Effects of Phase Feeding on Growth Performance, Nutrient Digestibility and Nutrient Excretion of Growing Barrows and Gilts[a]

Y. G. Kim*, J. Jin, J. D. Kim, J. H. Kim and In K. Han
Department of Animal Science and Technology, College of Agriculture and Life Sciences
Seoul National University, Suweon 441-744, Korea

ABSTRACT : A total of 120 growing crossbred pigs (Landrace×Large White×Duroc) with equal numbers of barrows and gilts were used in the feeding trial in a 2×3 factorial arrangement (gender by feeding regimens) to investigate the effect of phase feeding on growth performance during the 25 to 58 kg body weight growth stage, and 6 pigs (three of each sex) were used in a metabolic trial. The growing period was divided into two phases and 4 different CP diets were used to make 3 different feeding regimens (GE18-GL18; 18% CP diets for both early and later growing period, GE18-GL16; 18% CP diet for early and 16% CP diet for later growing period, GE19-GL17; 19% CP diet for early and 17% CP diet for later growing period). There were no significant differences in growth performance among treatments during the entire growing period. However, during the later growing period, feed intake of barrows was significantly higher than that of gilts ($p<0.05$). Average daily gain of barrows was higher than that of gilts ($p>0.05$). Based on the result, growth performance differences between barrows and gilts appeared to begin after 40 kg of body weight. There was no significant difference in digestibility among treatments or between sexes. During the early growing period the 18% CP diet showed better digestibility than the 19% CP diet. However, during the later growing period, the 18% and 17% CP diets exhibited similar digestibilities, although 16% CP diet showed slightly lower digestibility than 18% and 17% CP diets. During the early growing period, fecal N and P excretion of pigs fed the 19% CP were higher than that of those fed the 18% CP diet. During later growing period, fecal N and P excretion by those receiving the two phase feeding compared to single phase feeding was reduced by 10.2% and 2.0%, respectively. In the gilts, the cost reduction by two phase feeding (GE18-GL16) compared to single feeding was around 3.81%, but that of barrows was only 0.52%. The results suggested that the same nutrient levels could be applied to barrows and gilts during the growing period. Also, this study suggested the optimum protein and lysine level for early and later growing pigs to be 18% CP, 1.0% lysine and 16% CP, 0.8% lysine, respectively. Feeding two diets to growing pigs, i.e., two-phase feeding, would be more appropriate than feeding a single diet on economic and environmental considerations. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 6 : 795-801*)

Key Words : Phase Feeding, Pigs, Nutrient Digestibility, Fecal Nutrient Excretion, Sex, Barrow, Gilt

INTRODUCTION

In a conventional feeding system, a growing animal is given free and continuous access to feeds. An attempt to meet the change in the animal's nutrient requirements over time, with increasing body weight and degree of maturity, is made by changing the nutrient composition of the feed. The more frequent the changes, the more precisely the requirements can be met. However, because handling a large number of feeds is unacceptable in practical swine farming, there is inevitably a compromise between the requirements of individuals, or of the herd, and the number of feeds used.

There has been a trend in the swine industry to formulate diets for maximizing performance with little concern for feed cost and nutrient oversupply. Pigs are usually given access to two or three dietary formulations of feeds from weaning to market weight and the differences between genotypes, sexes and states are often ignored. In such a situation, we have been satisfied with developing feeding programs and providing diets for average requirements of average pigs under average conditions during growing and finishing periods. However, there is great variability among pigs and feeding conditions within the swine industry while only a relatively small percentage of pigs in the industry are average.

Also, in recent pig production, a great deal of attention is being given world-wide to reduction of pollutants from livestock. By far the most feasible ways to reduce animal excreta are to improve digestibility of nutrients with biologically 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).

* Address reprint request to Y. G. Kim. Cheiljedang Co., #64, 3-Ka, Shinhung-Dong, Chung-Ku, Inchon 400-103, Korea. Tel: +82-32-881-2703, Fax: +82-32-834-6040, E-mail: ygkim@cheiljedang.com.

[a] This study was partially funded by the MAF-SGRP (Ministry of Agriculture and Forestry-Special Grants Research Program) in Korea.

Received February 27, 1999; Accepted June 8, 1999

Some researchers suggest that phase feeding can be an additional way to reduce the amount of animal excreta (Honeyman, 1996; Paik et al., 1996). Phase feeding is a method to use diets tailored to stage of production. This avoids over-feeding and excretion of unwanted nutrients in the manure (Paik et al., 1996). Jongbloed and Lenis (1992) and Paik et al. (1996) suggested that with phase feeding, nitrogen and phosphorus excretion could be reduced by 2～10%. Honeyman (1996) also suggested that nitrogen and phosphorus excretion could be decreased by phase feeding. Since amino acid requirements of the pig change as it grows, phase feeding could be introduced as a desirable method to reduce animal excreta without sacrificing animal performance.

This study was carried out to investigate the effects of different feeding regimens on 1) growth performance, 2) nutrient digestibility and 3) nutrient excretion of growing gilts and barrows.

MATERIALS AND METHODS

A total of 120 crossbred growing pigs (Landrace × Large White × Duroc) with equal numbers of barrows and gilts averaging 24.9 kg body weight was used in a 2×3 factorial arrangement (gender by feeding regimens) to investigate the effect of phase feeding on growth performance of barrows and gilts.

Experimental diets were formulated with mainly corn and soybean meal to contain four different protein and lysine levels. The growing period was divided into two phases (early: 25-41 kg BW, and later: 41-58 kg BW growing period) to investigate the effects of phase feeding for grower pigs. Four different experimental diets were used to make three different feeding regimens (GE18-GL18; 18% CP diets for both early and later growing periods, GE18-GL16; 18% CP diet for early and 16% CP diet for later growing period, GE19-GL17; 19% CP diet for early and 17% CP diet for later growing period). During the early growing period, two different diets, 18% crude protein (1.0% lysine) and 19% crude protein (1.1% lysine) were fed to pigs. During later growing period, three different feeds, 18% crude protein (1.0% lysine), 17% crude protein (0.9% lysine) and 16% crude protein (0.8% lysine) were fed to pigs. Major limiting amino acids were added to diets according to the ideal amino acids pattern suggested by Baker and Chung (1992). The formula and chemical composition of experimental feeds are presented in table 1.

Pigs were housed in a concrete-floored pens, with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water throughout five weeks of the experimental period. The temperature within house ranged from 18 to 22℃.

Total fecal collection method was used for the determination of nutrient digestibilities. Nutrient digestibility was measured twice, once in the first half of the experimental period and then in the second half of the period. For early growing period, 6 pigs (3 barrows and 3 gilts) averaging 30.5 kg body weight were housed in individual metabolic crates, and for later growing period, 6 pigs (3 barrows and 3 gilts) averaging 48 kg body weight were used. After four days of adaptation, total excreta were collected for three consecutive days. The amount of feed consumed and total excreta were recorded daily during the metabolic trial. Collected excreta were pooled and dried in an air-forced drying oven at 60℃ for 72 hours and then ground with 1 mm Wiley mill for chemical analyses. Analyses of proximate nutrients of

Table 1. Formula and chemical composition of the experimental diets

Protein level (%)	19	18	17	16
Ingredients (%):				
Corn	43.35	46.18	49.13	52.30
Wheat	15.00	15.00	15.00	15.00
Soybean meal	30.11	27.50	24.83	21.75
White fish meal	1.00	1.00	1.00	1.00
Animal fat	3.73	3.53	3.28	3.05
Molasses	4.00	4.00	4.00	4.00
Limestone	0.38	0.38	0.38	0.38
Tricalciumphosphate	1.48	1.50	1.50	1.53
Salt	0.25	0.25	0.25	0.25
L-Lysine-HCl	0.08	0.04	0.02	0.00
Threonine	0.00	0.00	0.00	0.12
Premix[1]	0.63	0.63	0.63	0.63
Total	100.00	100.00	100.00	100.00
Chemical composition[2]:				
Metabolizable energy (Mcal/kg)	3.35 (3.34)[3]	3.35 (3.33)	3.35 (3.34)	3.34 (3.33)
Crude protein (%)	19.00 (19.01)	18.00 (17.98)	17.00 (17.02)	16.00 (15.95)
Lysine (%)	1.10 (1.08)	1.00 (1.02)	0.91 (0.94)	0.82 (0.83)
Methionine +cystine (%)	0.62 (0.54)	0.60 (0.52)	0.57 (0.50)	0.54 (0.49)
Threonine (%)	0.73 (0.70)	0.69 (0.65)	0.65 (0.63)	0.54 (0.50)
Tryptophan (%)	0.24 (0.21)	0.23 (0.23)	0.21 (0.20)	0.20 (0.18)

[1] Supplied per kg 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.

[3] Chemically defined value.

Table 2. Effects of phase feeding on growth performance

Treatment	Barrows			Gilts			SE[1]	Contrast
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		Barrow vs Gilt
25 to 41 kg (0 to 3 wks)								
ADG (kg)	0.782	0.798	0.781	0.800	0.761	0.754	0.01	0.6051
ADFI (kg)	1.488	1.532	1.458	1.570	1.578	1.391	0.03	0.7400
F/G	1.90[ab]	1.93[ab]	1.87[ab]	1.96[ab]	2.04[a]	1.82[b]	0.03	0.4685
41 to 58 kg (4 to 6 wks)								
ADG (kg)	0.817	0.805	0.815	0.757	0.782	0.772	0.02	0.0671
ADFI (kg)	1.889	1.957	1.967	1.802	1.787	1.767	0.04	0.0073
F/G	2.32	2.42	2.44	2.38	2.30	2.29	0.03	0.3113
25 to 58 kg (0 to 6 wks)								
ADG (kg)	0.800	0.797	0.798	0.779	0.781	0.769	0.01	0.0670
ADFI (kg)	1.686[ab]	1.744[a]	1.713[ab]	1.686[ab]	1.683[ab]	1.579[b]	0.03	0.0815
F/G	2.11	2.18	2.15	2.16	2.16	2.05	0.02	0.5408

[a,b] Means with different superscripts in a row differ ($p<0.05$). [1] Pooled standard error.
Abbreviations: GE18-GL18, 18% CP diet for early growing period-18% CP diet for later growing period; GE18-GL16, 18% CP diet for early growing period-16% CP diet for later growing period; GE19-GL17, 19% CP diet for early growing period-17% CP diet for later growing period.

experimental diets and excreta were made according to the methods of AOAC (1990). Amino acids contents were determined, following acid hydrolysis with 6N HCl at 110℃ for 16 hours (Mason, 1984), using an amino acid analyzer (Biochrom 20, Pharmacia Biotech., England).

Statistical analysis was carried out to compare means by Duncan's multiple range test (Duncan, 1955), using the General Linear Model (GLM) procedure of SAS (1985). Main effects were sex and feeding program.

RESULTS AND DISCUSSION

Growth performance

The effects of phase feeding on the growth performance of barrows and gilts are summarized in table 2. During early growing period, average daily gain and feed intake were not significantly different among treatments. The feed efficiency of gilts fed the GE19-GL17 feeding regimen was significantly ($p<0.05$) better than that of gilt fed on GE18-GL16 feeding regimen, while there was no significant difference in barrows. During the later growing period, no significant differences due to feeding regimen were found in any of the criteria measured. Through the whole growing period, feed intake of barrows fed on GE18-GL16 feeding regimen was significantly higher than that of gilts fed on GE19-GL17 feeding regimen, but average daily gain and feed/gain was not significantly different among treatments.

During the early growing period, the significant differences between sexes were not found for any criteria, but during later growing period, feed intake was significantly higher in barrows than in gilts ($p<0.05$). Average daily gain of barrows tended to be higher than that of gilts, although there was no significant difference. According to these results, sex differences became clear after 40 kg body weight. Yen et al. (1986a, b) also reported that sex difference begin to appear around 30 to 35 kg of body weight. Throughout the whole growing period, there was no interaction between feeding regimen and gender. Giles et al. (1986) obtained similar results showing that regardless of energy intake during the growing period (20 to 50 kg body weight), barrows and gilts exhibited similar responses to dietary lysine. Castell et al. (1985) found no sex×diet interaction and diet effects when comparing performance of boars, gilts and barrows fed diets formulated to contain either 0.84% or 0.76% lysine. Yen et al. (1986a) evaluated the responses of [Landrace×(Landrace×Large White)] boars, barrows and gilts to various level of lysine (0.75% to 1.45% of the diet). There were no differences in performance among sexes nor diet×sex interactions.

In summary, there was no significant difference among treatments in any criteria measured during growing period (25 to 58 kg body weight). During the whole experimental period, barrows and gilts showed similar performance, therefore it seemed that the same nutrient levels could be applied to barrows and gilts during this period. The results may suggest that feeding 18 or 19 % crude protein diet to pigs during

Table 3. Effects of phase feeding on nutrient digestibility[1]

Treatment	Barrows			Gilts			SE[2]	Contrast Barrow vs Gilt
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		
25 to 41 kg (0 to 3 wks)								
Dry matter (%)	89.22	90.42	85.00	88.55	89.59	85.51	0.85	0.3766
Crude protein (%)	86.17	88.74	83.09	86.22	87.10	83.27	0.93	0.8066
Crde ash (%)	74.96	77.79	64.77	71.31	77.86	65.04	1.88	0.7352
Crude fat (%)	81.36	84.34	77.76	83.30	84.96	75.29	1.76	0.9425
Phosphorus (%)	72.71	76.76	64.16	69.81	76.83	63.19	2.00	0.7261
41 to 58 kg (4 to 6 wks)								
Dry matter (%)	88.41	87.65	87.48	88.65	87.27	87.96	0.58	0.9259
Crude protein (%)	86.11	84.66	86.64	85.56	84.67	86.83	0.66	0.9387
Crde ash (%)	69.27	61.35	63.68	72.55	58.71	66.24	2.11	0.8055
Crude fat (%)	86.25	83.55	85.65	85.21	82.98	82.04	1.42	0.6041
Phosphorus (%)	68.03	61.47	59.09	71.31	62.31	63.50	1.97	0.4939

[a,b] Means with different superscripts in a row differ (p<0.05).
[1] For early growing period, 3 barrows and 3 gilts weighing 30.5 kg body weight were used to measure nutrient digestibility. For later growing period, 3 barrows and 3 gilts weighing 48 kg body weight were used.
[2] Pooled standard error.

the whole growing period (25 to 58 kg) would oversupply nutrients beyond their potential to grow. Therefore, the optimum protein level for early and later growing pigs is 18% and 16% CP, respectively. Supplying protein above these levels cause wastage of protein and increase pollution. This is because animal is unable to utilize excessive amino acids for protein synthesis (Chen et al., 1996). Therefore, two phase feeding regimen should be considered desirable from the standpoints of economy and pollution.

Nutrient digestibility

Table 3 shows the effects of phase feeding on nutrient digestibility by growing barrows and gilts. There was no significant difference in nutrient digestibility among treatments and between sexes. During the early growing period, the protein digestibility of pigs fed on 19% CP diet was lower than that of pigs fed on 18% CP diet, but the difference was not significant (p>0.05). The results showed that supplying early growing pigs over 18 % CP diets would decrease protein digestibility. During the later growing period, there was no treatment or sex effect on digestibility. Though there was no significant difference, pigs fed on the 16% protein diet during the later growing period showed lower protein digestibility than pigs fed on 18% and 17% CP diets.

Table 4 and 5 show the effect of phase feeding on amino acid digestibility. Amino acid digestibility showed similar trends to crude protein digestibility. During the early growing period, amino acid digestibility of 19% CP diet was lower than that of the 18% CP diet; during the later growing period, amino acid digestibility by pigs fed on lower protein diets (16% CP diet) was lower than that of pigs fed on 18% and 17% CP diets. There was no significant difference in amino acid digestibility between sexes.

In summary, there was no significant difference in proximate nutrient digestibility among treatment and between sexes during the whole growing period. During the early growing period the 18% CP diet was more digestible than the 19% CP diet, but during the later growing period, the 18% and 17% CP diets showed similar digestibility values. The 16% CP diet was slightly lower in digestibility than the 18% and 17% CP diets.

Fecal nutrient excretion

Table 6 summarizes the effects of phase feeding on fecal nutrient excretion by growing barrows and gilts. During the early growing period, DM, nitrogen and phosphorus excretion of pigs fed on 19% CP diet were higher than that of 18% CP diet. This result indicates that feeding a high protein diet over 18% for early growing pigs increased fecal nutrient excretion. During the later growing period, although there was no significant differences in fecal nutrient excretion, the fecal N and P excretion by pigs fed 16% CP diet were lower than that of 18% CP diet. Fecal N and P excretion by pigs assigned to the two-phase feeding groups (GE18-GL16 and GE19-GL17) compared to single phase feeding group (GE18-GL18) was calculated to be reduced by 10.2% and 2.0%, respectively. These results suggested that two phase feeding instead

Table 4. Effects of phase feeding on amino acids digestibility (25 to 41 kg)[1]

Treatment	Barrows			Gilts			SE[2]	Contrast
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		Barrow vs Gilt
Essential amino acids (%)								
Threonine	90.10[ab]	92.74[a]	83.15[b]	88.44[ab]	88.86[ab]	85.49[ab]	1.10	0.5859
Valine	88.97	89.96	81.58	88.03	89.11	84.53	1.15	0.8475
Methionine	83.22	86.11	74.84	83.16	83.32	73.93	1.80	0.7159
Isoleucine	89.75	90.57	83.12	88.94	89.84	85.54	1.11	0.8948
Leucine	90.38[a]	91.55[a]	75.90[b]	92.56[a]	91.21[a]	86.95[ab]	2.00	0.2320
Phenylalanine	89.53[ab]	91.56[a]	82.79[b]	89.16[ab]	87.91[ab]	84.27[ab]	1.13	0.6834
Histidine	86.32	89.96	85.74	88.49	86.17	85.73	0.97	0.7991
Lysine	89.76	91.23	84.33	89.03	89.69	85.44	1.01	0.8455
Arginie	95.05	95.16	92.11	94.56	94.79	93.29	0.53	0.9236
Submean	89.23[ab]	90.97[a]	82.62[b]	89.15[ab]	88.99[ab]	85.02[ab]	1.07	0.9546
Non-essintial amino acids (%)								
Aspartate	92.54	92.29	88.41	91.13	91.12	89.00	0.63	0.5893
Serine	92.91	92.86	87.88	91.34	92.19	89.37	0.73	0.8577
Glutamine	96.40[a]	94.67[ab]	90.79[b]	93.79[ab]	94.29[ab]	92.31[ab]	0.65	0.6773
Proline	93.65	93.91	87.34	91.57	93.88	88.46	1.04	0.8677
Glycine	88.56	90.08	81.96	88.42	88.86	83.64	1.23	0.9646
Alanine	85.64[ab]	87.59[a]	76.43[b]	84.95[ab]	86.26[ab]	81.51[ab]	1.44	0.7073
Tyrosine	89.82[ab]	92.93[a]	83.66[b]	90.43[ab]	90.93[ab]	86.40[ab]	1.18	0.8414
Submean	91.36	92.05	85.21	90.23	91.07	87.24	0.94	0.9890
Total	90.18[ab]	91.45[a]	83.77[b]	89.63[ab]	89.91[ab]	86.01[ab]	1.01	0.9787

[1] For early growing period, 3 barrows and 3 gilts weighing 30.5 kg body weight were used to measure nutrient digestibility.
[2] Pooled standard error. [a,b] Means with different superscripts in a row differ ($p<0.05$).

Table 5. Effects of phase feeding on amino acids digestibility (41 to 58 kg)[1]

Treatment	Barrows			Gilts			SE[2]	Contrast
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		Barrow vs Gilt
Essential amino acids (%)								
Threonine	88.05[ab]	84.13[ab]	89.21[a]	87.22[ab]	83.28[b]	88.19[ab]	0.76	0.4959
Valine	88.55	84.54	88.40	87.19	85.63	86.73	0.67	0.6426
Methionine	83.59	80.10	82.82	82.63	79.60	79.22	1.20	0.5391
Isoleucine	89.10	84.90	90.09	87.92	86.20	88.00	0.67	0.6090
Leucine	90.61	87.39	90.13	93.27	88.56	88.79	0.84	0.6318
Phenylalanine	87.72	85.83	89.69	88.09	83.71	88.43	1.03	0.6553
Histidine	86.69	90.76	91.08	86.20	88.99	90.27	0.89	0.5602
Lysine	88.96	85.45	90.68	88.05	85.76	89.37	0.79	0.6875
Arginie	95.16	93.84	96.43	94.01	94.21	95.86	0.36	0.4932
Submean	88.74	86.33	89.84	88.29	86.22	88.32	0.70	0.6482
Non-essintial amino acids (%)								
Aspartate	90.69[a]	86.60[bc]	91.25[a]	88.77[ab]	85.00[c]	90.56[a]	0.64	0.0852
Serine	91.35	88.94	92.43	90.90	88.91	91.59	0.52	0.6559
Glutamine	93.97	92.14	94.54	93.46	92.23	93.92	0.37	0.6388
Proline	84.35	90.01	82.97	94.12	92.00	81.35	2.75	0.5771
Glycine	87.91	84.46	89.51	87.74	84.18	87.35	0.84	0.6106
Alanine	85.87	80.25	85.54	85.11	81.20	84.34	0.94	0.8577
Tyrosine	90.93	90.36	92.09	91.07	89.13	90.59	0.70	0.5965
Submean	89.30	87.54	89.76	90.17	87.52	88.53	0.56	0.9201
Total	88.99	86.86	89.80	89.12	86.80	88.41	0.59	0.7318

[1] For the later growing period, 3 barrows and 3 gilts weighing 48 kg body weight were used to measure nutrient digestibility.
[2] Pooled standard error. [a,b] Means with different superscripts in a row differ ($p<0.05$).

Table 6. Effects of phase feeding on fecal nutrient excretion (g/day)[1]

Treatment	Barrows			Gilts			SE[2]	Contrast Barrow vs Gilt
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		
25 to 41 kg								
Dry matter	143.67	140.63	158.34	149.71	150.81	166.81	7.99	0.6707
Nitrogen	6.32	6.16	7.46	6.30	6.44	7.55	0.33	0.8737
Phosphorus	2.86[ab]	2.44[b]	4.14[a]	3.17[ab]	2.43[b]	4.25[a]	0.24	0.7293
41 to 58 kg								
Dry matter	162.39	150.66	156.03	162.24	149.85	151.71	4.44	0.8682
Nitrogen	6.80	6.00	6.29	6.60	6.03	6.12	0.25	0.8480
Phosphorus	3.69	3.47	3.93	3.31	3.39	3.50	0.18	0.4843

[a,b] Means with different superscripts in a row differ ($p<0.05$).
[1] For early growing period, 3 barrows and 3 gilts weighing 30.5 kg body weight were used to measure nutrient digestibility; for later growing period, 3 barrows and 3 gilts weighing 48 kg body weight were used.
[2] Pooled standard error.

Table 7. Comparison of economics of different feeding regimen[1]

Treatment	Barrows			Gilts			SE[2]	Contrast Barrow vs Gilt
	GE18-GL18	GE18-GL16	GE19-GL17	GE18-GL18	GE18-GL16	GE19-GL17		
TWG (kg)	33.6	33.4	33.5	32.7	32.8	32.3	0.49	0.3831
TFC (₩)	19,297	19,183	19,483	19,258	18,540	17,979	366.39	0.3576
FCG (₩)	573.4	570.4	581.6	588.2	565.8	557.2	4.91	0.6396

[1] Feed production costs for each diet were 265.2 ₩/kg for 19% CP, 256.9 ₩/kg for 18% CP, 248.8 ₩/kg for 17% CP, 239.8 ₩/kg for 16% CP, respectively.
[2] Pooled standard error.
Abbreviations: TWG, Total weight gain; TFC, Total feed cost; FCG, Feed cost/kg weight gain (₩).

of single phase feeding during growing period could reduce fecal N and P excretion. This is in agreement with 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. Comparing GE18-GL16 feeding regimen with GE19-GL17 feeding regimen, fecal DM, N and P excretion were reduced in the GE18-GL16 group. There was no significant difference between sexes during the whole experimental period.

Feed cost

Table 7 shows the effect of different feeding regimens on the feed cost of growing pigs. Total feed cost (₩) per pigs and feed cost per kg weight gain were not significantly different among treatments and between sexes. There was a trend in total feed cost and feed cost per kg weight gain of two phase feeding (GE18-GL16) groups to be lower than that of the single feeding group (GE18-GL18). The difference in feed cost between single and two phase feeding during growing period was greater in gilts than in barrows. In barrows, the cost reduction by percentage on two phase feeding (GE18-GL16) compared to on single phase feeding (GE18-GL18) was only 0.52%, but that of gilts was 3.81%. Therefore, it can be suggested that phase feeding is more desirable for gilts than barrows. These results are similar to Han et al. (1998) who reported that total feed cost of single phase feeding was higher than two phase feeding. More cost reduction by two phase feeding could be expected as the price of protein sources increases. These results suggest that two phase feeding for growing period could save feed costs compared to single phase feeding.

REFERENCES

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

Baker, D. G. and T. K. Chung. 1992. Ideal protein for swine and poultry. Bio Kyowa Technical Review. #4.

Castell, A. G., R. L. Cliplef and R. M. McKay. 1985. Effects of diet, litter, and sex type on the performance (from 22 to 90 kg live weight) and carcass measurements of crossbred pigs. Can. J. Anim. Sci. 65:821.

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.

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.

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

Giles, L. R., E. S. Batterham and E. B. Dettmann. 1986. Amino acid and energy interactions in growing pigs. Anim. Prod. 42:133.

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. Sohn and M. K. Kim. 1998. Effect of phase feeding on the growth performance and nutrient utilization in finishing pigs. Asain-Aus. J. Anim. Sci. 11(5):559.

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.

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.

Heo, K. N., In K. Han and H. Lee. 1995. Protein sparing effect and amino acid utilization in broilers fed two types of lysine. Asian-Aus. J. Anim. Sci. 8(4):403.

Honeyman, M. S. 1996. Sustainability issues of U.S. swine production. J. Anim. Sci. 74:1410.

Jin, C. F., J. H. Kim, I. 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):1.

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

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.

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.

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

Mason, V. C. 1984. Metabolism of nitrogenous compound in the large gut [Emphasis on recent findings in the sheep and pig]. Proc. Nutr. Soc. 43:45.

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.

NRC. 1998. Nutrient Requirements of Swine (10th Ed.). National Academy Press, Washington, DC.

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(6):615.

Park, H. Y., I. K. Han and K. N. Heo. 1994. Effects of supplementation of single cell protein and yeast culture on growth performance in broiler chicks. Korean J. Anim. Nutr. Feed. 18(5):346.

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

Watkins, L. E., L. A. Swiger and D. C. Mahan. 1977. Effects and interactions of breed group, sex and protein level on performance of swine. J. Anim. Sci. 45:1977.

Yen, H. T., D. J. A. Cole and D. Lewis. 1986a. Amino acid requirements of growing pigs. 7. The responses 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 responses of pigs from 50 to 90 kg live weight to dietary ideal protein. Anim. Prod. 43:155.