碩 士 學 位 論 文

肥肉豚 飼料에서 비타민과 微量 鑛物質 補充劑의 除去가 成長, 飼料效率 및 屠體特性에 미치는 影響

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Effects of Deletion of Supplementary Vitamins and Trace Minerals on Growth, Feed Efficiency and Carcass Quality in Finishing Pigs

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要　約

본 연구는 비육돈 사료중 vitamin과 미량광물질 보충제의 제거가 성장, 사료효율, hemoglobin 함량, 도체특성, 근육 vitamin E 수준 및 혈청과 분 미량광물질 함량에 미치는 영향을 구명하기 위하여 실시되었다.

실험 1에서는 불결한 시설환경(환기와 온도조절이 되지 않는 콘크리트 바닥에 톱밥을 덮은 시설에서 사육)에 비육돈(평균체중 70kg) 45두를 대조구(vitamin과 미양광물질 보충제를 첨가한 구)와 보충제를 50% 제거한 구 및 보충제를 100% 제거한 구에 각 3반복으로 반복당 5마리씩 배치하여 출하시(평균체중 107 - 109 kg)까지 사육하였다. 실험 2에서는 최적 시설환경(환기와 온도조절이 자동으로 되고 스레트식 바닥에 소독 및 청소 등이 철저히 수행되는 시설에서 사육)에 비육돈(평균체중 56 kg) 36마리를 대조구(vitamin과 미량광물질 보충제를 첨가한 구), 사료Ⅰ(보충제를 100% 제거한 구) 및 사료Ⅱ(사료Ⅰ에서 실험종료 마지막 2주간 사료 kg당 vitamin E 100 mg을 첨가한 구)를 각 3반복으로 반복당 4마리씩 배치하여 출하시(평균체중 102 kg)까지 사육하였다.

두 실험에서 일당증체량이나 사료섭취량 및 사료효율에는 사료처리간 유의적인 차이가 없었다. 하지만, 실험 2에서 유의적인 차이는 없었으나 대조구 사료를 급여한 비육돈이 처리구(사료Ⅰ 또는 Ⅱ) 사료를 급여한 비육돈보다 일당증체량이나 사료섭취량이 증가되는 경향을 보였다. 도체율 및 등지방두께도 처리간 유의적인 차이를 보이지 않았다. 대조구를 급여한 비육돈에서는 처리구를 급여한 비육돈에 비해 분 미량광물질 함량(특히, Mn, Zn, Mo)이 유의적으로 높았다. 혈청 미량광물질 함량은 처리에 의해 영향을 받지 않았다. 비육돈에서 사료중 보충제의 제거에 의해 근육 vitamin E 함량은 감소하였으나, 마지막 2주간의 α-tocopherol acetate의 첨가에 의해 근육 vitamin E 함량이 대조구보다 더 유의적으로 증가하였다.

본 실험의 결과는 비육돈에 있어서 사료중에 vitamin과 미량광물질 보충제의 첨가는 성장이나 도체특성에 영향을 미치지 않았고, 보충제의 제거에 의한 근육

vitamin E 함량의 감소는 출하전 마지막 2주간 사료에 α-tocopherol acetate를 첨가함으로써 방지 될 수 있었다.

Ⅰ. Introduction

Almost 70% of the pig production cost is attributed to feeds. Approximately one-third of the feed required by pigs through market weight is consumed during the finishing period. Therefore, reduction of feed costs during the finishing period is an important factor as a means of increasing profits in pig production.

Attempts have been made to reduce these costs deleting supplementary vitamins and trace minerals from finishing pig diets (Patience and Gillis, 1995; Mavromichalis et al., 1999; McGlone 2000) and finishing broiler diets (Deyhim and Teeter, 1993; Waldroup, 1968). These studies showed that deleting the supplementary vitamins and trace minerals in diets during finishing period had no adverse effect on growth. However, Edmonds (2001) reported that finishing pigs fed diets devoid of supplemental vitamins and trace minerals had markedly reduced muscle vitamin E content in both longissimus muscle and ham.

Requirement of finishing-pigs for vitamin E is 11 IU/kg of diet (NRC, 1998). Corn and soybean meal-basis diets do not contain adequate amount of vitamin E to meet the requirement. Therefore, corn soybean meal-basied diets need to be supplemented with vitamin E. Previous studies showed that the addition of α-tocopherol to diets increased vitamin E concentration in longissimus muscle (Cannon et al., 1996; Corino et al., 1999). Also, several investigations reported that meat quality improved when dietary α-tocopheryl acetate levels were 100 to 200 mg/kg of diet, compared with the meat quality when pigs were fed 10 mg/kg of diet (Asghar et al., 1989; Buckley et al., 1989; Monahan et al., 1990b, 1992, 1994b).

The objective of this study was to determine the effect of deletion of supplementary vitamins and trace minerals in diets on growth, feed efficiency, carcass quality, muscle vitamin E contents, and serum, muscle and fecal trace mineral contents in finishing pigs.

Ⅱ. Literature Review

1. Vitamin and Trace mineral requirements of swine

Generally, supplementing vitamins and trace minerals has been a common practice in diet formulation for finishing pigs. In table 1 showed that vitamin and trace mineral levels in a corn-soybean meal-based diet were compared with the NRC recommended levels (1998). Most water-soluble vitamins (biotin, folacin, niacin, pantothenic acid, riboflavin, thiamin and vitamin B_6) are shown to be adequate to meet the NRC requirement for finishing pigs.

Biotin is present in most common feedstuffs in more-than-adequate (National Research Council, 1998). Anderson (1978) reported that the bioavailability of biotin in yellow corn and soybean meal is high for the chick. A considerable portion of biotin requirement in pigs is presumed to come from bacterial synthesis in the gut. Russertt (1976b) reported that soy products are rich in bioavailable choline, and starting, growing, and finishing pigs have not shown responses to supplemental choline when it was added to corn-soybean meal or corn-isolated soy protein diets. Tsiagbe et al. (1982) also reported that choline supplementation did not increase gains or feed efficiency for pullets from 8 to 20 weeks.

NRC requirement (1998) of folacin is 0.3 mg/kg of diet for finishing pigs. Folacin level of corn-soybean meal diet is 0.33 mg/kg of diet. This meets the requirement for finishing pigs. Niacin requirement is 7 mg/kg of diet for finishing pigs (NRC, 1998). Corn-soybean meal diet includes 24.1 mg niacin/kg of diet(Table 1). Yen (1978) and Copelin (1980) reported that studies with 45 kg pigs fed corn-soybean meal diets have indicated no performance improvements due to niacin supplementation.

The pantothenic acid requirement of finishing pigs (NRC, 1998) is 7 mg/kg of diet. This is met by corn-soybean meal diet (Table 1). The riboflavin requirement of finishing pigs is 2.0 mg/kg of diet (NRC, 1998). Corn-soybean meal diets are adequate in meeting riboflavin requirement (Table 1). Krider (1949) and Terrill (1954) reported that riboflavin requirement is 1.1 mg/kg for growing pigs fed synthetic diets. The thiamin requirement (NRC, 1998) which in 1 mg/kg of diet for finishing pigs, can be met by corn-soybean meal diets that provide 3.45 mg/kg (Table 1). The requirement of vitamin B_6 of finishing pigs is 1.0 mg/kg of diet (NRC, 1998) and can be met by corn-soybean meal diets that contains 4.68 mg/kg (Table 1). Miller(1957) suggested that a dietary requirement of vitamin B ranged 1.0 to 2.0 mg/kg of diet for the pig weighed about 2 to 10 kg of body weight.

Fat-soluble vitamins (A, D, E and K) is deficient for finishing pigs in corn-soybean meal diets (Table 1). Edmonds (2001) reported that finishing pigs fed diets devoid of supplemental vitamins and trace minerals had markedly reduced muscle vitamin E content in both longissimus muscle and ham. Cannon et al., (1996) and Corino et al. (1999) reported that feeding α-tocopherol 100 mg/kg and 300 mg/kg diet, respectively, for 84 d and 60 d, respectively, increased α-tocopherol concentration in longissimus muscle.

Most of the trace minerals (copper, iron and manganese) are adequate in corn and soybean meal based diets (Table 1). A corn-soybean meal diet contains 5.5 mg Cu/kg (Table 1), which is adequate to meet the requirement (NRC, 1998) for finishing pigs. Okonkwo (1979) and Hill (1983a) reported that 5 to 6 ppm Cu in the diet is adequate for the neonatal pig. The requirement for later stages of growth is probably no greater than 5 to 6 ppm (NRC, 1998). Iron is required at 40 to 50 mg/kg of diet for finishing pigs (NRC, 1998). A corn-soybean meal diets contain 54.6 mg Fe/kg of diet (Table 1). This level is adequate to meet the requirement (NRC, 1998). Biehl (1997) reported that soybean meal contains 175 to 200 ppm of iron and the bioavailability of iron in soybean meal is 38 percent, based on hemoglobin depletion-repletion assays in chicks. But, the requirement for finishing pig has not been reported.

Manganese requirement is 2 mg/kg of diet (NRC, 1998). Manganese level in corn-soybean meal diets is 10.1 mg/kg (Table 1). Svajgr (1969) reported that a corn-soybean meal diet contains ample manganese for normal growth and bone formation in growth-finishing pigs. Gromwell et al. (1975) reported that gain and feed/gain responses for iodine level of diets had not significant differences in growing pigs (Initial BW 9.7kg and for 51 d experimental period). Atkins (1984) and Ku (1973) reported that selenium supplement had no significant effect on average daily gain, feed intake or gain to feed ratio for swine. Smith et al. (1970) reported that the zinc requirement is about 50 ppm/kg feed for growing swine. The corn-soybean meal-based diet contains 22 mg Zn/kg.

2. Deletion of supplemental Vitamins and Trace minerals in finishing pigs

It has been a common practice to supplement pig diets with vitamins and trace minerals even in finishing pigs. However, a recent study (Mavromichalis et al., 1999) reported no effect of feeding diets containing supplementary vitamins and trace minerals on growth and carcass quality during the last 28- to 30-d of finishing period (feeding was started at 85 kg of body weight.) . Similarly, McGlone(2000) reported that deletion of supplemental minerals and vitamins during the late finishing period did not affect pig weight gain and feed intake (initial average body weight 92kg and 80kg for trials 1 and 2, respectively). Patience and Gillis(1995, 1996) also showed no significant differences in growth performance or carcass traits when vitamin and trace mineral premixes were withdrawn from broiler diets during the last 17 or 35 to 36 days.

Kim at al.(1997) revealed no significant effect from a 45-d withdrawal of vitamins and trace minerals supplementation on finishing pig performance or meat quality factors, such as color, firmness and marbling. In contrast, Spurlock et al.(1998) reported that withdrawal of vitamin and trace mineral premixes for 44 d from diets fed finishing pigs resulted in a significant decrease in weight gain and feed intake. Similarly, Edmonds and Arentson (2001) reported that pigs fed diets supplemented with vitamins and trace minerals increased weight gain and feed intake compared with those obtained with diets containing no supplements in finishing pigs. They also found that removing premixes from diets fed for 6 wk resulted in a 49% decrease in ham muscle vitamin E concentrations compared with those of pigs that were fed diets with supplements.

Ⅲ. Materials and Methods

1. Animals and diets

In experiment 1, three replicates of 5 cross-bred (Landrace×Large White×Duroc) pigs (average weight, 70 kg) each were assigned to a control (with complete premixes), 50% or 100% deletion of the premixes and fed to market weight under a sub-optimum housing condition without electrical ventilation or temperature control. Concrete floors (2.5×2.5 m) covered with saw dust.

In experiment 2, three replicates of 4 Landrace pigs (average weight, 56 kg) each were assigned to one of the following diets: a control (with vitamin and trace mineral premixes), diet Ⅰ (100% deletion of premixes) or diet Ⅱ (diet Ⅰ plus 100 mg/kg diet of supplementary vitamin E for the last 2 wk of experiment), and fed to market weight under an optimum housing condition with automatic ventilation and temperature control system. The floor(3×3 m) was 70 % slatted and 30 % concrete.

Pigs were allowed to have free access to diets and water during the entire feeding period (49 days for both experiments). Feed consumption and body weight were recorded every 2 - 3 wk during the experiments, and average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G/F) were calculated.

2. Sample collection

Blood samples were collected from the vena cava into EDTA-treated tubes on d 30 and 49 at the end of experiment 1, and into tubes without EDTA on d 30 and 49 in experiment 2, after fasting (12 hr). Spot fecal samples were taken from the floor on d 49 in experiment 2 to analyze fecal trace mineral contents. Muscle samples were taken from ham area right after slaughter, and stored at -20℃ for later analysis in experiment 2.

3. Blood analysis

Hemoglobin (Hb) concentration, red blood cell (RBC) count and hematocrit (Hct) were determined using the automatic analyzer (Sysmex K-1000, TOA Medical Electronics, Kobe, Japan). For the determination of RBC count, 4μL whole blood was diluted 1:25000 (blood : saline) before the measurement by the sample rotor valve. Exactly 0.25ml of diluted sample were measured by a volumetric ball-float type manometer, and aspirated through the aperture (75μL of diameter) of the transducer. When RBC passed through the aperture, the electrical resistance between the electrodes increased causing a change in voltage between the electrodes which are proportional to the resistance change. These small voltage changes were amplified and transferred to the discriminator circuit. Then RBC were discriminated by their respective comparators and indicated as number of RBC per 1μL of whole blood (number×10^6/μL) according to the data counted between the fixed upper and lower discrimination levels of RBC. The hematocrit was measured automatically by pulse height(voltage change) produced which the 1:25000 final dilution of whole blood were passed through the transducer aperture, was calculated by integrating these pulses between two discrimination levels and was expressed as the ratio of the total RBC volume to the whole blood. The hemoglobin concentration was measured by the sodium lauryl sulfate hemoglobin (SLS-Hb) method using sulfolyser hemoglobin reagent as lysing reagent and the surfactants lysed the red blood cell membrane releasing hemoglobin. The globin group of the released hemoglobin molecule was altered by the hydrophilic alkyl group of sodium lauryl sulfate. Though the conversion of hemoglobin from the ferrous (Fe^{+2}) to the ferric (Fe^{+3}) state formed methemoglobin and this SLS-Hb hemichrome molecule measured by light absorbance methods at 540 nm wavelength.

4. Determination of carcass characteristics

Pigs were slaughtered at the end of feeding experiments and slaughter and hot carcass weights were measured, and dressing percentage was calculated. Backfat thickness was measured at the 11th thoracic and 1st lumbar vertebra.

5. Determination of trace mineral concentrations in diet, serum, muscle and feces, and α-tocopherol contents in muscle and serum

In experiment 2, to determination of trace mineral contents in diet, feces and serum, the samples were digested with acid according to the AOAC (1996) and measured by method using inductively coupled plasma atomic emission spectrometer (ICP-AES; Spectro Analytical Instruments, GmbH, Kleve, Germany). By the energy enriched argon gas within the heavy electrified torch of ICP-AES, the energy level of sprayed sample was increased and the amount of emitted light resulted from elevated energy of samples was measured by spectro-photometery and total concentration of trace mineral in the sample was computed with this emission data.

For the determination of α-tocopherol contents in wet muscle and serum, α-tocopherol was extracted by simplified method of Liu et al. (1996) with a slight modification. Meat (1 g) or serum (1 mL) samples were transferred into 15 mL conical tube. Each tube received 4 mL of saponification solution (11% KOH, wt/vol; 55% ethanol, vol/vol; 45% distilled water, vol/vol) and 0.12 g of ascorbic acid which was used for preventing α-tocopherol oxidation, and samples were saponified at 80℃ for 30 min. After saponification 2 mL of isooctane was added to each tube and strongly vortexed for 2 min. Tubes were allowed to stand for separation of aqueous and extracted isooctane phases. The upper isooctane phase was transferred into autosampler vial. Each 30 ㎕ of extracted sample was injected into high performance liquid chromatography (HPLC; model no. 616/626, Waters, Miliford, MA, USA) which is equipped with a stainless steel column with µPorasil (3.9×300 mm, 10 ㎛) as a stationary phase. Detection or quantitative determination was performed using a UV detector (Waters 486) operating at 280 nm. The mobile phase was the mixture of 97% isooctane and 3% tetrahydrofuran in HPLC grade at a 0.8m/min of flow rate.

6. Statistical analysis

Data were subjected to analyses of variance (ANOVA) in a completely randomized design on SAS package (SAS, 1988). 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.

Ⅳ. Results and Discussion

1. Effect of deletion of supplementary vitamins and trace minerals on growth and carcass quality in finishing pigs

In experiment 1, average daily gain±SD was 0.78±0.04, 0.73±0.03 and 0.74 ±0.05 kg for control, 50% deletion and 100% deletion of supplementary vitamins and trace minerals over a 7-week feeding period, respectively. Their respective feed:gain ratio, and carcass backfat thickness (mm) were 3.86±0.05, 3.90±0.20 and 3.96±0.05, and 23.7±2.49, 24.5±4.68 and 25.3±4.86. Deletion of vitamins and trace minerals from diets during the last 7 wk before slaughter had no effect ($P > 0.05$) on average daily gain ($P > 0.36$), feed:gain ($P > 0.62$) and backfat thickness ($P > 0.57$) (Table 4).

In experiment 2, average daily gain was 0.99±0.07, 0.91±0.02 and 0.90±0.02 kg for control, diet Ⅰ(100% deletion of premixes) and diet Ⅱ(diet Ⅰ plus 100 mg vitamin E/kg diet for the last 2 wk of experiment) over a 49-d feeding period, respectively. Their respective average daily feed intake was 3.10±0.12, 2.95± 0.06 and 2.94±0.05. Feed:gain ratio, and carcass backfat thickness (mm) were 3.14±0.23, 3.24±0.26 and 3.25±0.10, and 19.9±4.45, 19.0±3.78 and 18.7±6.74 for control, diet Ⅰ and diet Ⅱ, respectively. No significant differences were found among treatments in average daily gain ($P > 0.23$), average daily feed intake ($P > 0.12$) and feed/gain ratio ($P > 0.77$) during the last 49 d before slaughter, but weight gain and feed intake in pigs fed the control diet tended to be higher than those found in pigs fed a diet Ⅰ and diet Ⅱ, although the difference was not significant ($P > 0.05$) (Table 6).

These data are in agreement with Patience and Gillis (1995, 1996), who observed no 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. Similarly, removal of vitamin and trace mineral premixes from broiler diets during the last 1 to 3 wk before marketing had no effect on growth performance (Skinner et al., 1992b; Deyhim and Teeter, 1993; Christmas et al., 1995). Mavromichalis et al. (1999) and McGlone (2000) also reported that omitting vitamin and trace mineral premixes from the diet during the late finishing period had no effect on average daily gain and feed/gain in finishing pigs.

Although not significant, weight gain and feed intake in pigs fed the control diet tended to be higher than those found in the pigs fed a diet without premixes in experiment 2. Edmonds and Arentson (2001) found 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 those without supplements during the last 12 wk. Spurlock et al. (1998) also reported that withdrawal of premixes for 44 d from diets fed finishing pigs resulted in a significant decrease in weight gain and feed intake.

2. Effect of supplementary vitamin E on serum and muscle vitamin E contents in finishing pigs fed a diet without vitamin and trace mineral premixes

Average muscle α-tocopherol contents (mg/kg)±SD in ham was 3.74±0.53, 2.45±1.20 and 4.59±0.84 for control, diet Ⅰ (100% deletion of premixes) and diet Ⅱ (diet Ⅰ plus 100 mg vitamin E/kg diet for the last 2 wk), respectively. Average serum α-tocopherol contents(mg/L) was 1.50±0.72, 1.18±0.62 and 1.65±0.37 for control, diet Ⅰ and diet Ⅱ, respectively (Table 6). α-Tocopherol level in muscle of pigs fed diet II increased about 81% (P < 0.001) over that of pigs fed diet I, while α-tocopherol content in the serum was not significantly different among treatments.

Cannon et al. (1996) reported that α-tocopherol concentration was 10 times greater in longissimus muscle of pigs fed a diet containing 100 mg vitamin E/kg feed than in longissimus muscle of pigs fed a control. Another pig study done by Corino et al. (1999) showed that vitamin E concentrations in longissimus muscle increased 50% following feeding a high level of vitamin E (300 mg/kg diet) vs a low level (25 mg/kg) for 60 d in a late finishing period.

Monahan et al. (1990) reported that plasma and tissue levels of α-tocopherol were 2.5 to 3.0 times highter in pigs fed a diet supplemented with vitamin E (200 mg/kg diet) than in those fed a basal diet (30 mg/kg). Dove and Ewan (1991) reported that the addition of α-tocopheryl acetate (22 IU/kg diet) to a diet increased the α-tocopherol concentrations in bile, ham, heart, pancreas, kidney, spleen, liver, and psoas and longissimus muscle. Jensen et al. (1990) indicated that serum and liver α-tocopherol concentrations reflected the short-term vitamin E status of the pig, and that muscle and fat tissue concentrations reflected the long-term vitamin E status of the pig. Anderson (1995) reported that pigs (62 IU/kg diet) fed any of the compounds, DL-α-tocopherol, DL-α-tocopheryl acetate, D-α-tocopherol, and D-α-tocopheryl acetate had tissue α-tocopherol concentrations higher than the negative control. Soler-velasquez et al. (1998) and Anderson et al. (1995) indicated that additional α-tocopherol would be most likely stored in liver or muscle tissues. Bartov and Frigg (1992) reported that the stability of meat of birds fed the various combinations of vitamin E was significantly higher than that of birds which did not receive additional vitamin E.

Edmonds and Arentson (2001) reported that muscle vitamin E concentration in pigs fed a diet without vitamin and trace mineral premixes for 12 wk was markedly ($P < 0.001$) lower (61%) than was the case for pigs fed the diet with supplements. This lowered vitamin E content in the muscle can be replenished by adding 100 mg vitamin E/kg diet for the last 2 wk before slaughter, as shown in our study (Table 5).

3. Effect of deletion of supplementary vitamins and trace minerals on hemoglobin content, red blood cell count and hematocrit

Hemoglobin content (g/100 mL blood), hematocrit (volume %) and red blood cell counts (millions/mL)±SD were 14.2±0.7, 13.4±1.1 and 13.7±1.3; 44.5±2.0, 42.6±3.6 and 44.2±4.0; and 734±42, 697±79 and 719±69 for control, 50% deletion and 100% deletion of supplementary vitamins and trace minerals, respectively (Table 5). None of these values were significantly different among treatments.

Zimmerman (1980) reported that hemoglobin levels of 10 g/dL blood are considered adequate. A hemoglobin level, 8 g/dL, is suggestive of, or is borderline, of anemia, and a level less than 7 g/dL represents anemia. Values found in our study ranged from 13.4 to 13.7g/dL. Wilkinson et al. (1977) found that addition of Se, Cu and Zn in growing-finishing diets revealed no significant treatment differences in RBC Se uptake, plasma Se, Cu and Zn, whole blood Se, or hematocrit. Red blood cell counts and hematocrit values were found adequate in all pigs tested in our study.

4. Effect of deletion of supplementary vitamins and trace minerals on the fecal, muscle and serum trace mineral contents in finishing pigs

Fecal contents (mg/kg DM) of Mn, Zn and Mo were decreased ($P < 0.01$) by deleting premixes in the diets. However, all other mineral contents in the feces were not different among treatmints (Table 7).

Se content in muscle was reduced ($P < .0001$) 13 % over the control by deleting vitamin and trace mineral premixes. Mo also decreased ($P < 0.001$) by removing the premixes compared with the control. Withdrawing the premixes from diet for 49 d resulted in a 15 % and 27 % reduction in muscle Pb ($P < 0.01$) and Co ($P < 0.001$), respectively. Deletion of supplementary vitamins and trace minerals from diets during the last 49 d before slaughter had a significant effect on muscle Mo, Pb and Co (Table 8).

Removing vitamin and trace mineral premixes from diets during the last 49 d before slaughter had no effect on serum Cr, Mn, Fe, Cu, Zn, Mo, Cd, Pb, Co, and Ni (Table 9). Most minerals in feces, muscle and serum were not influenced by the dietary supplement. Significant differences in fecal Mn, Zn and Mo between the control and pigs fed the diet without the premixes were assumed to be due to the differences in their dietary concentrations (Table 3).

Significant reduction ($P < 0.001$) in fecal Mn, Zn and Mo in the pigs fed a diet without premixes compared with the control indicates that environmental load of some minerals can be reduced by removing supplementary minerals without adverse effect on animal performances. Edmonds and Arentson(2001) reported that muscle copper level was reduced by feeding pigs diets without supplement for 12 wk compared with that found in pigs fed diets with supplement. They also found decreased zinc concentration in longissimus muscle of pigs fed a diet with the supplement for 6 weeks compared with that found without the supplement.

V. Summary

Two experiments were conducted to determine the effects of deletion of vitamin and trace mineral premixes from diets on growth, feed efficiency, carcass quality, hemoglobin content, muscle vitamin E content, and serum and fecal trace mineral contents in finishing pigs. In experiment 1, three replicates of 5 pigs each (average weight, 70 kg) were assigned to a control (with VIT+TM premixes), 50% or 100% deletion of the premixes and fed to market weight under a suboptimal environment with saw dust-covered concrete floor and no electrical ventilation. In experiment 2, three replicates of 4 pigs (average weight, 56 kg) each were assigned to one of the following diets; a control (with premixes), diet I (100% deletion of premixes) or diet II (diet I plus 100 mg vitamin E/kg diet for the last 2 wk of experiment), and fed to market weight under a optimal environment with slat floor, electrical ventilation and temperature control. No significant differences were found in average daily gain (ADG), average daily feed intake (ADFI), and feed/gain among treatments in both experiments, but in experiment 2 done with younger pigs ADG and ADFI in the control group tended to be higher than those found in the pigs fed a diet without premixes. Dressing percentage and backfat thickness were not significantly different among treatments. Fecal trace mineral contents in pigs fed the control diet were significantly ($P<0.01$) higher, especially Mn (two folds), Zn (three) and Mo (two) compared with those found in pigs fed diets without premixes. Serum trace mineral contents were not influenced by diets. The deletion of premixes decreased ($P<0.01$) muscle α-tocopherol contents, but addition of α-tocopherol acetate for the last 2 wk before slaughter increased vitamin E content up to the control level. Results indicate that supplementary vitamins and trace minerals

are not required for normal growth or carcass quality in finishing pigs, and lowered vitamin E content in the muscle by deletion of premixes can be reversed by addition of α-tocopherol for the last 2 wk before slaughter.

Key Words: Pigs, vitamins, trace minerals, growth

Table 1. Comparison of trace mineral and vitamin contents in diets with their a requirements in finishing pigs (90 % DM basis)

Item	Corn[1]	Soybean meal[1]	Corn +soybean meal[2]	Requirement[3]	
				50-80kg	80-120kg
Trace minerals (per kg of diet)					
Copper (mg)	3	20	5.5	3.50	3.00
Iodine (mg)	-	-	-	0.14	0.14
Iron (mg)	29	202	54.6	50	40
Manganese (mg)	7	29	10.1	2.00	2.00
Selenium (mg)	0.07	0.32	0.11	0.15	0.15
Zinc (mg)	18	50	22	50	50
Vitamins (per kg of diet)					
Vitamin A (IU)	213.6	53.4	175	1300	1300
Vitamin D_3 (IU)	-	-	-	150	150
Vitamin E (IU)	8.3	2.3	6.75	11	11
Vitamin K (mg)	-	-	-	0.50	0.50
Biotin (mg)	0.06	0.27	0.09	0.05	0.05
Folacin (mg)	0.15	1.37	0.33	0.30	0.30
Niacin, available (mg)	24c	34	24.1	7.00	7.00
Pantothenic acid (mg)	6.0	16	7.22	7.00	7.00
Riboflavin (mg)	1.2	2.9	9.84	2.00	2.00
Thiamin (mg)	3.5	4.5	3.45	1.00	1.00
Vitamin B_6 (mg)	5.0	6.0	4.68	1.00	1.00
Vitamin B_{12} (µg)	-	-	-	5.00	5.00

[1]Trace mineral and vitamin composition of feed ingredients(corn and soybean meal) commonly used for swine(NRC, 1998)

[2]Based on corn and soybean meal with the ratio of 77 : 15.8.

[3]Requirements of swine (NRC, 1998)

Table 2. Composition of experimental diets (Exp. 1)

Item	Control	1/2(VIT+TM)[1]	0(VIT+TM)[1]
Ingredients, % of diet			
Corn	77	77.075	77.15
Soybean meal	15.8	15.8	15.8
Molasses	3	3	3
Lysine	0.1	0.1	0.1
Limestone	0.6	0.6	0.6
Tricalcium phosphate	1	1	1
Tallow	2	2	2
Premix(VIT+TM)[2]	0.15	0.075	0
Salt	0.35	0.35	0.35

[1]Vitamin and trace mineral premixes

[2]Contents per kg 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 3. Composition of experimental diets (Exp. 2)

Item	Control	Without Premix (Diet Ⅰ or Diet Ⅱ[1])
Ingredients, % of diet		
Corn	58.23	58.43
Soybean meal	22.77	22.77
Wheat	5.00	5.00
Wheat bran	5.00	5.00
Molasses	3.00	3.00
Tallow	4.25	4.25
Salt	0.30	0.30
Tricalcium phosphate	0.95	0.95
Limestone	0.30	0.30
Premix[2]	0.20	-
Analyzed composition, mg/kg(DM basis)		
Se	3.53	3.37
Cr	<2.33	<2.33
Mn	57.8	36.9
Fe	329.0	303.0
Cu	93.3	91.6
Zn	178.8	88.6
Mo	2.13	1.45
Cd	<0.28	<0.28
Pb	7.06	6.92
Co	1.16	0.78
Ni	8.0	7.91

[1]α-Tocopherol acetate (100mg/kg diet) was supplied for last 14 d.

[2]Contents per kg 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.

Table 4. Effect of deletion of supplementary vitamins and trace minerals on weight gain, feed/gain and backfat thickness in finishing pigs (Exp. 1)

Item	Control	1/2(VIT+TM)[1]	0(VIT+TM)[1]	P
Initial wt., kg	70.2±0.91	69.6±0.41	70.3±1.61	
Final wt., kg	109.1±2.04	106.5±1.30	107.7±1.22	0.2071
ADG[2], kg/d				
0 - 3 wk.	0.68±0.04	0.66±0.03	0.68±0.05	0.7822
3 - 7 wk.	0.84±0.05	0.78±0.08	0.80±0.06	0.4960
0 - 7 wk.	0.78±0.04	0.73±0.03	0.74±0.05	0.3626
ADFI[3], kg/d				
0 - 3 wk.	2.71±0.07[a]	2.55±0.01[b]	2.60±0.06[b]	0.0328
3 - 7 wk.	3.13±0.15	2.90±0.10	3.03±0.25	0.3454
0 - 7 wk.	3.00±0.10	2.85±0.05	2.97±0.21	0.4219
F/G ratio[4]				
0 - 3 wk.	3.95±0.19	3.85±0.22	3.66±0.26	0.3582
3 - 7 wk.	3.70±0.17	3.80±0.50	3.83±0.21	0.8771
0 - 7 wk.	3.86±0.05	3.90±0.20	3.96±0.05	0.6297
Backfat thickness, mm	23.7±2.49	24.5±4.68	25.3±4.86	0.5780

[1]Vitamin and trace mineral premixes

[2]Average daily gain

[3]Average daily feed intake

[4]Feed intake/weight gain

Table 5. Effect of deletion of supplementary vitamins and trace minerals on hemoglobin content, red blood cell count and hematocrit in finishing pigs (Exp. 1)

Item	Control	1/2(VIT+TM)[1]	0(VIT+TM)[1]	P
Hemoglobin (g/100mL blood)	14.2±0.66	13.4±1.08	13.7±1.27	0.1520
Red blood cell count (million/mL)	734.2±41.8	696.8±78.6	718.6±69.2	0.2965
Hematocrit (Volume%)	44.5±1.95	42.6±3.59	44.2±4.0	0.2610

Values are means with standard deviation of 45 pigs.

[1]Vitamin and trace mineral premixes

Table 6. Effect of deletion of supplementary vitamins and trace minerals on weight gain, feed/gain, serum and muscle vitamin E in finishing pigs[1] (Exp. 2)

Item	Control	Without Premix (Diet Ⅰ)	Without Premix + With Vitamine E[2] (Diet Ⅱ)	P
ADG, kg/d				
0 – 30 d.	0.98±0.09	0.90±0.10	0.89±0.03	0.3904
31 – 49 d.	1.01±0.18	0.94±0.02	0.91±0.05	0.5759
0 – 49 d.	0.99±0.07	0.91±0.06	0.90±0.02	0.2350
ADFI, kg/d				
0 – 30 d.	3.07±0.10	2.93±0.10	2.92±0.06	0.1477
31 – 49 d.	3.08±0.20	2.98±0.06	2.97±0.08	0.6124
0 – 49 d.	3.10±0.12	2.95±0.06	2.94±0.05	0.1239
F/G ratio				
0 – 30 d.	3.15±0.20	3.28±0.34	3.24±0.07	0.7951
31 – 49 d.	3.09±0.34	3.18±0.14	3.25±0.17	0.6976
0 – 49 d.	3.14±0.23	3.24±0.26	3.25±0.10	0.7799
Serum vitamin E, mg/L				
at d 30	1.70±0.50	1.41±0.48	1.31±0.31	0.1106
at d 49	1.50±0.72	1.18±0.62	1.65±0.37	0.1772
Muscle vitamin E, mg/kg[3]	3.74±0.53[b]	2.45±0.42[c]	4.59±0.84[a]	0.0001
Back fat thickness, mm	19.9±4.54	19.0±3.78	18.7±6.74	0.8454
Dressing percentage	71.6±6.63	72.8±7.68	70.5±7.03	0.8454

Values are means with standard deviation of 12 pigs (4 pigs/pen and three pens/treatment)

[abc]Values in the same row sharing no common superscripts differ significantly ($P<0.05$)

[1]Pigs with an average initial BW of 56.3 kg and an average final BW of 102.1 kg.

[2] α-Tocopherol acetate (100mg/kg diet) was supplied for last 14 d.

[3]Muscle α-tocopherol content in ham area (wet basis).

Table 7. Effect of deletion of supplementary vitamins and trace minerals on the fecal trace mineral contents in finishing pigs (Exp. 2)

Item	Control	Without Premix (Diet Ⅰ)	Without Premix + With Vitamine E (Diet Ⅱ)	P
Fecal TM[2], mg/kg				
Se	5.13±0.33	4.98±0.08	4.69±0.23	0.1568
Cr	11.2±1.70	11.1±1.13	13.1±1.25	0.2218
Mn	345.7±34.3[a]	146.7±8.02[b]	166.3±17.9[b]	0.0001
Fe	1723±34.6	1556±154.0	1545±50.4	0.1107
Cu	520.3±45.5	458.0±58.9	502.6±46.4	0.3632
Zn	1086.3±68.0[a]	301.8±44.5[b]	312.0±37.0[b]	0.0001
Mo	3.73±0.55[a]	1.97±0.04[b]	2.17±0.56[b]	0.0013
Cd	0.39±0.05	0.48±0.18	0.40±0.08	0.6331
Pb	6.66±1.36	5.40±1.25	7.70±1.31	0.1791
Co	1.70±0.07	1.51±0.38	1.94±0.18	0.1844
Ni	17.5±2.60	16.0±1.05	17.2±1.03	0.5453

Values are means with standard deviation of three replicates of pooled samples.

[ab]Values in the same row sharing no common superscripts differ significantly ($P<0.05$)

[1]α-Tocopherol acetate (100mg/kg diet) was supplied for last 14 d.

[2]Trace mineral contents (dry matter basis).

Table 8. Effects of omitting vitamins and trace minerals on the muscle trace mineral contents in finishing pigs(Exp. 2)

Item	Control	Without Premix (Diet Ⅰ)	Without Premix + With Vitamine E[1] (Diet Ⅱ)	P
Muscle TM[2], mg/kg				
Se	1.64±0.12[a]	1.42±0.14[b]	1.36±0.13[b]	0.0001
Cr	<0.5	<0.5	<0.5	-
Mn	0.10±0.01	0.09±0.01	0.09±0.01	0.3107
Fe	7.84±1.60	8.14±1.59	7.93±1.42	0.8830
Cu	1.26±0.30	1.32±0.26	1.14±0.37	0.2462
Zn	14.46±2.52	14.16±1.78	13.11±2.31	0.1241
Mo	0.17±0.03[a]	0.13±0.04[b]	0.11±0.02[b]	0.0002
Cd	0.021±0.004	0.019±0.003	0.018±0.002	0.1451
Pb	0.66±0.11[a]	0.56±0.24[ab]	0.43±0.11[b]	0.0096
Co	0.11±0.02[a]	0.08±0.02[b]	0.06±0.01[b]	0.0001
Ni	0.71±0.10	0.64±0.08	0.71±0.17	0.3496

Values are means with standard deviation of 12 pigs.

[ab]Values in the same row sharing no common superscripts differ significantly ($P<0.05$)

[1]α-Tocopherol acetate (100 mg/kg diet) was supplied for last 14 d.

[2]Trace mineral contents in ham area (wet basis).

Table 9. Effect of deletion of supplementary vitamins and trace minerals on the serum trace mineral contents in finishing pigs (Exp. 2)

Item	Control	Without Premix (Diet Ⅰ)	Without Premix + With Vitamine E[1] (Diet Ⅱ)	P
Serum TM[2], mg/kg				
Se				
at d 30	<0.31	<0.31	<0.31	
at d 49	<0.31	<0.31	<0.31	
Cr				
at d 30	1.60±0.09	1.52±0.32	1.57±0.25	0.1212
at d 49	2.24±0.42	2.26±0.35	2.21±0.29	0.9327
Mn				
at d 30	0.15±0.02	0.16±0.04	0.16±0.03	0.7159
at d 49	0.20±0.03	0.21±0.03	0.21±0.03	0.4596
Fe				
at d 30	8.00±1.96	9.07±2.76	10.13±2.43	0.1118
at d 49	11.87±3.07	12.16±2.27	10.81±3.18	0.4889
Cu				
at d 30	1.67±0.25	1.71±0.44	1.83±0.29	0.4678
at d 49	1.68±0.31	1.87±0.46	1.82±0.30	0.1676
Zn				
at d 30	2.84±0.46	2.85±0.48	2.97±0.44	0.7496
at d 49	2.66±0.53	2.49±0.51	2.63±0.61	0.7396
Mo				
at d 30	0.22±0.12	0.28±0.18	0.33±0.13	0.2022
at d 49	0.29±0.16	0.41±0.18	0.40±0.12	0.1268
Cd				
at d 30	0.06±0.02	0.08±0.03	0.09±0.02	0.1608
at d 49	0.07±0.03	0.10±0.03	0.10±0.02	0.0647
Pb				
at d 30	1.15±0.64	1.24±0.63	1.61±0.65	0.1903
at d 49	1.54±0.64	1.99±0.90	2.11±0.82	0.1974
Co				
at d 30	0.30±0.11	0.36±0.18	0.40±0.13	0.2943
at d 49	0.43±0.14	0.53±0.18	0.52±0.12	0.2611
Ni				
at d 30	1.54±0.53	1.52±0.92	1.53±0.57	0.9958
at d 49	1.63±0.58	1.81±0.64	1.94±0.47	0.4266

Values are means with standard deviation of 12 pigs.
[1]α-Tocopherol acetate (100 mg/kg diet) was supplied for last 14 d.
[2]Trace mineral contents

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감사의 글

이제 2 년간의 대학원 생활을 마감하는 지금 내 자신을 되돌아보며 그 동안 많은 도움을 주신 주위 분들에게 고마운 마음을 갖게 됩니다.

이 논문이 완성되기까지 저에게 학문의 길을 깨닫게 해주시고 아낌없는 지도와 격려를 해 주신 지도교수 김규일 박사님께 진심으로 감사 드립니다. 더불어 따뜻한 정성으로 지도를 해 주신 양영훈 교수님과 강정숙 교수님께도 감사 드립니다. 또한 학기동안 항상 관심을 기울여 주시고 용기를 주신 정창조 교수님, 김중계 교수님, 강태숙 교수님, 이현종 교수님, 김문철 교수님, 강민수 교수님, 박찬규 교수님께도 감사의 뜻을 전합니다.

어려운 여건 속에서도 모든 과정을 마칠 수 있게 도와주신 농협나주배합사료공장 최동철 장장님 이하 전 직원에게도 이 글을 빌어 감사의 마음을 전합니다.

석사 입학에서부터 논문의 탈고까지 많은 도움을 주신 제주농업시험장 이종언 연구사님께 감사 드립니다. 또한 동물 영양학 실험실에서 같이 고생해 준 주은숙 원우와 그리고 이기영, 윤병권, 장진영, 고유나, 정오준, 양충홍, 박윤호 후배들에게 고마움을 전합니다. 이제는 다시 볼 수 없게 된 고 김상조군에게도 고인의 명복을 빕니다.

대학원 생활을 동고동락한 황경준 원우 그리고 기숙사 생활을 도와준 동조에게도 고맙다는 말을 전하고 싶습니다.

끝으로 항상 그 자리에서 저를 믿고 지켜봐 주시는 사랑하는 나의 가족, 특히 부모님께 감사의 마음을 전하며 이러한 마음을 이 한 권의 논문으로 대신 하고자 합니다.