Effect of Phase Feeding on the Growth Performance and Nutrient Utilization in Finishing Pigs

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ABSTRACT : This study was conducted to investigate the effects of different feeding regimen on the growth and nutrients excretion in finishing pigs. A total of 80 pigs (59.91 kg BW) and 6 pigs (85 kg BW) were employed in a growth trial and metabolic trial, respectively. Treatments were grower-grower (GG), grower-early finisher (GE), early finisher-early finisher (EE), and early finisher-late finisher (EL) diet feeding regimens for feeding trial and G, E, L diets for metabolic trial. Through whole experimental period, no significant difference was found in any of the criteria measured. Pigs fed on a GG regimen gained slightly faster than pigs fed on other feeding regimens, with no significant difference. Although there was a trend that pigs fed on a GG or GE regimen showed improved feed/gain over pigs fed on a EE or EL regimen, the difference also was not significant.

In the metabolic trial, dry matter and phosphorus digestibility was not affected by diets, however, phosphorus digestibility tended to be decreased as nutrients contents was decreasing in the diets. Crude protein digestibility was significantly influenced by the nutrients contents in the diets. The data suggested that 11.7% crude protein seemed to be low for the 85 kg pigs. Though nutrients excretion was not significantly influenced by dietary treatment except phosphorus, there was a trend that pigs fed diets with low nutrient content excreted less amount of nitrogen and phosphorus than pigs fed diets with high nutrients content.

There was a trend that GG or GE feeding regimen had a favorable effect on carcass grade when only 10 lighter pigs of each treatment were subjected to statistical analysis. However, with 10 heavier pigs, EE and EL feeding regimen showed better carcass grade, though the difference was not significant.

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. It rather seems that to meet nutrient requirements for the each growth phase is more important in economical pork production

(**Key Words**: Phase Feeding, Pigs, Growth, Carcass Characteristics)

INTRODUCTION

A great deal of attention is being given to reduce pollutants excretion from livestock all over the world. By far, the most feasible ways to reduce animal excreta are to improve digestibility of nutrients with metabolic active substances, such as enzymes or yeast (Kwon et al., 1995a, b; Noh et al., 1995; Park et al., 1994; Han and Min, 1991), and to reduce crude protein content in the diet using synthetic amino acids (Han et al., 1978, 1995; Chae et al., 1988; Daghir, 1983; Heo et al., 1995; Jin et al., 1998). Recently, some researchers suggest phase feeding as an alternative method to reduce the amount of animal excreta (Jongbloed and Lenis, 1992; Lenis, 1989; Honeyman, 1993; Paik et al., 1996; Honeyman, 1996). Phase feeding is a method to use diets tailored to their stage of production. This avoids over-feeding and the excretion of unwanted nutrients in the manure (Paik et al., 1996). Paik et al. (1996) and Jongbloed and Lenis (1992) suggested that nitrogen and phosphorus excretion could be reduced by 2-10% under phase feeding.

There have been a trend in swine industry to formulate diets for maximizing production performance with little concern for nutrient oversupply. In 1995, 4.73 million ton of swine feeds was produced in Korea, of which only 1.9% was for finishing pigs. This means that producers have oversupplied nutrients for their pigs, and most of finishing pigs were given growing pig diets.

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However, in recent pig production, producers should be aware that sustainability of animal agriculture is as important as high production performance. The oversupplied nitrogen is lost via ammonia volatilization, denitrification and nitrate leaching which pollute air and water. Especially finishing pigs consume 1.5 to 2.0 times more feed than young or growing pigs, therefore the effect of undigested nitrogen and phosphorus on environment is getting more critical. As the amino acid requirements for pig changes when pig grow, phase feeding could be introduced as an alternative method to reduce animal excreta without sacrificing animal growth performance. Thus this study was undertaken to investigate the effect of different feeding regimen on the growth performance and nutrients excretion in finishing pigs.

MATERIALS AND METHODS

A total of 80 finishing pigs (Landrace × Duroc × Large White) averaged 59.91 kg of body weight were chosen and allotted to different phase feeding regimen. Four treatments were employed in this study; grower diet-grower diet (GG), grower diet-early finisher diet (GE), early finisher diet-early finisher diet (EE), early finisher diet-late finisher diet (EL) for early finishing stage (60 to 83 kg) and late finishing stage (83 to 105 kg), respectively. Each treatment had four replicates with five pigs per replicate. Experimental diets were formulated to contain 15.8%, 13.6%, 11.7% crude protein for grower, early finisher and late finisher diet, respectively. The major four limiting amino acids were added to maintain the same amino acid ratio among experimental diets. The formula and chemical composition of experimental diets are presented in table 1.

Pigs were housed in a concrete floored pen, with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water throughout whole experimental period. Temperature was not controlled in this study. Since this study was initiated in November and finished in January, the range of temperature in the building varied according to the environmental temperature from 4℃ to 16℃.

For the determination of the amount of excreted nutrients, total fecal collection method was used. A total of 6 pigs (3 males and 3 females) averaged 85 kg of body weight were chosen and housed in an individual metabolic cage. Three different diets were offered to the pigs on a weekly rotation basis. After four days of adaptation period, total excreta were collected following three days. The amount of feed consumed and total excreta were recorded daily during the metabolism trial. Collected excreta were pooled and dried in an air forced drying oven at 60℃ for 72 hours and ground with 1 mm Wiley Mill for chemical analysis.

Analysis of proximate nutrients composition of experimental diets and excreta was conducted 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 analysis for the present data was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) procedure of SAS (1985) package program.

Table 1. Formula and chemical composition of the experimental diets

	Growing period	Early Finishing Period	Late Finishing Period
Ingredients :			
Corn	60.41	63.12	65.40
Wheat Mill	10.12	15.00	20.00
Soybean meal (46%)	20.64	13.66	7.04
Calcium Carbonate	0.90	0.48	0.60
Defl. Phosphorus	1.56	1.32	1.06
Salt	0.30	0.30	0.30
Animal Fat	2.00	2.00	1.50
Molasses	3.00	3.00	.00
Choline Chloride (60%)	0.01	0.03	0.05
L-Lysine 78%	–	–	0.01
Lysine (liquid 23%)	0.81	0.87	0.83
DL-Methionine (98%)	0.05	0.01	–
Vit.-Min. Premix[1]	0.20	0.20	0.20
Total	100.00	100.00	100.00
Chemical Composition[2] :			
DE (Kcal/kg)	3,445.0	3,445.0	3,445.0
Crude protein (%)	15.8	13.6	11.7
Lysine (%)	1.00	0.85	0.70
Met. + Cys. (%)	0.60	0.51	0.42
Threonine (%)	0.58	0.49	0.41
Tryptophan (%)	0.18	0.15	0.13
Ca (%)	0.75	0.70	0.65
Total P (%)	0.65	0.60	0.55

[1] Provided the following per kilogram of diet : vatamin A 5,500 IU, vatamin 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.

RESULTS AND DISCUSSION

1. Growth performance

Table 2 summarized the effect of different feeding regimen on the growth performance of finishing pigs. Through whole experimental period, no significant difference was found in any of the criteria measured. Pigs fed on a GG regimen gained slightly faster than pigs fed on other feeding regimen, but the difference was not significant. Although there was a trend that pigs fed on a GG or GE regimen showed improved feed/gain over pigs fed on a EE or EL regimen, the difference also was not significant. Nam and Aherne (1995) reported that in the 50 to 105 kg growth phase, feeding systems had no effect on pig growth performance, when they were examining the effects of choice and phase feeding for growing-finishing pigs. Koch (1990) demonstrated that in pigs, by using a diet low in protein (11 vs. 13.9%) but supplemented with the most limiting four amino acids (lysine, methionine, threonine and tryptophan), there was no reduction in weight gain or feed conversion efficiency but N excretion was reduced by nearly 30%. Since our diets were formulated to contain 15.8%, 13.6%, 11.7% crude protein for each growing stage, the results suggested that over 14% of crude protein diets for late finishing pigs did not necessarily guarantee high growth rate. It rather seems that meeting the animal's need for amino acids without providing excesses is more important. According to the recent reports (Owen et al., 1994; Gourley et al., 1993; Nam and Aherne, 1995), pigs do not have the ability to control protein intake to meet their requirements. Consumption of protein above the requirement results in protein wastage because the animal is unable to convert dietary amino acids to body protein (Chen et al., 1996). Thus adequate level of protein can save the expensive protein sources.

Table 2. Effects of different feeding regimen on the growth performance of finishing pigs

Feeding regimen[1]	GG	GE	EE	EL	SE[2]
(60 kg ~83 kg)					
Initial Weight (kg)	59.7	60.0	59.8	60.1	1.34
Final Weight (kg)	82.1	82.5	82.2	83.2	1.35
Average Daily Gain (kg)	0.803	0.803	0.803	0.825	0.01
Average Daily Feed Intake (kg)	2.72	2.76	2.86	2.84	0.04
Feed/Gain	3.40	3.45	3.56	3.44	0.05
(83 kg ~105 kg)					
Final Weight (kg)	105.9	105.2	105.0	105.4	1.39
Average Daily Gain (kg)	0.74	0.71	0.71	0.70	0.01
Average Daily Feed Intake (kg)	2.89	2.88	2.90	2.91	0.02
Feed/Gain	3.91	4.07	4.10	4.19	0.06
(60 kg~105 kg)					
Initial Weight (kg)	59.7	60.0	59.8	60.1	1.34
Final Weight (kg)	105.9	105.2	105.0	105.4	1.39
Average Daily Gain (kg)	0.77	0.76	0.75	0.76	0.01
Average Daily Feed Intake (kg)	2.82	2.83	2.89	2.88	0.03
Feed/Gain	3.65	3.76	3.83	3.81	0.04

[1] GG : Grower-Grower, GE : Grower-Early Finisher, EE : Early Finisher-Early Finisher, EL : Early Finisher-Late Finisher.
[2] Pooled Standard Error.
Note : no significant difference was found.

2. Nutrients utilization

Table 3 and 4 showed the effects of different nutrient content of the diets on the nutrient digestibility and nutrient excretion. These data were obtained with 85 kg pigs (3 males and 3 females). Dry matter and phosphorus digestibility was not affected by dietary treatment, however in phosphorus digestibility, there was a trend to be decreasing as nutrient contents diminished in the diets. Crude protein digestibility was significantly influenced by the nutrient contents in the diets. The data suggested that 11.7% crude protein seemed to be low for the 85 kg pigs. Between grower and early finisher diets, there was no

Table 3. Effects of different nutrient contents on the nutrient digestibility of finishing pigs

Items	Treatments			SE[2]
	Grower	Early Finisher	Late Finisher	
Female				
Dry matter (%)	83.7	87.0	84.7	0.83
Crude protein (%)	80.4	82.8	76.2	1.39
Phosphorus (%)	53.9	59.9	50.7	2.76
Male				
Dry matter (%)	84.8	82.1	82.6	0.90
Crude protein (%)	81.1	75.2	73.7	1.79
Phosphorus (%)	57.0	49.5	46.9	2.12
Combined				
Dry matter (%)	84.2	84.5	83.6	0.64
Crude protein (%)	80.8[a]	79.0[ab]	74.9[b]	1.17
Phosphorus (%)	55.5	54.7	48.8	1.75

[a,b] Means with different superscript in the same row differ at $p < 0.05$.
[2] Pooled Standard Error.

Table 4. Effects of different nutrient contents on the nutrient excretion of finishing pigs

Items	Treatments			SE[2]
	Grower	Early Finisher	Late Finisher	
Female				
Dry matter (g/day)	407.6	381.0	403.8	14.10
Nitrogen (g/day)	12.4	11.2	11.2	0.45
Phosphorus (g/day)	9.1[a]	8.3[ab]	7.1[b]	0.41
Male				
Dry matter (g/day)	391.1	339.1	371.1	27.82
Nitrogen (g/day)	13.0	10.3	10.6	0.99
Phosphorus (g/day)	8.4	6.5	6.3	0.55
Combined				
Dry matter (g/day)	399.3	360.0	387.5	15.57
Nitrogen (g/day)	12.7	10.7	10.9	0.53
Phosphorus (g/day)	8.7[a]	7.4[ab]	6.7[b]	0.36

[a,b] Means with different superscript in the same row differ at $p < 0.05$.
[2] Pooled Standard Error.

significant difference in crude protein digestibility. Though nutrient excretion was not significantly influenced by dietary treatment except phosphorus, there was a trend that pigs fed low nutrient content diets excreted less amount of nitrogen and phosphorus than pigs fed high nutrient content diet. In this study, reducing about 2% unit of crude protein resulted in 18% of reduction in N excretion in 85 kg pigs. This result reasonably agreed with the results of Lenis (1989) who reported that lowering the protein level in the diets for growing pigs by 2% units resulted in about 25% reduction of N excretion. Jongbloed and Lenis (1992) also suggested that lowering dietary crude protein level for growing-finishing pigs by 2% would reduce N excretion by approximately 20%. Recently, Carter et al. (1996) indicated that N excretion could be reduced by 35% through diet manipulation. In our study, it was assumed that the big variance among individual pigs caused no significant difference. Another possible explanation is that the limiting amino acids were not adjusted to the same level when the crude protein

level was lowered. In most previous studies, major limiting amino acids were adjusted using crystalline amino acids to maintain the same major amino acids contents with the control diet. Thus for the 85 kg pigs, the major limiting amino acids content in the finisher diets, especially for the late finisher diet, might not be adequate for effective N digestion and absorption.

Though the nitrogen excretion via urine was not investigated in this study, in pig production, the main part of ammonia emission originated from urea in urine (Lenis, 1989). A much bigger proportion of the pigs' 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 (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 upon 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 effect of pig production. From the result of this experiment, for 85 kg pigs, over 14% crude protein does not necessarily mean high growth rate, while 11.6 % crude protein seems to be a bit low for the pigs weighing 85 kg body weight. Thus feeding high nutrients density diets for whole finishing period does not look very economical. The growth performance with different feeding regimen also supported the fact that pigs do not always grow well on high nutrients density diets. However, which level of nutrients density is adequate for the each growth stages are remained to be investigated. Also, the nutrients density for different sex should be examined for the application of phase feeding to the practical swine industry. The required nutrients can be different depending on the sex, feed ingredients, genetics and environmental condition etc.

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 raised in a closed building. In modern pig production, most of pigs are raised in closed building, there should be more study on the relationship between feeding regimen and ammonia production.

3. Carcass characteristics

Table 5 summarized the result of carcass evaluation of pigs fed on different feeding regimen. There was a trend that GG or GE feeding regimen had a favorable effect on carcass grade when only 10 lighter pigs of each treatment were subjected to statistical analysis. However, with 10 heavier pigs, EE and EL feeding regimen showed better carcass grade, though the difference was not significant.

Table 5. Effects of phase feeding on carcass characteristics of finishing pigs

Feeding regimen[1]	GG	GE	EE	EL	SE[2]
Lighter 10 pigs					
Slaughter Weight (kg)	105.4[a]	103.5[a]	102.5[a]	98.2[b]	0.71
Carcass percentage (%)	78.2	78.8	79.6	78.0	0.37
10th rib backfat thickness (cm)	2.55[ab]	2.82[a]	2.70[ab]	2.39[b]	0.71
Carcass grade	2.10[ab]	1.90[b]	2.20[ab]	2.60[a]	0.11
Heavier 10 pigs					
Slaughter Weight (kg)	115.5	113.8	112.6	114.4	0.74
Carcass percentage (%)	78.2	76.3	77.9	78.2	0.37
10th rib backfat thickness (cm)	3.00	2.58	2.85	2.94	0.75
Carcass grade	2.30	2.00	1.90	1.80	0.10
Total					
Slaughter Weight (kg)	110.5	108.7	107.5	106.3	0.83
Carcass percentage (%)	78.2	77.6	78.8	78.1	0.27
10th rib backfat thickness (cm)	2.77	2.70	2.77	2.66	0.53
Carcass grade	2.20	1.95	2.05	2.20	0.08

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

It seemed that backfat thickness and carcass grade are not related closely in Korean carcass evaluation system. Backfat thickness of lighter pigs fed on EL regimen was significantly reduced, but carcass grade was worst in pigs fed EL regimen. But it should be noticed that with lighter pigs high nutrients density diets were favorable, and with heavier pigs, low nutrient density diets were favorable in terms of carcass evaluation without any significant effect on growth performance. Thus it can be concluded that producers should feed pig diets with adequate nutrient content for the each growth phase of pigs.

4. Feed cost

Table 6 showed the feed cost per kg weight gain of finishing pigs fed on different feeding regimen. Total feed cost per pig were significantly high in GG regimen than EL regimen, however, feed cost per kg weight gain was not significantly different among dietary regimen.

The results of this study suggested that producers generally oversupply nutrients for the finishing pigs which resulted in wastage of costly protein ingredients and inorganic phosphate supplements as well as undesirable environmental pollution. N excretion can be reduced by up to 20% with two phase feeding compared to single phase feeding system. With the use of synthetic amino acids and highly digestible feed ingredients, N and P excretion is expected to be reduced further. Multiphase 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, this does not look as a feasible way to be incorporated into practical pig industry unless a producer has a computerized mechanical feeding system. Thus, two or three phase feeding for finisher pig could be recommended to reduce pollutant excretion from pigs.

Table 6. Effects of different feeding regimen on the feed cost per gain in finishing pigs*

Feeding regimen[1]	GG	GE	EE	EL	SE
Total weight gain (kg)	46.2	45.3	45.2	45.2	0.48
Total Feed Cost/pig (₩)	31,041[a]	30,271[ab]	30,146[ab]	29,055[b]	352.6
Feed Cost/kg weight gain (₩)	672	671	667	642	7.5

[1] See table 2. for abbreviation.

*: Feed production cost for each diets were 183.87 ₩/kg for grower, 174.23 ₩/kg for early finisher and 163.78 ₩/kg for late finisher diet, respectively.

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