Effect of Phase Feeding on the Growth Performance, Nutrient Utilization and Carcass Characteristics in Finishing Pigs[a]

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ABSTRACT : This study was carried out to establish an optimum number of phase feeding regimen which enable to reduce nutrients excretion without affecting growth performance and to investigate the effects of different feeding regimens on growth performance, nutrients excretion and carcass characteristics in finishing pigs. A total of 120 finishing pigs (an average initial body weight of 54.3 kg) were assigned to the feeding trial and 12 pigs were assigned to the metabolic trial. Treatments included one phase (54 to 104 kg), two phase (54 to 80 and 80 to 104 kg), three phase (54 to 70, 70 to 90 and 90 to 104 kg) and four phase (54 to 65, 65 to 80, 80 to 95, 95 to 104 kg) feeding regimens. Experimental diets were formulated to contain 16% crude protein for one phase feeding regimen, 16% and 12% crude protein for two phase feeding regimen, 16%, 14% and 12% crude protein for three phase feeding regimen, and 16%, 14.7%, 13.4% and 12% crude protein for four phase feeding regimen, respectively. Although there were no significant differences in any criteria measured during the entire experimental period, pigs reared in three phase feeding regimen grew slightly faster than those reared in other feeding regimens and showed a tendency to increase ADFI during the whole experimental period. The metabolic trial indicated that there were no significant differences in DM (dry matter), CP (crude protein) and P (phosphorus) digestibilities. However, fecal nutrient excretion except P was significantly influenced by feeding regimens. DM excretion of one phase feeding group was significantly higher than that of three phase feeding group and daily fecal N (nitrogen) excretion of one phase feeding group was higher than that of other phase feeding groups ($p<0.05$). Three and four phase feeding regimens resulted in 12% lower fecal N and DM excretion than one phase feeding regimen. Blood urea concentrations were lower for pigs reared in two, three and four phase feeding regimens than for those reared in one phase feeding regimen ($p<0.05$). Three phase feeding regimen for the finishing period showed better carcass grade than one phase feeding regimen, though the difference was not significant. The tenth rib fat thickness of pigs fed on four phase feeding regimen was reduced most and there was a trend that backfat thickness decreased as the number of phases increased. Feed cost per kg weight gain was significantly low in four phase feeding group than one phase feeding group ($p<0.05$). In summary, it seemed that producers generally oversupply the expensive nutrients for the finishing pigs. High nutrient diets do not always guarantee high growth rate of pigs and cause more unwanted nutrient excretion. It rather seems that meeting nutrient requirements for the each growth phase is more important for the reduction of pollutants and economical pork production. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 8 : 1137-1146*)

Key Words : Phase Feeding, Finishing Pigs, Growth Performances, Carcass Characteristics, Blood Urea Nitrogen, Nutrient Excretion

INTRODUCTION

There is an increasing concern on the negative impact of livestock production systems on the environment. The most feasible ways to reduce animal excreta are to improve digestibility of nutrients by adding metabolically active substances, such as enzymes or yeast (Han and Min, 1991; Kwon et al., 1995a, b; Noh et al., 1995), and to reduce dietary crude protein content by adding synthetic amino acids (Han et al., 1978, 1995; Daghir, 1983; Jin et al., 1997; Chae et al., 1998). Recently, it has been recognized that phase feeding could be used to reduce nitrogen and phosphorous excretion by feeding pigs in accordance with age and physiological state (Jongbloed and Lenis, 1992; Paik et al., 1996; Mosenthin, 1996; Honeyman, 1996). The concept of phase feeding dictates the use of multiple diets to better match the continuously changing nutrient needs of growing pigs. Generally, it has been known that conventional feeding programs (usually one or two phase feeding in finishing period) can not be a suitable regimen to meet the rapidly changing nutrient requirements of pigs. Therefore, as solutions of this problem, a phase feeding system and a choice feeding system have been developed. In previous studies, it was reported that individually housed pigs could differentiate diets of different protein levels and tended to intake as much protein as to meet their requirement (Devilat et al., 1970; Kyriazakis et al., 1990). However, more recently, a series of studies have shown that pigs do not have the ability to select a protein intake to meet

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their requirement when provided a choice of isoenergetic diet differing in protein content (Gourley et al., 1993; Owen et al., 1994; Nam and Aherne, 1995). Based on this finding, it is more likely that phase feeding system is a more appropriate method for reduction of pollutants and feeding nutrients tailored to their stage of production in pigs. Considering the fact that finishing pigs excrete much more pollutants than do piglets or growing pigs and both amino acids and phosphorus concentrations per kg feed decreases as the live weight of the pig increases, it is evident that phase feeding system is very effective to reduce pollutant excretion from finishing pigs. In 1995, a total of 4.73 million tons of swine feeds were produced in Korea, out of which only 1.9% accounted for finisher diet (Han, 1996). This means that swine producers in Korea have oversupplied nutrient to their pigs, and over 90% of finishing pigs were raised on growing pig diets. In addition, it has been pointed out that nutrient requirement for finishing pigs is so highly established that it may cause waste of precious protein source and negative impact on the environment.

In our previous study, Han et al. (1998) reported that two phase feeding regimen using low-nutrients diets for finishing pigs was so effective as to reduce N and P excretion without sacrificing growth performance. Therefore, this experiment was carried out to establish the optimum number of phase feeding regimens for finishing pigs and to investigate the effects of different feeding regimen on growth performance, nutrients excretion and carcass characteristics of finishing pigs.

MATERIALS AND METHODS

A total of 120 finishing pigs (Landrace × Large White × Duroc) averaging 54.3±0.7 kg of body weight were chosen and allotted to four different phase feeding regimens. Experimental design and feeding program are listed in table 1. Each treatment had six replicates with five pigs per replicate. Treatments included one phase (54 to 104 kg), two phase (54 to 80 and 80 to 104 kg), three phase (54 to 70 kg, 70 to 90 kg and 90 to 104 kg) and four phase (54 to 65 kg, 65 to 80 kg, 80 to 95 kg and 95 to 104 kg) feeding groups. Experimental diets were formulated to contain 16% crude protein for one phase feeding regimen, 16% and 12% crude protein for two phase feeding regimen, 16%, 14% and 12% crude protein for three phase feeding regimen, and 16%, 14.7%, 13.4% and 12% crude protein for four phase feeding regimen, respectively. The three major limiting amino acids (lysine, methionine and threonine) were added to diets according to the ideal amino acids pattern suggested by Chung and Baker (1992). To make 14.7% and 13.4% crude protein diets, 16% crude protein diet was mixed with 12% crude protein diet in proportion. The formula and chemical composition of experimental diets are presented in table 2.

Table 1. Experimental design

	Treat 1	Treat 2	Treat 3	Treat 4
No. of phase	Single	Two	Three	Four
Replication	6	6	6	6
Pigs/pen	5	5	5	5
Sub total	30	30	30	30

(Total 120 pigs)

Treat 1: One phase (54~104 kg, CP 16%).
Treat 2: Two phase (54~80 kg, CP 16%), (80~104 kg, CP 12%).
Treat 3: Three phase (54~70 kg, CP 16%), (70~90 kg, CP 14%), (90~104 kg, CP 12%).
Treat 4: Four phase (54~65 kg, CP 16%), (65~80, CP 14.7%), (80~95 kg, CP 13.4%), (95~104 kg, CP 12%).

Table 2. Formula and chemical composition of the experimental diets

Items	Diet 1	Diet 2	Diet 3
Ingredients:			
Corn	68.232	74.302	78.362
Soybean meal (44%)	23.44	18.05	12.53
Wheat bran	3.00	2.50	3.90
Tallow	2.60	2.30	2.40
Limestone	0.30	0.20	0.20
Tricalcium phosphate	1.50	1.70	1.74
NaCl	0.30	0.30	0.30
L-lysine-HCl	0.11	0.16	0.13
DL-Methionine (98%)	0.07	0.03	0.01
Threonine	0.04	0.05	0.02
Vit.-min. premix[1]	0.293	0.293	0.293
Antibiotics	0.060	0.060	0.060
Choline chloride	0.055	0.055	0.055
Total	100.00	100.00	100.00
Chemical composition[2]:			
ME (kcal/kg)	3,350.00	3,350.00	3,350.00
Crude protein (%)	16.00	14.00	12.00
Lysine (%)	0.92	0.81	0.65
Met.+cys. (%)	0.61	0.52	0.42
Threonine (%)	0.64	0.56	0.46
Ca (%)	0.70	0.71	0.70
Total P (%)	0.60	0.61	0.60

[1] Provided the following per kilogram of diet: vitamin A 5,500 IU, vitamin D_3 550 IU, vitamin E 27 IU, menadione sodium bisulfate 2.5 mg, pantothenic acid 27 mg, niacin 33 mg, riboflavin 5.5 mg, vitamin B_{12} 0.04 mg, thiamin 5 mg, pyridoxine 3 mg, biotin 0.24 mg, folic acid 1.5 mg, choline chloride 700 mg, selenium 0.15 mg, manganese 0.03 g, zinc 0.1 g, iron 0.1 g, iodine 0.5 mg, magnesium 0.1 g.
[2] Calculated value.

Pigs were housed in a concrete floored pen (1.6 m × 3 m), equipped with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water throughout the whole experimental period. Temperature was not controlled in this study. Since this experiment was initiated in May and finished in July, the range of temperature in the building varied according to the environmental temperature from 22 to 31℃.

To determine the excreted amount of nutrients, feces were collected every day. 12 pigs averaging 62 kg, 72 kg, 87 kg, 100 kg of body weight, respectively, were housed in an individual metabolic cage. Diets corresponding to each of the phase feeding regimen were offered to the pigs. After four days of adaptation period, pigs were subjected to 3-d collection period. Total amount of feeds consumed and excreta were recorded daily during the metabolic trial. Collected excreta were pooled, sealed in plastic bags, and stored at -20℃ until they were dried in an air forced drying oven at 60℃ for 72 hours. Dried fecal samples were ground with 1 mm Wiley Mill for chemical analyses.

Blood was sampled directly from the jugular vein. The samples obtained between 07:00 and 07:30, before the pigs were fed. At this time, no feed was left in feeders from the previous feeding. This time of blood collection was considered appropriate because previous research (Arentson, 1990) indicated that blood urea nitrogen (BUN) response to different dietary lysine concentration were similar in fed and unfed pigs. Blood samples from six pigs per treatment were obtained weekly. In order to avoid individual difference in feed intake a total of 24 pigs having similar body weights were picked out for blood sample collection before the experiment began. Initial BUN (adjustment period) was used as a covariate. Blood was collected from the same pigs each week during the whole experimental period. This was considered appropriate because one previous study (Phillip et al., 1998) suggested that it would be desirable to take blood from just a few pigs rather than selecting all pigs for blood sampling. After blood sample collection, all samples were quickly transferred to a centrifuge tube and then centrifuged for 15 min at 3,000 rpm in a cold chamber (5℃). The serum was carefully removed to plastic vials and stored at -20℃ for blood urea analyses. Total blood urea concentration was analyzed by blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning Diagnostics Co.).

The entire experimental pigs were slaughtered when they reached to an average body weight of 104 kg. The tenth rib fat thickness (cm), carcass percentage (%) and carcass grade were measured.

Analyses of proximate nutrients of experimental diets and excreta was done according to the methods of AOAC (1990), and gross energy content was measured using the Adiabatic Bomb Calorimeter (Model 1241, Parr Instrument Co., USA).

Statistical analyses were made by comparing means using Duncan's multiple range test (Duncan, 1955), by General Linear Model (GLM) procedure of SAS (1985) package program.

RESULTS AND DISCUSSION

Growth performance

Table 3 summarized the effect of different feeding regimens on the growth performance of finishing pigs. From 54 to 70 kg, average daily gain (ADG), average daily feed intake (ADFI) and feed/gain (F/G) were not affected by treatment. From 70 to 90 kg, feed intake was lowest for pigs reared in four phase feeding regimen ($p<0.05$). However, increased ADG at low ADFI resulted in improved F/G of pigs reared in four phase feeding regimen. Throughout the whole experimental period, no significant difference was found in any of the criteria measured. Pigs reared in three phase feeding regimen gained weight slightly faster than pigs fed on other feeding regimens and showed a tendency to increase ADFI during the whole experimental period, but the difference was not significant. F/G was numerically improved in pigs reared in four phase feeding regimen.

Nam and Aherne (1995) reported that in the growth phase from 50 to 110 kg, phase feeding systems had no effect on growth performance. Han et al. (1998) indicated that there was no effect of different feeding regimen on the growth performance of finishing pigs (60 to 105 kg) in a study to evaluate the effect of phase feeding regimen of 4 different combinations of diets for grower, early finisher and late finisher. Their results coincided with the result from this study. Recently, Cahn et al. (1998) fed three diets with different crude protein levels (16.5, 14.5 and 12.5%), but similar net energy and ileal digestible lysine, methionine+cystine, threonine and tryptophan contents to growing-finishing pigs. They observed no significant effects of reduced protein levels on daily gain, feed intake, feed conversion ratio and carcass yield but a significant reduction of N excretion as crude protein level in diet decreased. Dourmad et al. (1996) reported that the requirement for true digestible lysine decreased from about 0.80 g/MJ in NE at 50 kg to 0.63 g/MJ at 100 kg live weight.

In the present experiment, it is interesting to note that there was no significant difference in growth performances between one phase feeding (High CP feeding group) and two phase feeding (Low CP feeding group) for an entire finishing period. In previous works, it has been found that lysine requirements for the finishing pig can be even lower. Goodband et al. (1989) observed no additional

Table 3. Effects of different feeding regimen on the growth performance of finishing pigs

Items	Treat 1[1]	Treat 2	Treat 3	Treat 4	MSE[2]
(54 to 70 kg)					
Initial weight (kg)	54.21	54.25	54.15	54.17	0.11
Final weight (kg)	70.94	70.83	71.26	70.82	0.98
ADG (kg)	0.796	0.789	0.815	0.793	0.05
ADFI (kg)	2.53	2.49	2.58	2.54	0.11
Feed/gain	3.17	3.16	3.17	3.20	0.16
(70 to 90 kg)					
Final weight (kg)	91.56	91.34	91.93	92.14	1.71
ADG (kg)	0.859	0.854	0.861	0.889	0.05
ADFI (kg)	2.65[ab]	2.60[ab]	2.74[a]	2.56[b]	0.12
Feed/gain	3.08[ab]	3.06[ab]	3.19[a]	2.88[b]	0.17
(90 to 104 kg)					
Final weight (kg)	103.45	103.41	104.38	104.16	1.84
ADG (kg)	0.660	0.671	0.692	0.668	0.06
ADFI (kg)	2.41	2.52	2.48	2.47	0.20
Feed/gain	3.66	3.79	3.60	3.72	0.19
(54 to 104 kg)					
Initial weight (kg)	54.21	54.25	54.15	54.17	0.10
Final weight (kg)	103.45	103.41	104.38	104.16	1.83
ADG (kg)	0.771	0.771	0.789	0.783	0.03
ADFI (kg)	2.53	2.54	2.60	2.52	0.07
Feed/gain	3.28	3.28	3.29	3.22	0.09

[1] See table 1 for abbreviation; [2] Mean standard error.
[a,b] Means in the same row with different superscripts differ ($p<0.05$).

improvements in performance when pigs were offered a dietary lysine content exceeding 0.60%. Cromwell et al. (1993) suggested that barrows and gilts weighing 47 to 103 kg required 0.60% lysine and more than 0.90% lysine in corn-soybean meal diets for maximum performance and carcass leanness, respectively. Nelssen et al. (1995) reported that finishing gilts from 90 kg to 110 kg require between 0.60% to 0.70% (18 to 20 g/d) of dietary lysine to maximize both growth performance and carcass characteristics. Also, Hines et al. (1993) reported that there was no significant difference in ADG and ADFI between pigs fed the low lysine diets with 0.80 and 0.60% lysine for the growing (20 to 68 kg) and finishing (68 to 113 kg) period of the two phases, respectively, and pigs fed the high lysine diets with 0.95, 0.80, 0.70 and 0.60% lysine for the growing-finishing period of the four phases (20 to 45 kg, 45 to 68 kg, 68 to 90 kg and 90 to 113 kg, respectively). More recently, Friesen et al. (1995) studied on dietary lysine requirement for high-lean growth gilts from 72 to 136 kg. In their study, growth performances were not influenced by different lysine levels of diets (0.62 to 1.13% total lysine). Dourmad et al. (1996) reported that ADG appeared much less sensitive to digestible lysine supply which is below the requirement in finishing pigs than in growing pigs. Therefore, based on the data from these studies and the present study, it can be suggested that over 14% of crude protein for finishing pigs does not necessarily guarantee high growth rate and diet of 12% crude protein might be fed to finishing pigs for the latter part of finishing period. It rather seems that meeting the animal's need for amino acids without over-supply is more important. Consequently, phase feeding regimen which enable pigs to closely meet their nutrient requirement without over-feeding is a very effective method to reduce pollutant excretion without affecting animal growth performance.

Nutrients utilization

Table 4 showed the effects of different phase feeding regimens on the nutrient digestibility and fecal nutrient excretion. No significant difference was found in dry DM, CP and P digestibilities. However, fecal nutrient excretion except for P was significantly influenced by dietary treatment. Daily DM excretion of one phase feeding group was significantly higher than that of three phase feeding group and daily N excretion of one phase feeding group was higher than that of other phase feeding group ($p<0.05$). In this study, three and four phase feeding regimens resulted in 12% lower N and DM excretion than one phase feeding regimen, respectively. This result obviously

Table 4. Effects of different feeding regimens on the nutrient digestibility and fecal nutrient excretion of finishing pigs

Items	Treat 1[1]	Treat 2	Treat 3	Treat 4	MSE[2]
Nutrient digestibilites,					
Dry matter (%)	85.3	85.8	86.7	85.9	1.32
Crude protein (%)	83.1	82.7	83.1	83.0	1.79
Phosphorus (%)	45.1	45.8	45.7	45.6	5.22
Fecal nutrient excretions					
Dry matter (g/day)	282.8[a]	270.3[ab]	248.4[b]	263.4[ab]	26.60
Nitrogen (g/day)	8.9[a]	8.0[b]	7.8[b]	7.9[b]	0.99
Phosphorus (g/day)	6.29	6.43	6.03	6.18	0.58

[1] See table 1 for abbreviation; [2] Mean standard error.
[a,b] Means with different superscript in the same row differ at $p<0.05$.

shows that the application of phase feeding regimen to pigs for the finishing period is very effective to reduce N excretion.

It has been known that phase feeding is a desirable feeding regimen that could reduce a large amount of nutrient excretion by feeding pigs in accordance with age and physiological state without deterioration of performances in pigs (Jongbloed and Lenis, 1992; Paik et al., 1996; Mosenthin, 1996; Honeyman, 1996). Koch et al. (1990) reported that by matching the feed's nutrient composition to pig's requirement at a given age and weight through phase feeding system, N excretion could be reduced by 14% and N retention could be improved by 10%. Lenis (1989) and Coppoolse et al. (1990) reported that N and P excretion could be reduced 6% by going from one feed for the grower-finisher period to two feeds. Han et al. (1998) investigated the effects of different nutrient contents of the diets on the nutrient digestibility and nutrient excretion in finishing pigs and reported that there was a trend that pigs fed low nutrient content diets excreted less amount of N and P than pigs fed high nutrient content diet, and reducing about 2 percentage unit of CP resulted in 18% reduction in N excretion from 85 kg pigs. In the present study, since all experimental diets are formulated to contain the same levels of total P (0.6% of diets), it seems that there was no significant difference in P digestibility and excretion between treatments.

According to the research by Henry and Dourmad (1993), a slightly larger reduction in N and P excretion by growing pigs could be achieved by the multi-phase feeding. Bourdon et al. (1995) applied multi-phase feeding to growing-finishing castrated male pigs between 25 and 100 kg live weight and decreased dietary protein levels, with supplementary addition of limiting amino acids, down to 13 and 10.7% in the multi-phase diets A and B, respectively compared to a single control diet containing 16.7% crude protein. They reported that the amount of N excretion was reduced by even 50% with 10% accounting for multi-phase feeding. Jongbloed and Lenis (1992) also suggested that with this regard, the multi-phase feeding system in finishing pigs is a still more potent means to achieve an important reduction in N excretion than the usual two-phase feeding technique.

Though nitrogen excretion via urine was not investigated in this study, the main part of ammonia emission is originated from urea in urine (Lenis, 1989). A much bigger proportion of N excretion appears in the urine, mainly as a result of degradation of superfluous amino acids which can not be used for body protein deposition in pigs (Lenis, 1989; Jongbloed and Lenis, 1992). Also protein digested in the hindgut is excreted mostly as urinary N (Lenis, 1989). Thus, it should be considered to provide nutrients to pigs according to the each growth stage as a feeding regimen for successful swine industry not only for the improvement in growth rate but also for the environmental contamination by pig production. Recently, Obrock et al. (1997) investigated the effects of dietary protein concentration on ammonia production in swine facilities. They found that reducing dietary crude protein by 4% and formulating the diet to meet the requirements for the first four limiting amino acids decreased aerial ammonia concentration by 29%. These results mean that reducing protein concentration could reduce nitrogen excretion as well as ammonia production. A decrease in ammonia production should be beneficial for both pigs and human, if pigs were raised in a closed building. Since, most of modern pigs are raised in a closed building, there should be more study on the relationship between feeding regimen and ammonia production.

Blood urea nitrogen concentration

The response of blood urea concentration vs time (week) to different feeding regimens during the 63-day experiment is shown in table 5 and figure 1. Blood urea nitrogen (BUN) concentration ranged from 7.9 to

Table 5. The response of BUN to different feeding regimens for finishing pigs

Item	Treat 1[1]	Treat 2	Treat 3	Treat 4	MSE[2]
BUN mg/dL (54 to 70 kg BW)					
1 wk	9.52	10.10	10.37	10.88	1.44
2 wk	12.41	11.46	11.59	10.57	2.24
3 wk	11.73	11.27	11.49	9.22	1.86
Sub mean	11.22	10.94	11.15	10.22	1.66
BUN mg/dL (70 to 90 kg BW)					
4 wk	12.23	12.01	9.23	9.55	2.58
5 wk	13.05	10.46	10.15	10.59	2.45
6 wk	13.27	11.69	10.87	10.79	2.05
Sub mean	12.85	11.38	10.08	10.31	2.08
BUN mg/dL (90 to 104 kg BW)					
7 wk	13.35^{a}	9.92^{b}	9.10^{b}	10.73^{ab}	1.99
8 wk	13.40^{a}	8.82^{b}	7.94^{b}	8.88^{b}	1.97
9 wk	13.72^{a}	8.68^{bc}	8.29^{c}	9.96^{b}	1.25
Sub mean	13.49^{a}	9.14^{b}	8.44^{b}	9.86^{b}	1.44
Total	12.57^{a}	10.48^{b}	9.89^{b}	10.13^{b}	1.53

[1] See table 1 for abbreviation; [2] Mean standard error.
^{a,b,c} Means in the same row with different superscripts differ ($p<0.05$).

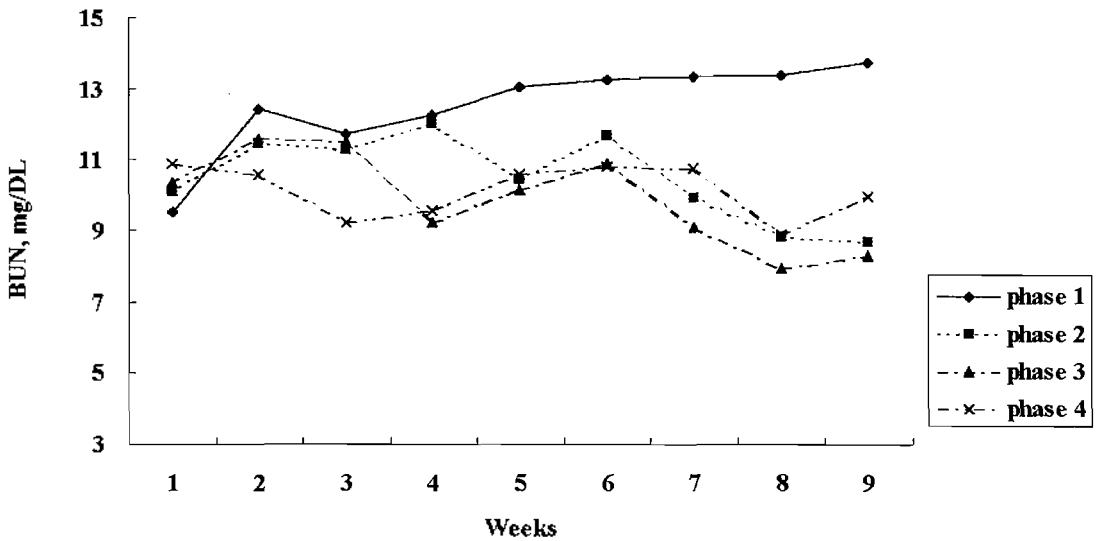

Figure 1. The responses of BUN to different feeding regimens for finishing pigs

13.6 mg/dL in this experiment. Over time, BUN concentration tended to decrease in pigs reared in two and three phase feeing regimen, whereas BUN concentration increased significantly in pig reared in one phase feeding regimen ($p<0.05$). The difference of BUN concentration between one phase feeding regimen and other feeding regimens became greater in the latter period of the experiment than in the former one. This observation is in good agreement with previous research that showed BUN concentration is higher in pigs fed high protein diet than pigs fed low protein diet (Chen et al., 1995, 1996; Gomez et al., 1998). For the entire experiment period, BUN concentration was highest in one phase feeding group but lowest in three phase feeing group ($p<0.05$). BUN concentrations were lower for pigs reared in two, three and four phase feeding regimen than for pigs reared in one phase feeing regimen ($p<0.05$).

An excess blood urea concentration may be expected when dietary protein is increased or amino

Table 6. Effects of different feeding regimens on carcass characteristics of finishing pigs

Items	Treat 1[1]	Treat 2	Treat 3	Treat 4	MSE[2]
Slaughter weight (kg)	103.45	103.41	104.38	104.46	1.90
Carcass weight (kg)	79.30	78.87	80.07	79.23	1.99
Carcass percentage (%)	76.66	76.30	76.76	76.12	1.17
10th rib backfat thickness (cm)	2.60	2.51	2.48	2.40	0.56
Carcass grade[3]	1.22	1.13	1.11	1.14	0.08

[1] See table 1 for abbreviation; [2] Mean standard error.
[3] Based on a scale with 1=grade A, 2=grade B, 3=grade C, 4=grade D.

acids surplus above the requirement are consumed by pigs (Gomez et al., 1998). Measuring BUN concentrations can offer an alternative and simpler means of assessing requirements for dietary protein (Phillip et al., 1998). Changes in BUN concentration in response to altered dietary levels of amino acids have also been utilized previously to estimate amino acid requirements of growing-finishing pigs (Lewis et al., 1980; Yen et al., 1986a, b; Coma and Zimmerman, 1993). This is because animals have little ability to store amino acids in the free state. Therefore, if amino acids are not immediately required for protein synthesis they are readily broken down and either deaminated or used as an energy source. Amino acids pools exceeding the requirement are therefore catabolized, then causing a sharp rise in BUN concentration.

In this study, the lower BUN concentrations in pigs reared in more than two phase feeding regimens than in pigs reared in one phase feeding regimen during the latter period of experiment may reflect the reductions in dietary protein provided or that low CP diet was better suited to meet the requirements for later-part finishing pigs. In addition, this observation could be supported by growth performance of present experiment. Obviously, the elevation of blood urea concentration for one phase feeding group is indicative of excess dietary protein intake throughout the entire experimental period. Although there was no statistical significance found in BUN concentration between individual treatment during early finishing period, figure 1 and table 4 suggests that reduction in BUN concentration observed from 7 wk to 9 wk (approximately 90 to 110 kg) in more than two phase feeding groups is indicative of that 12% CP diet might be sufficient for the later stages of growth or the utilization efficiency of protein may be improved in the low protein diet.

Carcass characteristics

Table 6 shows the results of carcass evaluation of pigs reared in different feeding regimen. It was observed that three phase feeding regimen tended to have more favorable effects than other feeding regimens on overall carcass characteristics, but the difference was not significant. Feeding regimens of over one phase for the finishing period showed better carcass grade, though the difference was not significant. The tenth rib fat thickness of pigs fed on four phase feeding regimen was reduced and there was a trend that backfat thickness decreased as the number of phases increased. This is in good agreement with the findings of Nam and Aherne (1995) and Han et al. (1998). In their studies, Han et al. (1998) investigated the effect of phase feeding on carcass characteristics of finishing pigs and reported that backfat thickness of lighter pigs averaging 104 kg of slaughter weight fed low nutrient density diets was significantly reduced. Nam and Aherne (1995) reported that there was a decreasing tendency in back fatness and an increasing tendency in carcass dressing percentage ($p<0.05$) in those pigs reared in three phase feeding regimen (18-16-14% crude protein for growing-finishing period), in comparison with those pigs fed in one phase feeding regimen (16% crude protein for growing-finishing period).

However, there exist different results on carcass characteristics of pigs fed low CP diets. Latimier and Dourmad (1993) reported that dressing percentage at slaughter increased when protein supply decreased and carcass composition at slaughter was not affected by the protein content of diet, which is in agreement with the results of Henry and Perez (1986). Hahn et al. (1995) reported that 14.5% CP diet and 13.5% CP diet fed from 50 to 90 kg and 90 to 110 kg, respectively, produced the same growth performance and carcass characteristics as that obtained by feeding a 17% CP corn-soybean meal diet to pigs of 50 to 110 kg. However, in the research of Bourdon et al. (1995), there was a tendency for slightly decreased growth rate and increased backfat thickness of multi-phase fed pigs in the finishing period. They postulated that increased fatness might be due to some amino acids shortage in part of the finishing period or a relatively increased net energy content of the low crude protein diets, because of a reduced energy needed for deamination of excess amino acids. Thus, more energy might be available in the low crude protein diets resulting in greater levels of fat deposition. However, Dourmad et al. (1996) reported

Table 7. Effects of different feeding regimens on the feed cost per gain in finishing pigs

Items	Treat 1[1]	Treat 2	Treat 3	Treat 4	MSE[2]
Total weight gain (kg)	49.2	49.2	50.2	50.0	1.84
Total feed cost/pig (₩)	45,657	44,299	45,634	44,213	1343.9
Feed cost/kg weight gain (₩)	927.5[a]	902.1[ab]	908.4[ab]	884.8[b]	31.8

[1] See table 1 for abbreviation; [2] Mean standard error.
[a,b] Means in the same row with different superscripts differ ($p<0.05$).
* Feed production cost for each diets were 286.26 ₩/kg for CP 16% diet, 281.49 ₩/kg for CP 14.7% diet, 278.93 ₩/kg for CP 14% diet, 275.74 ₩/kg for CP 13.4% diet, 268.29 ₩/kg for CP 12% diet, respectively.

that carcass composition at slaughter was not affected by protein content of the diet and energy sparing effect due to reduced protein content was not found. Efficiency of DE utilization for growth decreased when protein content of the diet increased.

Examination of the backfat measurement in this experiment reveals a trend for decreased backfat thickness in those pigs reared in phase feeding regimens compared with those pigs fed on one phase feeding regimen. The data are supported by Loughmiller et al. (1996) who reported that finishing pigs of 90 to 110 kg tended to have decreased lean tissue accretion and increased fat depths with increasing levels of lysine and the total dietary lysine level necessary to optimize growth performance and carcass characteristics for high lean finishing gilts from 90 to 110 kg was approximately 0.60% (18 g/d). Since the pig's ability to consume feed usually exceeds its capacity to deposit protein during the finishing phase of the growing period (Whittemore, 1987), a relatively large portion of the energy and protein ingested during this period might be deposited as carcass fat or excreted via urine, thus lowering the protein to fat ratio in the carcass. Therefore, it is very important that swine producers should feed the pig the diets containing adequate nutrient content without excess of precious protein during the each growth phase. Thus, phase feeding regimen for finishing pigs seems to be one of the methods for the future quality pork production.

Feed cost

Table 7 summarized the feed cost per kg weight gain of finishing pigs reared in different feeding regimen. Total feed cost per pig was significantly high in one phase and three phase feeding group than two phase feeding group, however, feed cost per kg weight gain was significantly low in four phase feeding group than one phase feeding group ($p<0.05$). Although it was not significant, two phase and three phase feeding regimen had numerically lower feed cost per kg weight gain than one phase feeding regimen. In this study, total feed cost per pig under three phase feeding regimen was not different from that of one phase feeding regimen. This resulted from increased feed intake of pigs given the three phase feeding regimen for finishing period. However, reduction in diet cost should not be the only criterion for decision making in pork production. Improvements in carcass lean content or carcass grade can result in improvements in economic returns. In this experiment, since pigs given the three phase feeding regimen showed a trend of better carcass grade and thinner back fat thickness than pigs given one phase feeding regimen for the entire experimental period, we expect that net economic value of three phase feeding regimen vs one phase feeding regimen is greater than that of feed cost evaluation.

Based on these results from the present experiment, over three phase feeding regimen had a tendency for a little improvement in carcass quality and growth performances compared to one phase feeding regimen. N excretion can be reduced by up to 12% with over two phase feeding compared to one phase feeding system. The results of this study show that high nutrient diets do not always guarantee high growth rate of pigs and cause more unwanted nutrient excretion and also suggest that producers generally oversupply nutrients to the finishing pigs, which resulted in wastage of costly protein ingredients and inorganic phosphate supplements as well as undesirable environmental pollution. Considering the fact that most pigs in Korea are still fed a customer dictated diets, which would oversupply N and P, during a period of 30 to 110 kg body weight, it is desirable that phase feeding regimen reducing pollutant excretion without deteriorating of growth performances for growing-finishing pigs should be accepted as a practical feeding system in Korea. On the other hands, multi-phase feeding with weekly mixing of two feeds (high and low concentration in crude protein and minerals) reduced N output further compared with a two phase feeding (Jongbloed and Lenis, 1992). However, in practical condition, especially in Korea, it is hardly feasible to apply this multi-phase feeding system into practical pig industry due to the need of more facilities to store feeds and a computerized mechanical feeding system (Henry and Dourmad, 1993). Therefore, it is recommended that the optimum number of phase feeding regimens for practical

finishing pig production be three or four phase feeding regimen for the finishing period to reduce pollutant excretion from swine facilities.

REFERENCES

AOAC. 1990. Official Method of Analysis (15th Ed.). Association of Official Analytical Chemists. Washington, DC.

Arentson, R. A. 1990. Threonine requirement of the young growing pig. M. S. Thesis. Iowa State University, Ames.

Bourdon, D., J. Y. Dourmad and Y. Henry. 1995. Réduction des rejets azotés chez le porc en croissance par la mise en oevre de lalimentation multi-phase, associée á labaissement du taux azoté, Journées Rech. Porcine en France. 27:269.

Cahn, T. T., A. J. A. Aarnink, J. B. Schutte, A. Sutton, D. J. Langhout and M. W. A. Verstegen. 1998a. Dietary protein affects nitrogen excretion and ammonia emission from slurry of growing-finishing pigs. Livest. Prod Sci. (56):181-191.

Chae, B. J., I. K. Han and M. K. Kim. 1988. Protein sparing effects of supplemental L-lysine in growing swine diet. Korean J. Anim. Nutr. Feed. 12(2):76.

Chen, H. Y., A. J. Lewis and P. S. Miller. 1996. The effects of dietary protein concentration on performance and visceral organ mass in finishing barrows and gilts. 1996 Nebraska Swine Report. pp. 25-27.

Chen, H. Y., P. S. Miller, A. J. Lewis, C. K. Wolverton and W. W. Stroup. 1995. Changes in plasma urea concentration can be used to determine protein requirement of two populations of pigs with different protein accretion rates. J. Anim. Sci. 73:2631-2639.

Chung, T. K. and D. H. Baker. 1992. Ideal amino acid pattern for 10 kilogram pigs. J. Anim. Sci. 70:3102.

Coma, J. and D. R. Zimmerman. 1993. Lysine requirement of finishing pigs determined by using plasma urea nitogen in shot-term trials. J. Anim. Sci. 71(Suppl. 1):168(Abstr.)

Coppoolse, J., A. M. van Vuuren, J. Huisman, W. M. M. A. Janssen, A. W. Jongbloed, N. P. Lenis and P. C. M. Simons. 1990. The excretion of nitrogen, phosphorus and potassium by farm animals, now and tomorrow (in Dutch), Dienst landbouwkundig Onderzoek, Wageningen, The Netherlands.

Cromwell, G. L., T. R. Cline, J. D. Crenshaw, T. D. Crenshaw, R. C. Ewan, C. R. Hamilton, A. J. Lewis, D. C. Mahan, E. R. Miller, J. E. Pettigrew, L. F. Tribble and T. L. Veum. 1993. The dietary protein and (or) lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510-1519.

Daghir, N. J. 1983. Effect of lysine and methionine supplementation of low protein rooster diets fed after six weeks of age. Poult. Sci. 62:1572.

Devilat, J., W. G. Pond and P. D. Miller. 1970. Dietary amino acid balance in growing-finishing pigs : effect on diet preference and performance. J. Anim. Sci. 36:536.

Dourmad, J. Y., D. Guillou, B. Seve, Y. Henry. 1996. Response to dietary lysine supply during the finishing period in pigs. Livest. Prod. Sci. 45:179-186.

Dourmad, J. Y., Y. Henry, D. Bourdon, N. Quiniou and D. Guillou. 1996. Effect of growth potential and dietary protein input on growth perfomance, carcass characteristics and nitogen output in growing-finishing pigs. In: Proceedings of the First International Symposium on Nitrogen Flow in Pig Production and Environmental Consequences (Ed. M. W. A. Verstegen, L. A. Den Hartog, G. J. M. Van Kempen and J. H. M. Metz). EAAP Publication no. 69, Wageningen, The Netherlands. p. 22.

Duncan, D. B. 1955. Multiple range and multiple F test. Biometrics. 11:1-42.

Friesen, K. G., J. L. Nelssen, R. D. Goodband, M. D. Tokach, J. A. Unruh, D. H. Kropf and B. J. Kerr. 1995. The effect of dietary lysine on growth, carcass composition and lipid metabolism in high-lean growth gilts fed from 72 to 136 kilograms. J. Anim. Sci. 73:3392-3401.

Gomez, S., S. M. Phillip, A. J. Lewis and H. Y. Chen. 1998. Responses of barrows consuming a diet formulated on an ideal protein basis at different feeding levels. Univ. of Nebraska Swine Rep. pp. 30-33.

Goodband, R. D., R. H. Hines, J. L. Nelssen, D. H. Kropf and G. R. Stoner. 1989. The effects of excess dietary lysine additions on growth performance and carcass composition of limit-fed growing-finishing pigs. J. Anim. Sci. 67:1916.

Gourley, G., B. Greenley and F. X. Aherne. 1993. Five-stage phase feeding versus self selection of high and low lysine deits in growing and finishing swine. J. Anim. Sci. 71:62(Abstr.)

Hahn, J. D., R. R. Biehl and D. H. Baker. 1995. Ideal digestible lysine level for ealry and late finishing swine. J. Anim. Sci. 1995. 73:773-784.

Han, I. K. and T. S. Min. 1991. The effects of dietary supplementation with Kemzyme in broilers. Korean J. Anim. Nutr. Feed. 15(1):9.

Han, I. K., J. H. Kim, K. S. Chu, Z. N. Xuan, K. S. Shon and M. K. Kim. 1998. Effect of phase feeding on the growth performance and nutrient utilization in finishing pigs. Asian-Aus. J. Anim. Sci. 11(5):559-565.

Han, I. K., K. Kwon, K. H. Na and M. I. Yoo. 1978. Protein sparing effect of L-lysine in the rations of weaning pigs and growing-finishing hogs. Korean J. Anim. Sci. 20(6):566-578.

Han, I. K., K. N. Heo, I. S. Shin and H. Lee. 1995. Protein Sparing Effect and Amino Acid Digestibilities of Supplemental Lysine and Methionine in Weanling Pigs. Asian-Aus. J. Anim. Sci. 8(4):393-402.

Han, In K. 1996. Development of low-pollution diet using metabolic active substances and synthetic amino acids. Seoul National University, Korea.

Henry, Y. and J. Y. Dourmad. 1993. Feeding strategy for minimizing nitrogen output in pigs. In: Proceedings of the First International Symposium on Nitrogen Flow in Pig Production and Environmental Consequences (Ed. M. W. A. Verstegen, L. A. Den Hartog, G. J. M. Van Kempen and J. H. M. Metz). EAAP Publication no. 69, Wageningen, The Netherlands. p. 137.

Henry, Y. and J. M. Perez. 1986. Effects de la supplémentation en lysine, associée à une réduction du taux de protéines, dans des régimes à base de maïs ou de blé sur les performances de croissance du porc. J. Rech. Porcine France. 18:57-66.

Hines, R. H., J. D. Hancock, C. G. Mills and D. A. Nichols. 1993. Effects of nursery diets on growth of pigs to market weight. Kansas State Univ. Swine Day Rep. pp. 77-84.

Honeyman, M. S. 1996. Sustainability Issues of U.S. Swine Production. J. Anim. Sci. 74:1410.

Jin, C. F., J. H. Kim, In K. Han and S. H. Bae. 1997. Effects of supplemental synthetic amino acids to the low protein diets on the performance of growing pigs. Asian-Aus. J. Anim. Sci. 11:1-7.

Jongbloed, A. W. and N. Lenis. 1992. Alteration of nutrition as a means to reduce environmental pollution by pigs. Livest. Prod. Sci. 31:75.

Koch, F. 1990. Amino acid formulation to improve carcass quality and limit nitrogen load in waste. Proceedings of the 6th Annual Carolina Swine Nutrition Conference. Raleigh, North Carolina, USA, pp. 76-95.

Kwon, K., I. K. Han, K. S. Sohn and C. H. Kwon. 1995a. Effects of microbial phytase on performance, nutrient digestibility and phosphorus excretion in growing-finishing pigs fed corn-soy diets. Korean J. Anim. Sci. 37(4):341-352.

Kwon, K., I. K. Han, K. S. Sohn, C. H. Kwon and J. H. Kwack. 1995b. Effects of microbial phytase on performance, nutrient digestibility and phosphorus excretion in weaning-growing pigs fed corn-wheat-soy diets. Korean. J. Anim. Sci. 37(4):353-362.

Kyriazakis, I., G. C. Emmans and C. T. Whittemore. 1990. Diet selection in pigs: choices made by growing pigs given food of different protein contents. Anim. Prod. 51:189.

Latimier, P. and J. Dourmad. 1993. Effect of three protein feeding strategies for growing-finishing pigs on growth performance and nitrogen output in the slurry and in the air. In: Nitrogen Flow in Pig Production and Environmental Consequences (Ed. M. W. A. Verstegen, L. A. Den Hartog, G. J. M. Van Kempen and J. H. M. Metz). EAAP Publ. No. 69. Pudoc, Wageningen, The Netherlands. pp. 242-246.

Lenis, N. P. 1989. Lower nitrogen excretion in pig husbandry by feeding: current and future possibilities. Neth. J. Agric. Sci. 37:61-70.

Lewis, A. J. E., E. R. Peo, Jr., B. D. Moser and T. D. Crenshaw. 1980. Lysine requirement of pigs weighing 5 to 15 kg fed practical diets with and without added fat. J. Anim. Sci. 51:361.

Loughmiller, J. A., J. L. Nelssen, R. D. Goodband, M. D. Tokach, I. H. Kim, J. C. Woodworth, J. W. Smith II, J. R. Bergstrom, K. Hongtrakul, W. B. Nessmith and R. E. Musser. 1996. Dietary lysine requirement for optimal growth performance and carcass characteristics of late finishing gilts. Kansas State Univ. Swine Day Rep. pp. 126-129.

Mosenthin, R. H. 1996. Swine nutrition research in germany. Seoul National University.

Nam, D. S. and F. X. Aherne. 1995. A comparison of choice and phase feeding for growing-finishing pigs. Can. J. Anim. Sci. 75:93-98.

Nelssen, J. L., J. A. Loughmiller, R. D. Goodband, M. D. Tokach, I. H. Kim, J. C. Woodworth, J. W. Smith II, J. R. Bergstrom, K. Hongtrakul, W. B. Nessmith and R. E. Musser. 1995. Dietary lysine requirement for optimal growth performance and carcass characteristics of late finishing pigs. Kansas State Univ. Swine Day Rep. pp. 77-84.

Noh, S. H., H. K. Moon, I. K. Han and I. S. Shin. 1995. Effect of dietary growth promoting substances on the growth performance in pig. Korean. J. Anim. Sci. 37(1):66-72.

Obrock, C. H., P. S. Miller and A. J. Lewis. 1997. The effects of reducing dietary crude protein concentration on odor in swine facilities. 1997 Nebraska Swine Report. pp. 14-16.

Owen, K. Q., D. A. Knabe, K. G. Burgoon and E. J. Gregg. 1994. Self-selection of diets and lysine requirements of growing-finishing swine. J. Anim. Sci. 72:554-564.

Paik, I. K., R. Blair and J. Jacob. 1996. Strategies to reduce environmental pollution from animal manure : Principles and nutritional management. A review. Asian-Aus. J. Anim. Sci. 9:615-636.

Phillip, S. M., A. J. Lewis and H. Y. Chen. 1998. Plasma urea can be used to identify the protein requirements of group-penned finishing (130 to 220 lb) barrows and gilts fed corn-soybean diets. Univ. of Nebraska Swine Rep. 30-33.

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

Whittemore, C. T. 1987. Manipulation of the growth rate of farm animals to meet changing market demands. Agric. Prog. 62:1.

Yen, H. T., D. J. A. Cole and D. Lewis. 1986a. Amino acid requirements of growing pigs. 7. The response of pigs from 25 to 55 kg live weight to dietary ideal protein. Anim. Prod. 43:141.

Yen, H. T., D. J. A. Cole and D. Lewis. 1986b. Amino acid requirements of growing pigs. 8. The response of pigs from 50 to 90 kg live weight to dietary ideal protein. Anim. Prod. 43:155.