deleted[1)]	
		50%	100%
Corn	77.0	77.075	77.15
Soybean meal, 44% CP	15.8	15.8	15.8
Molasses	3.0	3.0	3.0
Lysine HCL	0.1	0.1	0.1
Limestone	0.6	0.6	0.6
Tricalcium phosphate	1.0	1.0	1.0
Tallow	2.0	2.0	2.0
Premix[2)]	0.15	0.075	0
Salt	0.35	0.35	0.35

1) Diets with 50 or 100% of the vitamin and trace mineral premixes deleted.
2) Provided the following per kg of diet: Fe, 120 mg; Cu, 9 mg; Mn, 30 mg; Zn, 48 mg; I, 0.3 mg; Se, 0.15 mg; vitamin A, 7,500 IU; vitamin D_3, 1,500 IU; vitamin E, 37.5 IU; vitamin K_3, 22.5 mg; vitamin B_1, 1.5 mg; vitamin B_2, 3.0 mg; vitamin B_6, 1.5 mg; vitamin B_{12}, 0.015 mg; pantothenic acid, 7.5 mg; niacin, 30 mg; biotin, 0.075 mg; folic acid, 1.5 mg.

Table 2. Composition of experimental diets used for Exp. 2 (% as-fed basis)

Ingredient	Control	Diet-P[1)]	Diet-P+E[1)]
Corn	58.23	58.43	58.43
Soybean meal	22.77	22.77	22.77
Wheat	5.00	5.00	5.00
Wheat bran	5.00	5.00	5.00
Molasses	3.00	3.00	3.00
Tallow	4.25	4.25	4.25
Salt	0.30	0.30	0.30
Tricalcium phosphate	0.95	0.95	0.95
Limestone	0.30	0.30	0.30
Premix[2,3)]	0.20	−	−

1) Diet without premixes (Diet-P) and Diet-P supplemented with α-tocopheryl acetate (100 mg/kg diet) for the last 2 wk before slaughter (Diet-P+E).
2) Provided the following per kg of diet: Fe, 60 mg; Cu, 15 mg; Mn, 25 mg; Zn, 60 mg; I, 0.20 mg; Se, 0.25 mg; vitamin A, 8,000 IU; vitamin D_3, 1,500 IU; vitamin E, 30 IU; vitamin K, 1.5 mg; vitamin B_1, 1.0 mg; vitamin B_2, 4.0 mg; vitamin B_6, 2.0 mg; vitamin B_{12}, 0.02 mg; pantothenic acid, 7.5 mg; niacin, 20 mg; biotin, 0.1 mg; folic acid, 0.6 mg.
3) Analyzed trace mineral contents (mg/kg of control and Diet-P): Mn, 57.8 and 36.9; Fe, 329 and 303; Cu, 93.3 and 91.6; Zn, 179 and 89.

The breed of pigs and the composition of diets used in Exp. 2 were different from those used in Exp. 1, because modern housing facilities were used for Exp. 2 and defined protocols of the farm for pig management including the pig breed and dietary regime had to be used.

In both experiments, pigs were allowed to have free access to diets and water during the entire feeding period. Feed consumption and body weight were recorded at 3 wk and at the end (7 wk) of feeding experiments, average daily gain (ADG), average daily feed intake (ADFI) and gain/feed over the 3-or 7-wk feeding period were calculated.

2. Collection of blood, feces and muscle samples and determination of backfat thickness

Blood samples were collected into EDTA-treated tubes from the *vena cava* after a 12-h fasting period at the end of Exp. 1. Aliquots were used for determination of hemoglobin content, hematocrit and red blood cell counts, respectively. In Exp. 2, blood samples were taken into tubes without EDTA after a 12-h fasting period at the end and centrifuged, and serum samples were collected. To assess potential contribution of fecal trace minerals to environmental pollution, we collected three spot samples of feces from the floor of each pen on d 49 and pooled samples of each pen were used to analyze trace mineral contents in the feces. *Gluteus maxima* samples were taken right after slaughter. Samples were stored at −20℃ for later analysis. Backfat depth was manually measured at the 11th, 12th, 13th and 14th ribs on the midline and their average was used for backfat thickness (Exp. 1 and 2).

3. Determination of hemoglobin concentration, red blood cell count and hematocrit

Right after blood samples were collected from pigs used in Exp. 1, hemoglobin (Hb) concentration, red blood cell (RBC) count and hematocrit (Hct) were determined using an automatic analyzer of quantitative hematology (Sysmex K-1000, TOA Medical Electronics, Kobe, Japan) according to the manufacturer's instruction.

4. Determination of trace mineral concentrations in diet, serum and feces, and α-tocopherol contents in *gluteus maxima* and serum

Trace mineral contents in diet, feces, serum and muscle were measured by the AOAC procedures (1996) using an inductively coupled plasma atomic emission spectrometer (ICP-AES; SPECTRO Analytical Instruments, GmbH, Kleve, Germany) in Exp. 2. Alpha-tocopherol contents in *gluteus maxima* (on a wet basis) and serum were determined at 280 nm by the method developed by Liu et al. (1996) using HPLC (model no 616/626, Waters, Miliford, MA) equipped with a µPoracil column (3.9 × 300mm, 10µm) and UV detector (model no 486, Waters).

5. Statistical analysis

Data were subjected to analysis of variance (ANOVA) in a randomized complete block design on SAS package (SAS Inst. Inc., Cary, NC). The main source of variation for all variables was dietary treatments in ANOVA. Duncan's multiple-range test was used to compare mean values of individual treatments, when *F*-value was significant ($P < 0.05$).

Ⅲ. RESULTS

In both experiments, average daily gain, average daily feed intake, gain/feed and backfat thickness were not significantly different among the dietary treatments (Tables 3 and 4). However, average daily gain tended to decrease with the deletion of supplementary vitamins and minerals, especially in Exp. 2, in which the average daily gain was reduced 8% by deleting the premixes. Hemoglobin content, hematocrit and red blood cell count were not influenced by the deletion (Table 3). *Gluteus maxima* α-

Table 3. Effect of deletion of supplementary vitamins and trace minerals on weight gain, feed intake, feed efficiency, backfat thickness and hemoglobin concentration in finishing pigs (Exp. 1)

Item	Control	Premixes deleted[1)]	
		50%	100%
ADG[2)], kg	0.78 ± 0.023	0.73 ± 0.017	0.74 ± 0.028
ADFI[2)], kg	3.00 ± 0.057	2.85 ± 0.028	2.97 ± 0.121
Gain/feed[2)]	0.26 ± 0.02	0.26 ± 0.01	0.25 ± 0.005
Backfat thickness[3)], mm	23.7 ± 0.64	24.5 ± 1.20	25.3 ± 1.25
Hemoglobin[3)], g/100 mL	14.2 ± 0.17	13.4 ± 0.27	13.7 ± 0.32
Red blood cell[3)], no[4)]/mL	734 ± 10.8	697 ± 20.3	719 ± 17.8
Hematocrit[3)], % (vol/vol)	44.5 ± 0.50	42.6 ± 0.92	44.2 ± 1.04

1) Diets with 50 or 100% of the vitamin and trace mineral premixes deleted.
2) Values are means with SE of three pens of five pigs each; average initial weights were 70.5, 69.6 and 70.3 kg for control and diets with 50 or 100% of the premixes deleted, respectively.
3) Values are means with SE of three pens of 5 pigs each.
4) Values should be multiplied by 10^6 for cell numbers.

tocopherol content was reduced by removing the premixes (3.74 vs 2.45 mg/kg wet muscle), but was increased 81% by adding α-tococopheryl acetate to the diet fed for the last 2 wk before slaughter (2.45 vs 4.59).

A significant ($P < 0.01$) reduction in fecal Mn and Zn (Table 5) was found in pigs fed diet without the premixes compared to the control.

Table 4. Effects of deletion of supplementary vitamins and trace minerals on weight gain, feed intake, feed efficiency, backfat thickness and serum and muscle vitamin E concentrations in finishing pigs (Exp. 2)

Item	Control	Diet-P[1)]	Diet-P+E[1)]
ADG[2)], kg	0.99 ± 0.04	0.91 ± 0.034	0.90 ± 0.011
ADFI[2)], kg	3.10 ± 0.069	2.95 ± 0.034	2.94 ± 0.028
Gain/feed[2)]	0.32 ± 0.011	0.31 ± 0.014	0.31 ± 0.005
Backfat thickness[3)], mm	19.9 ± 1.3	19.0 ± 1.0	18.7 ± 0.5
Serum vitamin E[3)], mg/L	1.50 ± 0.20	1.18 ± 0.18	1.65 ± 0.10
Muscle vitamin E[3)], mg/kg[4)]	3.74 ± 0.15[b)]	2.45 ± 0.12[c)]	4.59 ± 0.24[a)]

1) Diet without premixes (Diet-P) and Diet-P supplemented with α-tocopherol acetate (100 mg/kg diet) for the last 2 wk before slaughter (Diet-P+E).
2) Values are means with SE of three pens of four pigs each; average initial weights were 55.9, 55.4 and 57.4 kg for control, Diet-P, Diet-P+E, respectively.
3) Values are means with SE of three pens of four pigs each.
4) Muscle α-tocopherol contents in *gluteus maxima* (on a wet basis).
abc Within a row, means without common superscript letters differ ($P < 0.01$).

Table 5. Effects of deletion of supplementary vitamins and trace minerals on fecal, muscle and serum trace mineral contents in finishing pigs (Exp. 2)

Trace mineral	Control	Diet-P[1)]	Diet-P+E[1)]
Feces[2)], mg/kg dry matter			
Mn	345 ± 19.8[a]	146 ± 4.6[b]	166 ± 10.3[b]
Fe	1,723 ± 20.0	1,556 ± 89.0	1,545 ± 29.1
Cu	520 ± 26.3	458 ± 34.0	502 ± 26.8
Zn	1,086 ± 39.3[a]	301 ± 25.7[b]	312 ± 21.3[b]
Gluteus maxima[3)], mg/kg wet weight			
Mn	0.10 ± 0.002	0.09 ± 0.002	0.09 ± 0.002
Fe	7.84 ± 0.46	8.14 ± 0.45	7.93 ± 0.41
Cu	1.26 ± 0.08	1.32 ± 0.07	1.14 ± 0.10
Zn	14.4 ± 0.72	14.1 ± 0.51	13.1 ± 0.66
Serum[3)], mg/L			
Mn	0.20 ± 0.008	0.21 ± 0.008	0.21 ± 0.008
Fe	11.8 ± 0.88	12.1 ± 0.65	10.8 ± 0.91
Cu	1.68 ± 0.08	1.87 ± 0.13	1.82 ± 0.08
Zn	2.66 ± 0.15	2.49 ± 0.14	2.63 ± 0.17

1) Diet without premixes(Diet-P) and Diet-P supplemented with α-tocopherol acetate(100mg/kg diet) for the last 2 wk before slaughter(Diet-P＋E).
2) Values are means with SE of three pens(each from pooled samples of three spot feces).
3) Values are means with SE of three pens of four pigs each.
ab Within a row, means without common superscript letters differ($P < 0.01$).

However, removing vitamin and trace mineral premixes from diets had no effect on serum levels of all minerals determined (Table 5).

Ⅳ. DISCUSSION

Our data support findings of other studies that no supplementary vitamins and trace minerals in grain-oil meal-based diets are required for optimum growth and feed efficiency in finishing pigs. Patience and Gillis (1995, 1996) found no adverse effect on growth performance and backfat thickness of pigs when vitamin and trace mineral premixes were omitted from wheat-barley-canola meal-based diets during the last 3 to 5 wk before marketing. Recent reports have shown that omitting vitamin and trace mineral premixes from diets during the late finishing period had no effect on average daily gain, feed efficiency or carcass quality in pigs (Mavromichalis et al., 1999; McGlone, 2000; Shaw et al., 2002).

By contrast, Edmonds and Arentson (2001) reported that pigs fed diets with vitamin and trace mineral premixes showed higher ($P < 0.05$) weight gain and greater ($P = 0.07$) feed intake than did pigs fed diets without supplements over the last 12-wk period in one (using 58-kg pigs) of the two experiments, but not in the other experiment (using 54-kg pigs). Spurlock et al. (1998) also reported that withdrawal of premixes for 44 d from diet fed finishing pigs resulted in a significant decrease in weight gain and feed intake. Although not significant, weight gain and feed intake tended to be higher in pigs fed the control diet than in pigs fed diet without the premixes in Exp. 2 of our study. Our data together with others' suggest that the amount of trace minerals supplied through grain-oil meal-based diets without supplements and some vitamins supplied through the basal ingredients and intestinal microbial synthesis may be on borderline in meeting the requirements. Thus, supplementary vitamins and trace minerals can be a safe guard to warrant maximum growth of finishing pigs under certain environments, especially during early finishing periods.

Hemoglobin content, red blood cell count and hematocrit values (Table 3) found in our study were considered to be adequate, clearly demonstrating no need of supplemental iron for finishing pigs. Fecal Mn and Zn contents of the control pigs were two to three times as high ($P < 0.01$) as in pigs fed diets without premixes, mainly due to their increased dietary intake (about 1.5 to 2 times) (see footnote to Table 2).

Edmonds and Arentson (2001) showed that muscle Cu level was reduced by feeding diet without premixes for 6 wk compared to a control in one (determined in ham) of the two experiments, but not in the other (*in longissimus*). They also determined muscle Zn and Fe contents, which were not affected by removing the premixes from diets. Shaw et al. (2002) also reported that withdrawal of premixes from diets during late finishing phase markedly decreased fecal mineral concentration. All trace minerals, except for Zn, supplied by the corn-soybean meal-based diet without the premixes used in our study exceeded the NRC (1998) recommended levels for finishing pigs, not considering their bioavailability. These data along with our fecal mineral excretion data indicate that supplementing diets with trace minerals for finishing pigs is likely to increase unnecessary feed costs and soil contamination by certain minerals (e.g., Mn and Zn) from manure.

The lowered vitamin E concentration in the pork has been an issue when finishing pigs are fed diets without premixes. Edmonds and Arentson (2001) reported that muscle (*longisssimus*) vitamin E level in pigs fed a diet without vitamin and trace mineral premixes for 12 wk was lower (61%) than was the case for pigs fed diet with supplements. This lower muscle vitamin E level can be reversed by feeding diets supplemented with vitamin E for the last 2 wk before slaughter, as shown in Table 4. Many other studies (Dove and Ewan, 1991; Anderson et al., 1995; Cannon et al., 1996; Soler-Velasquez et al., 1998; Corino et al., 1999) have shown that addition of α-tocopherol to diets increases its tissue concentrations and can be beneficial for improving product quality, such as shelf life and nutritional value.

In conclusion, supplementary vitamins and trace minerals may be unnecessary for optimum growth in finishing pigs, and vitamin E content in the muscle reduced by deletion of premixes can be reversed by adding α-tocopherol to diets fed for the last 2 wk before slaughter.

Ⅴ. 요　　약

비육후기 사료에서 비타민-미량광물질 첨가제의 제거가 돼지의 성장, 사료효율, 혈 중 헤모글로빈 농도, 돈육 내 비타민 E 및 분 중 미량광물질 함량에 미치는 영향을 구명하기 위하여 사육환경이 서로 다른 돈사에서 두 번의 시험이 수행되었다. 시험 1에서는 45두의 비육돈 (평균체중 70 kg, 3원교잡종)을 돈방 당 5두씩 배치하고, 대조구 (비타민－미량광물질 프리믹스 첨가), 프리믹스 50% 및 0% 첨가구에 각각 3돈방을 배치하여 환기와 온도가 제어되지 않는 재래식 톱밥돈사에서 7주동안 사양한 후 도축하였다. 시험 2에서는 돈사 환기 및 온도가 자동 조절되는 슬러리 무창돈사에서 36두의 요크셔 비육돈 (평균체중 56 kg)을 돈방 당 4두씩 배치, 대조구(비타민-미량광물질 프리믹스 첨가), 프리믹스 0% 및 프리믹스 0%+비타민 E(100 mg α-tocopherol acetate/kg) 첨가구에 각각 3돈방을 배치하여 7주 동안 사양 후 도축하였다. 두 시험에서 처리 간 일당증체량, 사료섭취량, 사료효율 및 도체특성은 유의차가 없었으나 시험 2에서는 대조구의 일당증체량이 약간 높은 경향을 보였다. 프리믹스의 미 첨가는 헤모글로빈 함량이나 적혈구 수에 영향을 주지 않았다. 분 중 Mn과 Zn 함량은 대조구에서 프리믹스를 첨가하지 않은 다른 처리에서 보다 매우 높게 ($P < 0.01$) 나타났다. 혈 중 미량광물질 함량은 처리간 유의차를 보이지 않았다. 햄 근육 (*gluteus maxima*) 내 α-tocopherol 함량은 프리믹스를 첨가하지 않음으로써 감소하였으나 ($P < 0.01$), 도살 전 2주 동안 α-tocopheryl acetate(100mg/kg diet)를 급여함으로써 프리믹스 첨가구보다도 더 증가하였다 ($P < 0.01$). 본 연구결과 돼지 비육후기 사료에 비타민-미량광물질 프리믹스의 첨가는 성장율에는 큰 영향을 미치지 않으면서 분 중 일부 미량광물질을 증가시키기 때문에 경제적인 손실과 토양오염의 위험이 있음을 말해 준다. 프리믹스 제거로 인한 고기 내 비티민 E 함량의 감소는 마지막 2주동안 α-tocopherol 를 첨가 급여함으로써 회복될 수 있다.

Ⅵ. REFERENCES

1. Anderson, L. E., Sr., Myer, R. O., Brendemuhl, J. H. and McDowell, L. R. 1995. Bioavailability of various vitamin E compounds for finishing swine. J. Anim. Sci. 73:490-495.
2. AOAC. 1996. Official Methods of Analysis. 16th ed. Assoc. Offic. Anal. Chem., Arlington, VA.
3. Cannon, J. E., Morgan, J. B., Schmidt, G. R., Tatum, J. D., Sofos, J. N., Smith, G. C., Delmore, R. J. and Williams, S. N. 1996. Growth and fresh meat quality characteristics of pigs supplemented with vitamin E. J. Anim. Sci. 74:98-105.
4. Carino C., Oriani, G., Pantaleo, L., Pastorelli, G. and Salvatori, G. 1999. Influence of dietary vitamin E supplementation on “Heavy” pig carcass characteristics, meat quality, and vitamin E status. J. Anim. Sci. 77:1755-1761.
5. Dove, C. R. and Ewan, R. C. 1991. Effect of vitamin E and copper on the vitamin E status and performance of growing pigs. J. Anim. Sci. 69:2516-2523.
6. Edmonds, M. S. and Arentson, B. E. 2001. Effect of supplemental vitamins and trace minerals on performance and carcass quality in finishing pigs. J. Anim. Sci. 79:141-147.
7. Liu, Q., Scheller, K. K. and Schaefer, D. M. 1996.

Technical note: A simplified procedure for vitamin E determination in beef muscle. J. Anim. Sci. 74: 2406-2410.
8. Mavromichalis, I., Hancock, J. D., Kim, I. H., Senne, B. W., Kropf, D. H., Kennedy, G. A., Hines, R. H. and Behnke, K. C. 1999. Effects of omitting vitamin and trace mineral premixes and (or) reducing inorganic phosphorous additions on growth performance, carcass characteristics, and muscle quality in finishing pigs. J. Anim. Sci. 77:2700-2708.
9. McGlone, J. J. 2000. Deletion of supplemental minerals and vitamins during the late finishing period does not affect pig weight gain and feed intake. J. Anim. Sci. 78:2797-2800.
10. NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.
11. Patience, J. F. and Gillis, D. 1995. Removal of vitamins and trace minerals from finishing diets: impact on animal performance. Pages 29-31 in Prairie Swine Centre Annu. Res. Rep. Saskatchewan, Canada.
12. Patience, J. F. and Gillis, D. 1996. Impact of pre-slaughter withdrawal of vitamin supplements on pig performance and meat quality. Pages 29-32 in Prairie Swine Centre Annu. Res. Rep. Saskatchewan, Canada.
13. Shaw, D. T., Rozeboom, D. W., Hill, G. M., Booren, A. M. and Link, J. E. 2002. Impact of vitamin and mineral supplement withdrawal and middling inclution on finishing pig growth performance, fecal mineral concentration, carcass characteristics, and the nutrient content and oxidative stability of pork. J. Anim. Sci. 80:2920-2930.
14. Soler-Velasquez, M. P., Brendemuhl, J. H., McDowell, L. R., Sheppard, K. A., Johnson, D. D. and Williams, S. N. 1998. Effects of supplemental vitamin E and canola oil on tissue tocopherol and liver fatty acid profile of finishing swine. J. Anim. Sci. 76:110-117.
15. Spurlock, M. E., Cornelius, S. G., Frank, G. R. and Willis, G. M. 1998. Growth performance of finishing pigs fed diets with or without supplemental vitamins and trace minerals and subjected to multiple immunological challenges. J. Anim. Sci. 76 (Suppl. 2):53(Abstr.).

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