VITAMIN AND AMINO ACID SUPPLEMENTATION OF DIETS FOR GROWING-FINISHING PIGS

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ABSTRACT

A series (6) of experiments were conducted to determine the effect of supplementing biotin, choline, vitamin E, pyridoxine, niacin and thiamine in diet of growing-finishing pigs. Each experiment consisted of four treatments with different levels of vitamin considered. Results showed that growing-finishing swine perform better when they were supplemented with 0.10 mg biotin, 1.0 g cholin, 10 I.U. vitamin E, 15 mg niacin, 4.0 mg pyridoxine and 4.0 mg thiamine per kg diet. Incidence of cracked toes was reduced up to 57% when biotin was supplemented at the rate of 0.20 mg per kg of diet. The different levels of supplementation did not affect the carcass quality and skin appearance of the pigs.

Another three experiments were conducted to investigate the effect of various levels of protein and lysine in diets for starter, grower and finisher pigs. Within experiment, all the three diets contained similar energy and other nutrients. Results of the three experiments showed that the performance of pigs fed with the three diets within experiment were similar when the levels of crude protein were maintained at same levels. Furthermore, reducing the protein level two percentage points and lysine levels to 0.02 percentage point for every reduction in crude protein gave similar performance compared to pigs in the other treatment groups.

Introduction

The swine industry has made great strides since 1950, and there is potential for even greater production efficiency in the future. The industry needs to increase greatly its efficiency of operation to compete effectively in price with other protein sources for human consumption. Two areas of interest in tackling this problem are vitamin and amino acid nutrition of growing-finishing pigs. Vitamins represent only a minute fraction of feed, amounting to less than 0.1% by weight and about 2% of the cost. Yet, a balanced vitamin fortification meeting the requirement of swine under a wide range of feeds and different production systems will offset the cost of adding vitamins. In the past years, many changes in feed formulation and other management practices have reduced the vitamin levels supplied by natural feed ingredients, thereby increasing vitamin supplementation requirements in swine. The levels and bioavailability of vitamins in feedstuffs vary widely, and the vitamin requirements of swine vary during their productive cycle. Optimum

performance in swine may not be achieved if their ration is formulated first to meet the minimum vitamin requirements and calculated values for vitamin content in feedstuffs. Vitamin deficiency in swine may result from inadequate levels of vitamins in many feed ingredients. Pathological changes and other conditions reduce absorption of vitamins from the gastrointestinal tract. In the Philippines, much of our knowledge of vitamin requirements of swine is from foreign countries. Only few studies have been conducted (Eusebio *et al.*, 1977) to determine the effect of adding vitamins to rations for growing-finishing pigs; hence, these series of studies were conducted.

The cost of providing relatively large quantities of specific amino acids in the diet for swine is a major concern of swine nutritionists. The primary sources of these amino acids are the protein found in common feed ingredients. Unfortunately, very few feed ingredients contain amino acids in proper amounts relative to the animal requirements. Furthermore, the amino acids, particularly those by-products used for swine feeding, may not be fully available (Carpenter, 1973; Erbersdobler, 1976; and Zebrowska, 1978). Lysine has been the subject of far more swine nutrition experiments than any other amino acid due to its serious deficiency in all the cereal grains which are the main ingredients in most practical rations (Meade, 1972). The levels of protein and lysine have been studied in other countries using corn and soybean meal based diets (Baker *et. al.*, 1975; Easter and Baker, 1980). The objective of this present research was to evaluate the effect of various protein and lysine levels of starter, grower and finisher diets on the growth performance of pigs.

Materials and Methods

Vitamins

Six experiments were conducted in this study, in each of which the supplementation for one vitamin was studied. Each experiment consisted of four treatments (Table 1) replicated seven times, except that on choline which was replicated

Table 1. Levels of added vitamin in diets (amount per kilogram diet)

Vitamin	*Treatment*			
	1	*2*	*3*	*4*
Biotin, mg	0	0.05	0.10	0.20
Choline, g	0	1.00	2.00	3.00
Vitamin E, I.U.	0	10.00	20.00	40.00
Niacin, mg	0	15.00	30.00	60.00
Pyridoxine, mg	0	1.00	2.00	3.00
Thiamin, mg	0	2.00	4.00	8.00

six times. The animals used were littermates and were alloted to the different treatments according to sex and weight. They were distributed randomly to the four treatments. The composition of the experimental diets are shown in Table 2. At the start of the experiment, the animals were fed 18 percent crude protein until they reached 20 kg. and 16 percent crude protein diet when they weighed 20 to 60 kg. A 14 percent crude protein ration was fed to the animals weighing 60 to 85 kg. The vitamin premix was formulated such that the amount of the vitamin in question added to the diet would be according to the desired levels as shown in Table 3.

The experimental animals were fed and watered ad-libitum individually in concrete pens. Standard swine management was practiced throughout the experiments. Animals were weighed at the start of the experiment and every two weeks thereafter. Data gathered included, feed consumption and biweekly weights of the animal from which feed conversion efficiency was computed.

For carcass evaluation, three representative animals from each treatment were slaughtered following standard procedure as soon as they reached 85 kg. Animals were also observed for the incidence of abnormalities and cracked toes. All data gathered were statistically analyzed using completely randomized design.

Amino acid

Seventy-two crossbred pigs were used in three experiments to determine the effect of various levels of protein and lysine in starter, grower and finisher diets.

Table 2. Composition of experimental rations

Ingredients	*Starter*	*Grower*	*Finisher*
Yellow corn	51.30	38.00	38.00
Ricebran	14.00	38.00	40.00
Soybean oil meal	25.00	15.00	10.00
Copra meal	5.00	4.00	6.00
Ipil-ipil leaf meal	2.00	2.00	4.00
Dicalcium phosphate	1.50	1.00	–
Salt	0.50	0.50	0.50
Limestone	0.20	1.00	1.00
Vitamin-mineral premix	0.50	0.50	0.50
Total	100	100	100
Calculated analysis			
Crude protein, %	18.16	15.89	14.76
Calcium, %	0.52	0.67	0.45
Available phosphorus, %	0.46	0.46	0.38
M.E., kcal/kg	3045	3044	3054

Table 3. Composition of the vitamin-mineral premix of the diets for growing-finishing pigs based on US-NRC, 1979

Ingredient	*Amount per kg premix*
Vitamin	
A, I.U	360,000
D, I.U	40,000
E, I.U	2,200
B_1, mg	220
B_2, mg	600
B_6, mg	299.97
Panthothenic acid, mg	2,199.78
Choline, mg	140,000
B_{12}, mg	3.0
Biotin, mg	20.00
Antioxidant	
PHT, g	20
Mineral	
Zn O, ppm	40,000
CuSO4, ppm	4,000
MnSO4, ppm	2,000
FeSO4, ppm	3,000

In the starter stage, 24 pigs averaging 10 kg were individually penned in 1m x 3m pens with concrete flooring, equipped with self-feeders and waterers. The 24 pigs were randomly alloted to three dietary treatments as shown in Table 4. In diet 1, the protein and lysine levels was 18% and 0.94%, respectively. This protein level is similar to the US-NRC (1979) requirement, but the lysine level was higher (NRC = 0.79%). The 0.94% lysine level used in this study is similar to European estimates of nutrient requirement (ARC, 1967 and AEC, 1978). In diet 2, the protein level was reduced to 16% while the lysine level was maintained at 0.94%. Diet 3 contained 16% protein while lysine was reduced to 0.90%. The three diets were composed of corn, soybean meal, ricebran, copra meal, minerals and vitamin supplements, and lysine and methionine when needed. All the other nutrients were formulated to satisfy the minimum requirements using a least cost formulation by a microcomputer. Individual weight gains and feed intake were recorded during the 4-week experiment.

In the grower stage, another 24 pigs averaging 26 kg were individually penned in the same pens as those used in the starter stage. They were alloted to three dietary treatments based on sex and litter. Diet 4 contained 16% crude protein and 0.81% lysine (Table 4). The protein level was similar to those set by the US-NRC (1979), while the lysine level was higher (US-NRC = 0.70%) but is in line with European recommendations. In diet 5, the protein level was lowered to 14% while maintaining the same lysine level as in diet 4 (0.81%). Diet 6 contained 14%

Table 4. Diets for starter, grower and finisher pigs

Ingredients	*Starter diet*			*Grower diet*		
	1	*2*	*3*	*4*	*5*	*6*
Corn	52.09	55.80	55.78	51.64	56.08	56.06
Soybean meal	25.14	18.84	18.96	18.92	12.53	12.65
Ricebran	9.72	12.12	12.07	16.85	18.62	18.56
Copra meal	10.00	10.00	10.00	10.00	10.00	10.00
Hycaphos	1.66	1.68	1.68	1.39	1.20	1.19
Limestone	0.69	0.71	0.70	0.50	0.69	0.70
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Vit-min. premix	0.20	0.20	0.20	0.20	0.20	0.20
Lysine	–	0.15	0.11	–	0.14	0.09
Methionine	–	–	–	–	0.04	0.05
Total	100	100	100	100	100	100

Table 4. cont.

Ingredients	*Finisher diet*		
	7	*8*	*9*
Corn	56.21	56.40	56.14
Soybean meal	12.14	6.09	8.14
Ricebran	–	5.30	6.17
Copra meal	17.28	17.63	18.00
Ipil-ipil	4.00	4.00	4.00
Hycaphos	1.45	1.46	1.48
Limestone	1.32	1.32	1.31
Molasses	7.00	7.00	7.00
Salt	0.50	0.50	0.50
Vit-min. premix	0.10	0.10	0.10
Lysine	–	0.17	0.13
Methionine	–	0.03	0.03
Total	100	100	100

crude protein and 0.77% lysine. All other nutrients in diets 4, 5 and 6 were formulated to satisfy the minimum requirement. Individual weight gains and feed intake were recorded during the 8-week experiment.

In the finisher stage, another 24 pigs averaging 61 kg were randomly distributed to three dietary treatments. Diet 7 was formulated to contain 14% crude protein and 0.65% lysine while diet 8 contained 12% crude protein and same lysine level. Diet 9 was formulated to contain 12% crude protein and 0.61% lysine.

Similarly, individual weight gain and feed intake were recorded during the experiment until the pigs reached 82 kg.

All feed ingredients and diets were chemically analyzed for proximate components according to AOAC (1975) methods. Data from the three experiments were analyzed using the complete randomized design (Snedecor and Cochran, 1967).

Results and Discussion

Vitamins

Biotin

The overall performance of pigs from 10 to 86 kg indicated that supplementation of biotin in the diet did not significantly affect the different parameters considered in this study (Table 5). Incorporation of 0.10 ppm biotin in the diet resulted in a better feed efficiency compared to the other treatment groups. Roche (1978) recommended 0.05 ppm level of biotin in the diet for finishing pigs and 0.08 to 0.10 ppm biotin in growing pigs. The US-NRC requirement for biotin by growing-finishing swine is 0.10 ppm.

Table 6 shows the percent incidence of cracked toes in animals as influenced by the different levels of biotin in the diet. Pigs without biotin supplementation had the highest percent incidence of cracked toes. As the biotin supplementation was increased from 0 to 0.10 ppm in the diet, the percent incidence of cracked toes decreased from 85.71% to 57.14%. Addition of biotin beyond 0.10 ppm level did not further reduce the incidence of cracked toes. Brooks (1982) showed that addition of biotin to sow diets resulted in a 69% reduction in foot lesions in sows.

Table 5. Production performance of pigs weighing an average of 11 to 86 kg fed diets supplemented with different levels of biotin

Criteria[a]	*mg biotin per kg diet*			
	1 *0*	*2* *0.05*	*3* *0.10*	*4* *0.20*
Initial weight, kg	10.64	10.64	10.71	10.64
Final weight, kg	86.29	85.71	85.14	86.79
Ave. daily gain, kg	0.46	0.41	0.45	0.44
Ave. daily feed consumption, kg	1.59	1.54	1.55	1.57
Feed efficiency, f/g	3.47	3.53	3.46	3.57
Feeding period, days	165	172	166	172

[a]No significant difference ($P > .050$)

Table 6. Percent incidence of cracked claws/toes in pigs fed diets supplemented with different levels of biotin

Treatment		*% cracked claws/toes*
1	0 ppm biotin	85.71
2	0.05 ppm biotin	71.43
3	0.10 ppm biotin	57.14
4	0.20 ppm biotin	57.14

The carcass characteristics of the pigs were likewise not significantly affected by the different levels of biotin in the diet (Table 7). There was, however, an improvement in carcass recovery and lean cut yield at 0.10 ppm biotin level. The dressing percentage and lean cut yield tended to increase as the amount of biotin increased from 0 to 0.10 ppm level, and decreased at 0.20 ppm level. No definite pattern was observed on the other criteria.

Table 7. Carcass characteristics of pigs fed diets supplemented with different levels of biotin

Criteria[a]	*Treatment*			
	1	*2*	*3*	*4*
Backfat thickness, cm	3.02	2.76	2.81	3.02
Carcass length, cm	74.59	76.02	75.62	77.02
Chilled carcasss, kg	61.20	61.38	62.85	63.75
Dressing percentage	71.89	72.04	74.62	72.79
Lean cut weight, kg	45.59	46.99	47.60	46.47
Percent ham and loin	44.88	45.78	45.24	44.48
Marbling score	1.75	2.00	1.50	1.50
Fat firmness score	3.00	2.75	3.25	3.00
Loin eye area, sq. cm.	26.74	62.91	27.86	29.26

[a]No significant difference (P> .05)

Choline

The effect of supplemental choline on the production performance of growing-finishing pigs is presented in Table 8. The data show that the addition of 1.0 g choline per kg diet improved the feed efficiency by 4.2% over the control. Furthermore, pigs supplemented with 1.0 g choline per kg diet consumed the least amount of feed until they reached 85.0 kg liveweight. Previous studies by Allee (1977), Bryant *et al.* (1978a), and Bryant *et al.* (1978b) showed no significant improve-

Table 8. Production performance of growing-finishing pigs weighing 10 to 85 kg fed diets supplemented with different levels of choline

Criteria[a]	*g choline per kg*			
	1	*2*	*3*	*4*
	0	*1.0*	*2.0*	*3.0*
Initial weight, kg	10.58	10.56	10.00	9.75
Ave. daily gain, kg	0.48	0.49	0.48	0.50
Feed consumption, kg	247.97	237.36	254.00	240.70
Feed efficiency, f/g	3.32	3.18	3.39	3.20
Feeding period, days	154	151	155	150

[a]No significant difference (P > .05)

ment in growth performance as a result of choline supplementation. In their studies, corn-soybean meal was the principal basal diet used, while in this study, by-products like copra meal and ricebran were included in the diet.

Data on carcass characteristics showed no significant difference in the variables measured although backfat was slightly greater in pigs supplemented with 1.0 g choline per kg diet (Table 9). In addition, pigs in treatment 2 had longer carcass (76.32 cm) and yielded more ham and loin (47.47%) compared to the other treatments.

Table 9. Carcass characteristics of pigs fed diets supplemented with different levels of choline

Criteria[a]	*Treatment*			
	1	*2*	*3*	*4*
Backfat thickness, cm	2.69	2.94	2.73	2.90
Carcass length, cm	74.72	76.32	75.62	76.18
Chilled carcass, kg	59.92	60.40	62.00	64.03
Dressing percentage	69.45	68.87	69.70	70.86
Lean cut yield, kg	45.49	46.17	46.46	47.89
% ham and loin	46.02	47.47	47.33	46.30

[a]No significant difference (P > .050)

Vitamin E

The data on Table 10 illustrate that a supplementation of 10 I.U. of vitamin E per kg diet gave the best response in terms of production performance. These

Table 10. Production performance of growing-finishing pigs weighing 12 to 85 kg liveweight fed diets supplemented with different levels of vitamin E

Criteria[a]	*IU Vitamin E per kg diet*			
	1	*2*	*3*	*4*
	0	*10*	*20*	*40*
Initial weight, kg	11.79	11.91	11.83	11.71
Final weight, kg	85.57	84.86	85.25	85.14
Ave. daily gain, kg	0.53	0.53	0.50	0.51
Ave. feed consumed, kg	229.04	223.02	242.94	236.10
Feed efficiency, f/g	3.10	3.06	3.31	3.22
Feeding period, days	140	137	147	144

[a]No significant difference (P > .05)

results confirmed the value recommended by Roche (1978), although it was slightly lower compared to the US-NRC requirement of 11 I.U. Per kg of diet. The performance of growing-finishing pigs decreased as vitamin E supplementation increased above 10 I.U. vitamin E per kg diet. The average daily gain was 0.53 kg for both the control group (treatment 1) and treatment 2 where it was 0.50 and 0.51 kg for treatments 3 and 4, respectively. Lowest feed consumption was observed for pigs in treatment 2, and highest for those in treatment 3. Same observation was noted for feed efficiency and length of feeding period.

The effect of vitamin E supplementation on the carcass quality of pigs was also evaluated (Table 11). Results revealed that the criteria used in evaluating the carcass quality were not significantly different among the treatments.

Table 11. Carcass characteristics of pigs fed diets supplemented with different levels of vitamin E

Criteria[a]	*Treatment*			
	1	*2*	*3*	*4*
Backfat thickness, cm	2.60	2.77	3.09	3.38
Carcass length, cm	73.77	74.33	75.30	75.97
Chilled carcass, kg	62.63	58.23	68.17	63.40
Dressing percentage	72.57	69.28	76.54	71.23
Lean cut yield, kg	45.96	43.63	51.03	44.71
% ham and loin	44.18	45.96	44.45	43.36
Marbling score	1.33	1.67	1.33	1.00
Fat firmness score	3.00	3.00	3.00	3.00
Loin eye area, sq. cm	30.82	31.92	28.29	23.29

[a]No significant difference (P > .05)

Niacin

The overall production performance of the pigs is presented in Table 12. Results show that the feeding period, total feed consumption, average daily gain and feed conversion efficiency of the animals were not statistically different among all treatments. However, pigs in treatment 2 had the least feed consumption and were the most efficient feed converter. Based on the data presented, supplementing niacin at a level higher than 15 mg per kg diet did not improve the performance of the animals.

Table 13 shows the carcass characteristics of pigs fed diets supplemented with different levels of niacin. It indicates that varying levels of niacin supplementation

Table 12. Production performance of growing-finishing pigs weighing 12 to 85 kg fed diets supplemented with different levels of niacin

Criteria[a]	*mg niacin per kg diet*			
	1	*2*	*3*	*4*
	0	*15*	*30*	*60*
Initial weight, kg	11.57	11.43	11.28	11.71
Final weight, kg	85.28	85.00	85.00	85.33
Ave. daily gain, kg	0.48	0.47	0.48	0.48
Ave. feed consumed, kg	264.26	266.68	266.26	269.50
Feed efficiency, f/g	3.69	3.62	3.61	3.66
Feeding period, days	153	149	154	152

[a]No significant difference (P > .05)

Table 13. Carcass characteristics of pigs fed diets supplemented with different levels of niacin

Criteria[a]	*Treatment*			
	1	*2*	*3*	*4*
Backfat thickness, cm	2.64	2.64	2.75	2.75
Carcass length, cm	76.80	79.84	78.22	76.13
Chilled carcass, kg	61.63	61.90	60.17	59.87
Dressing percentage	72.51	70.12	70.78	70.15
Lean cut weight, kg	46.87	44.98	45.12	44.78
% ham and loin	46.32	45.98	45.52	45.93
Marbling score	1.67	2.25	2.00	1.33
Fat firmness score	3.33	3.25	3.00	3.67
Loin eye area, sq. cm	28.38	28.83	28.19	28.60

[a]No significant difference (P > .05)

in the diet did not significantly affect the carcass quality of pigs. However, there was a slight improvement on the carcass quality of those fed with diet supplemented with 15 mg niacin as shown by the backfat thickness (2.64 cm), carcass length (79.84 3m) and chilled carcass weight (61.9 kg). The marbling score (2.25) and loin eye area were highest on pigs in treatment 2. The lean cut weight and percent ham and loin of pigs in treatment 2 were slightly lower compared to the control group. Based on the carcass evaluation, most of the carcass traits did not respond as niacin level was increased to 15 mg per kg diet.

Pyridoxine

No significant differences ($P < .05$) were observed in total feed consumed, average daily gain and feed conversion efficiency of animals among the treatments (Table 14). According to US-NRC (1979) growing-finishing swine require 1.1 mg of pyridoxine per kg of diet. In this experiment, pigs supplemented with 4.0 mg pyridoxine per kg of diet showed a consistently higher response for all the parameters measured and reached slaughter weight 7 to 9 days earlier than those from the other three dietary treatment groups. This observation is similar to that reported by Cunha (1977) wherein pyridoxine supplementation to corn-milo-soybean meal diet increased the rate of gain and feed conversion efficiency of growing-finishing pigs. These observations however, were in contrary to the work of Easter *et al.,* (1983) wherein the performance of pigs did not improve when corn-soybean meal diets were supplemented with pyridoxine.

The summary of carcass characteristics of pigs fed different levels of vitamin B6 is shown in Table 15. There were no significant differences on the different carcass traits measured among the different treatments. Carcass length of the animals tended to increase with increasing level of pyridoxine supplementation.

Table 14. Production performance of pigs weighing 12 to 85 kg fed diets supplemented with different levels of pyridoxine

Criteria[a]	*mg pyridoxine per kg diet*			
	1 *0*	*2* *1.0*	*3* *2.0*	*4* *4.0*
Initial weight, kg	12.50	12.31	12.31	12.63
Final weight, kg	85.03	85.07	84.95	84.94
Ave. daily gain, kg	0.53	0.53	0.52	0.56
Ave. feed consumed, kg	246.75	245.84	251.07	230.08
Feed efficiency, f/g	3.41	3.38	3.45	3.18
Feeding period, days	137	138	133	130

[a]No significant difference ($P > .05$)

Table 15. Carcass characteristics of pigs fed diets supplemented with different levels of pyridoxine

Criteria[a]	Treatment			
	1	*2*	*3*	*4*
Backfat thickness, cm	2.45	2.27	2.69	2.47
Carcass length, cm	75.50	75.67	75.95	76.82
Chilled carcass, kg	56.77	56.77	57.87	55.83
Dressing percentage	66.51	66.26	67.14	65.93
Lean cut weight, kg	42.82	42.98	40.99	42.24
% ham and loin	46.20	47.19	43.93	45.72
Marbling score	2.00	2.33	1.66	2.33
Fat firmness score	3.00	3.33	3.66	3.33
Loin eye area, sq. cm	25.47	25.55	24.52	23.67

[a]No significant difference (P > .05)

Thiamin

Table 16 reveals that pigs fed with diets supplemented with 0 or 2.0 mg thiamin per kg diet had the lowest average daily gain (0.56 kg) while those fed with diets supplemented with 4.0 and 8.0 mg thiamin per kg diet had an average daily gain of 0.57 and 0.60 kg, respectively. The least amount of feed consumed was observed in pigs where diets were supplemented with 4.0 mg thiamin resulting in a feed efficiency of 3.14. It seems that the level of 4.0 mg of thiamin per kg diet gave the best performance among the different levels. No carcass evaluation was done in this experiment due to malfunctioning of the chiller facilities of the Institute of Food Science and Technology at the end of the experiment.

Table 16. Production performance of pigs weighing 11 to 85 kg fed diets supplemented with different levels of thiamine

Criteria[a]	*mg thiamine per kg diet*			
	0 *1*	*2.0* *2*	*4.0* *3*	*8.0* *4*
Initial weight, kg	11.33	11.67	11.08	11.14
Final weight, kg	84.67	85.08	84.33	85.21
Ave. daily gain, kg	0.56	0.56	0.57	0.60
Ave. feed consumed, kg	232.92	232.80	230.08	234.29
Feed efficiency, f/g	3.18	3.17	3.14	3.16
Feeding period, days	130	130	128	130

[a]No significant difference (P > .05)

Lysine and protein levels

Calculated analyses of diets are presented in Table 17. The metabolizable energy contents of the 3 starter diets were similar (3100 kcal of ME per kg diet). In both the starter and grower diets, the levels of sulfur amino acids (methionine and cystine), tryptophan and threonine were a little higher for diets 1 and 4 than for the other diets (2, 3, 5 and 6), although the requirement for these amino acids are satisfied. In the grower diets, the energy contents were the same (3100 kcal of ME per kg of diet). Reduction in protein level of the starter diet resulted in a decrease of about ₱0.03 per kilogram of feed and decreasing further the lysine level resulted in another decrease of ₱0.03 per kg of feed. In the grower diets, reducing the protein level to 14% caused a reduction of ₱0.02 per kilogram of feed and reducing the lysine levels caused a further decrease in cost of ₱0.02 per kg of feed.

Table 17. Analysis of diets

Criteria	*Starter diet*			*Grower diet*		
	1	*2*	*3*	*4*	*5*	*6*
Crude protein, %	18.00	16.00	16.00	16.00	14.00	14.00
Lysine, %	0.94	0.94	0.90	0.81	0.81	0.77
Met-cystine, %	0.61	0.56	0.56	0.55	0.53	0.53
Tryptophan, %	0.25	0.22	0.22	0.22	0.20	0.20
Threonine, %	0.66	0.58	0.58	0.55	0.51	0.51
Calcium, %	0.80	0.80	0.80	0.65	0.65	0.65
Avail. phosphorus, %	0.35	0.35	0.35	0.30	0.30	0.30
Crude fiber, %	5.50	5.50	5.50	6.00	6.00	6.00
M.E., kcal/kg	3082	3100	3101	3100	3128	3120
Cost/kg, P	3.61	3.58	3.55	3.42	3.40	3.38

Table 17. cont.

Criteria	*Finisher diet*		
	7	*8*	*9*
Crude protein, %	14.00	12.00	12.00
Lysine, %	0.65	0.61	0.61
Met-cystine, %	0.53	0.53	0.53
Calcium, %	1.00	1.00	1.00
Avail. phosphorus, %	0.30	0.30	0.30
M.E., kcal/kg	3002	3004	3004

The performance of pigs in the starter stage is shown in Table 18. The average daily gain (ADG) of pigs fed with diet 3 was highest compared to that of pigs fed with diets 1 and 2. The ADG of pigs in this study is higher compared to the study of Lewis *et al.* (1980) where they fed pigs similar levels of lysine. Similar observations in feed efficiency (F/G) were observed as in ADG. Lowering the protein and lysine levels did not affect the performance of the pigs nor their feed consumption. Earlier work conducted by Baker *et al.* (1975) from the University of Illinois demonstrated that lower protein levels tend to lead to higher feed intake. These results agree with observations in this study.

Table 18. Performance of pigs during starter stage

Criteria[a]	*Treatment*		
Diet	*1*	*2*	*3*
Protein level	*18*	*16*	*16*
Lsyine level	*0.94*	*0.94*	*0.90*
No. of pigs	8	8	8
Initial weight, kg	10.44	9.81	9.90
Final weight, kg	22.12	21.12	22.60
Ave. daily gain, kg	0.40	0.39	0.44
Feed efficiency	2.61	2.52	2.14
Ave. daily feed consumption, kg	0.91	0.97	0.91

[a]No significant difference ($P > .05$)

In the grower stage, the ADG of pigs are similar for the three treatments (Table 19). This result agrees with earlier findings by Baker *et al.*, (1975) and Easter and Baker (1980) where they obtained similar growth rate when pigs were fed two levels of protein with similar lysine levels. Wahlstrom and Libal (1974) showed that performance of growing pigs fed either 13.5 or 17.5% crude protein was similar provided that the lower protein level was supplemented with 0.20% lysine.

The performance of pigs for all treatments during the finisher stage was similar as shown in Table 20. There was a reduction of feed consumption as the level of protein and amino acid decreased.

The results of these studies show that it is possible to reduce the lysine level by 0.02 percentage per unit reduction in crude protein for all growth stages. In these studies, lower protein levels generally tend to lead to higher feed intake and consequently a lower lysine requirement, when expressed as a percentage of the diet. Furthermore, when the protein level is reduced and the lysine level is restored by the addition of synthetic lysine, the overall availability of the lysine provided will be higher and the need for total lysine will be less. In other studies, high

Table 19. Performance of pigs during the grower stage

Criteria[a]	*Treatment*		
Diet	*4*	*5*	*6*
Protein level	*16*	*14*	*14*
Lysine level	*0.81*	*0.81*	*0.77*
No. of pigs	8	8	8
Initial weight, kg	26.50	26.40	26.50
Final weight, kg	60.12	57.25	59.50
Ave. daily gain, kg	0.59	0.54	0.58
Feed efficiency, f/g	3.21	3.55	3.28
Ave. daily feed consumption, kg	1.88	1.88	2.15

[a]No significant difference ($P > .05$)

Table 20. Performance of pigs during the finishing stage

Criteria[a]	*Treatment*		
Diet	*7*	*8*	*9*
Protein level	*14*	*12*	*12*
Lysine level	*0.65*	*0.65*	*0.61*
No. of pigs	8	8	8
Initial weight, kg	61.00	60.87	61.25
Final weight, kg	82.62	80.75	83.00
Ave. daily gain, kg	0.53	0.50	0.53
Feed efficiency, f/g	4.21	4.57	4.15
Ave. daily feed consumption, kg	2.22	2.19	2.18

[a]No significant difference ($P > .05$)

protein levels resulted in high levels of dietary arginine which may have interfered with lysine absorption and consequently increased lysine requirement. The decision to reduce the protein and lysine levels of swine diets for starter, grower and finisher pigs depends largely on economic consideration, which is the relative prices of corn, soybean meal and synthetic lysine.

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