Effects of Amino Acid Supplementation on Growth Performance for Weanling, Growing and Finishing Pigs

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ABSTRACT : Four feeding trials with 260 pigs were conducted to evaluate the effects of supplementing the diet with different amino acids on growth performance and blood metabolites for weanling, growing and finishing pigs. One hundred twenty weanling pigs (Exp. 1, BW 8 kg), eighty growing pigs (Exp. 2, BW 20 kg), thirty growing pigs (Exp. 3, BW 29 kg) and thirty finishing pigs (Exp. 4, BW 50 kg) were randomly allotted to different dietary treatments according to sex and body weight. Pigs weight and feed consumption were measured at initiation and termination of each trial with 4 weeks. At the end of trial, blood samples from three pigs selected in each pen (Exp. 1) and each pig (Exp. 2) were obtained to determine the level of blood urea nitrogen, glucose, insulin and cortisol in the serum. In Exp. 1, pigs fed diet supplemented both with lysine and methionine had the best feed conversion ratio ($p < 0.05$), but no significant differences ($p > 0.05$) were observed in ADG and ADFI. Pigs receiving control diet obtained the optimal ADG ($p < 0.05$), ADFI ($p < 0.05$) and F/G for the whole period. No differences were detected in serum glucose, insulin and cortisol concentrations. In Exp. 2, pigs receiving the control diet exhibited the lowest serum urea nitrogen ($p < 0.05$), ADG, F/G and serum insulin concentration increased linearly ($p < 0.05$) with the inclusion of lysine, methionine, threonine and tryptophan in diets. No significant differences ($p > 0.05$) were detected for glucose and cortisol content in pigs serum among dietary treatments. In Exp. 3 and 4, pigs growth rate increased linearly ($p < 0.01$), and feed conversion efficiency was also improved by addition of lysine, methionine, threonine and tryptophan. In conclusion, pigs fed diets supplemented with lysine, methionine, threonine and tryptophan together obtained optimal growth performance in growing and finishing periods.

(**Key Words**: Pig, Amino Acid, Performance, Blood Urea Nitrogen, Insulin, Cortisol, Glucose)

INTRODUCTION

The quality of dietary protein is determined by its content of amino acids (AA), and by their availability. Quality can be considered as the degree to which the composition of the absorbed AA mixture accords with the balance required by the animal. A more restricted definition of an ideal protein is one which includes the minimum quantity of each essential AA compatible with maximum utilization of the protein as a whole. The question of the dietary AA pattern required by growing pigs has been intensively reviewed in the past few years (Cole, 1978; Fuller, 1978; Cole, 1980; Henry, 1980; Low, 1980; Agricultural Research Council, 1981; Fuller and Chamberlain, 1982; Wiesemuller, 1983; Yen et al., 1986). The ideal protein was revised by the ARC (1981), who published the first estimate of an ideal protein for growing pigs. The ARC ideal protein was reestimated and improved by Fuller et al. (1989). However, the Fuller and Wang AA pattern contained neither arginine nor histidine. Clearly, both arginine and histidine are indispensable AA for growth of pigs. All of these patterns as above did not consider the digestibility of AA. Chung and Baker (1991, 1992) suggested the digestible AA pattern by utilization of the chemically defined AA basal diet and compare the difference among Illinois final AA pattern, Illinois ideal AA pattern, Fuller and Wang ideal AA pattern and NRC (1988) AA requirement pattern. Chung and Baker pattern (Illinois ideal AA pattern) was considered as the best AA pattern by now. Recent years, most of animal nutrition

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scientists formulated diets for swine on the basis of ideal protein and obtained optimum results in terms of growth, lean tissue deposition. However, the previous researches only evaluated pigs' growth perfor-mance, therefore the objectives of this research were to study the mechanism of improving swine growth perfor-mance with supplementing lysine, methionine, threonine and tryptophan under the different ideal protein pattern.

MATERIALS AND METHODS

Experiment 1

A total of 120 pigs weaned at 28 d (8 pigs/pen, 3 pens/treatment) were randomly allotted in different blocks according to the sex and weight. A pen provided a self-feeder and a waterer for *ad libitum* access to feeds and water. All the experimental diets were formulated on the basis of ideal protein pattern of Chung and Baker (1992). Pigs body weight and feed consumption were measured at initiation, 2 weeks postweaning and termination of trial, ADG, ADFI and F/G were determined. At the end of trial, blood samples from three pigs in each pen were obtained to test concentrations of blood urea nitrogen, glucose, insulin and cortisol in serum. The experimental period was 4 weeks. The composition of diets was provided in table 1.

Table 1. Formula and chemical composition of diet (Exp. 1)

Item	20% CP	18% CP + Lys	18% CP + Lys + Met	18% CP + Lys + Met + Thr	18% CP + Lys + Met + Thr + Trp
Corn (%)	64.26	70.03	69.94	69.89	69.88
SDPP* (%)	3.00	3.00	3.00	3.00	3.00
Soybean meal (%)	20.89	15.10	15.10	15.10	15.10
Dried Whey (%)	3.50	3.50	3.50	3.50	3.50
Fish meal (%)	4.00	4.00	4.00	4.00	4.00
Limestone (%)	0.35	0.33	0.33	0.33	0.33
Bone meal (%)	2.20	1.96	1.96	1.96	1.96
Salt (%)	0.30	0.30	0.30	0.30	0.30
Premix** (%)	1.00	1.00	1.00	1.00	1.00
Soybean oil (%)	0.50	0.50	0.50	0.50	0.50
Lysine · HCl (%)	–	0.28	0.28	0.28	0.28
dl-Met. (%)	–	–	0.09	0.09	0.09
Thr. (%)	–	–	–	0.05	0.05
Trp. (%)	–	–	–	–	0.01
Total (%)	100.00	100.00	100.00	100.00	100.00
Calculated:					
DE (Kcal/kg)	3,242	3,232	3,232	3,232	3,232
CP (%)	20.01	18.02	18.02	18.02	18.02
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.70	0.70	0.70	0.70	0.70
Avail. P (%)	0.30	0.29	0.29	0.29	0.29
Lysine (%)	1.25	1.25	1.25	1.25	1.25
Met + Cys (%)	0.71	0.53	0.75	0.75	0.75
Thr. (%)	0.85	0.76	0.76	0.81	0.81
Trp. (%)	0.27	0.22	0.22	0.22	0.23

* SDPP: Spray Dried Plasma Protein.

** Premix provided per kilogram of complete diet: chlortetracycline, 110 mg; sulfathiazole, 110 mg; vitamin A, 5,512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; methionine, 2.2 mg; riboflavin, 5.5 mg; d-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline, 551 mg; vitamin B_{12}, 27.6 μg; Mn, 100 mg; Fe, 100 mg; Zn, 100 mg; Ca, 40 mg; Cu, 250 mg; K, 4 mg; I, 0.3 mg; Na, 2 mg; Co, 1 mg; Se, 0.3 μg.

Experiment 2

A total of 80 pigs (4 pigs/pen, 4 pens/treatment) with 20 kg live weight were randomly allotted to different blocks according to the sex and body weight. Each pen provided a self-feeder and a waterer. All the experimental diets were formulated on the basis of ideal protein pattern of Chung and Baker (1992). Pigs' body weight and feed consumption were measured at initiation and termination of trial, and ADG, ADFI and F/G were determined. At the end of trial, blood samples from each pigs were obtained to detect concentrations of blood urea nitrogen, glucose, insulin and cortisol in the serum. The experimental period was 4 weeks. The composition of diet is provided in table 2.

Table 2. Formula and chemical composition of diet (Exp. 2)

Item	16% CP	14% CP + Lys	14% CP + Lys + Met	14% CP + Lys + Met + Thr	14% CP + Lys + Met + Thr + Trp
Corn (%)	60.06	68.77	68.70	68.61	68.60
Wheat bran (%)	15.00	11.00	11.00	11.00	11.00
Soybean meal (%)	10.00	9.00	9.00	9.00	9.00
Rapeseed meal (%)	5.00	3.00	3.00	3.00	3.00
Cottonseed meal (%)	6.00	4.00	4.00	4.00	4.00
Limestone (%)	0.86	0.71	0.71	0.71	0.71
Bone meal (%)	0.68	0.82	0.82	0.82	0.82
Salt (%)	0.30	0.30	0.30	0.30	0.30
Premix* (%)	1.00	1.00	1.00	1.00	1.00
Soybean oil (%)	1.10	1.10	1.10	1.10	1.10
Lysine · HCl (%)	–	0.30	0.30	0.30	0.30
dl-Met. (%)	–	–	0.07	0.07	0.07
Thr. (%)	–	–	–	0.09	0.09
Trp. (%)	–	–	–	–	0.01
Total (%)	100.00	100.00	100.00	100.00	100.00
Calculated :					
DE (Kcal/kg)	3,250	3,244	3,244	3,244	3,244
CP (%)	16.04	14.02	14.02	14.02	14.02
Ca (%)	0.60	0.59	0.59	0.59	0.59
P (%)	0.52	0.51	0.51	0.51	0.51
Avail. P (%)	0.28	0.28	0.28	0.28	0.28
Lysine (%)	0.76	0.75	0.75	0.75	0.75
Met + Cys (%)	0.45	0.42	0.49	0.49	0.49
Thr. (%)	0.54	0.41	0.41	0.50	0.50
Trp. (%)	0.16	0.13	0.13	0.13	0.13

* Premix provided per kilogram of complete diet: chlortetracycline, 110 mg; sulfathiazole, 110 mg; vitamin A, 5,512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; methionine, 2.2 mg; riboflavin, 5.5 mg; d-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline, 551 mg; vitamin B_{12}, 27.6 μg; Mn, 100 mg; Fe, 100 mg; Zn, 100 mg; Ca, 40 mg; Cu, 250 mg; K, 4 mg; I, 0.3 mg; Na, 2 mg; Co, 1 mg; Se, 0.3 μg.

Experiment 3 and Experiment 4

A total of 30 pigs (2 pigs/pen, 3 pens/treatment) with 29 kg (Exp. 3) and 50 kg (Exp. 4) body weight were randomly allotted to different blocks according to the sex and weight. A pen provided a feeder for *ad libitum* and a waterer. All the experimental diets were formulated on the basis of ideal protein pattern of Chung and Baker (1992). Pigs' body weight and feed consumption were measured at initiation and termination of trial. ADG, ADFI and F/G were determined. Both trials lasted 4 weeks. The composition of diet is provided in table 3 and 4.

Statistical analysis

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 (1988) package program. Data were analyzed as a randomized complete block design with pen as the experimental unit. The sex and body weight of pigs were served as a blocking criteria.

Table 3. Formula and chemical composition of diet (Exp. 3)

Item	16% CP	14% CP + Lys	14% CP + Lys + Met + Thr	14% CP + Lys + Met + Thr + Trp	14% CP + Lys + Met
Corn (%)	60.06	68.77	68.70	68.61	68.60
Wheat bran (%)	15.00	11.00	11.00	11.00	11.00
Soybean meal (%)	10.00	9.00	9.00	9.00	9.00
Rapeseed meal (%)	5.00	3.00	3.00	3.00	3.00
Cottonseed meal (%)	6.00	4.00	4.00	4.00	4.00
Limestone (%)	0.86	0.71	0.71	0.71	0.71
Bone meal (%)	0.68	0.82	0.82	0.82	0.82
Salt (%)	0.30	0.30	0.30	0.30	0.30
Premix (%)	1.00	1.00	1.00	1.00	1.00
Soybean oil (%)	1.10	1.10	1.10	1.10	1.10
Lysine · HCl (%)	–	0.30	0.30	0.30	0.30
dl-Met. (%)	–	–	0.07	0.07	0.07
Thr. (%)	–	–	–	0.09	0.09
Trp. (%)	–	–	–	–	0.01
Total (%)	100.00	100.00	100.00	100.00	100.00
Calculated:					
DE (Kcal/kg) (%)	3,250	3,244	3,244	3,244	3,244
CP (%)	16.04	14.02	14.02	14.02	14.02
Ca (%)	0.60	0.59	0.59	0.59	0.59
P (%)	0.52	0.51	0.51	0.51	0.51
Avail. P (%)	0.28	0.28	0.28	0.28	0.28
Lysine (%)	0.76	0.75	0.75	0.75	0.75
Met + Cys (%)	0.45	0.42	0.49	0.49	0.49
Thr. (%)	0.54	0.41	0.41	0.50	0.50
Trp. (%)	0.16	0.13	0.13	0.13	0.13

Premix provided per kilogram of complete diet: chlortetracycline, 110 mg; sulfathiazole, 110 mg; vitamin A, 5,512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; methionine, 2.2 mg; riboflavin, 5.5 mg; d-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline, 551 mg; vitamin B_{12}, 27.6 μg; Mn, 100 mg; Fe, 100 mg; Zn, 100 mg; Ca, 40 mg; Cu, 250 mg; K, 4 mg; I, 0.3 mg; Na, 2 mg; Co, 1 mg; Se, 0.3 μg.

Table 4. Formula and chemical composition of diet (Exp. 4)

Item	14% CP	12% CP + Lys	12% CP + Lys + Met	12% CP + Lys + Met + Thr	12% CP + Lys + Met + Thr + Trp
Corn (%)	67.29	72.17	72.16	72.13	72.11
Wheat bran (%)	14.50	14.50	14.50	14.50	14.50
Soybean meal (%)	5.20	–	–	–	–
Rapeseed meal (%)	5.00	5.00	5.00	5.00	5.00
Cottonseed meal (%)	5.00	5.00	5.00	5.00	5.00
Limestone (%)	1.20	1.40	1.40	1.40	1.40
Bone meal (%)	0.51	0.33	0.33	0.33	0.33
Salt (%)	0.30	0.30	0.30	0.30	0.30
Premix (%)	1.00	1.00	1.00	1.00	1.00
Lysine · HCl (%)	–	0.30	0.30	0.30	0.30
dl-Met. (%)	–	–	0.01	0.01	0.01
Thr. (%)	–	–	–	0.03	0.03
Trp. (%)	–	–	–	–	0.02
Total (%)	100.00	100.00	100.00	100.00	100.00
Calculated:					
DE (Kcal/kg)	3,052	3,052	3,052	3,052	3,052
CP (%)	14.01	12.01	12.01	12.01	12.01
Ca (%)	0.61	0.61	0.61	0.61	0.61
P (%)	0.47	0.47	0.47	0.47	0.47
Avail. P (%)	0.16	0.13	0.13	0.13	0.13
Lysine (%)	0.62	0.63	0.63	0.63	0.63
Met + Cys (%)	0.47	0.43	0.44	0.44	0.44
Thr. (%)	0.46	0.41	0.41	0.44	0.44
Trp. (%)	0.14	0.11	0.11	0.11	0.13

Premix provided per kilogram of complete diet: chlortetracycline, 110 mg; sulfathiazole, 110 mg; vitamin A, 5,512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; methionine, 2.2 mg; riboflavin, 5.5 mg; d-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline, 551 mg ; vitamin B_{12}, 27.6 μg; Mn, 100 mg; Fe, 100 mg; Zn, 100 mg; Ca, 40 mg; Cu, 250 mg; K, 4 mg; I, 0.3 mg; Na, 2 mg; Co, 1 mg; Se, 0.3 μg.

RESULTS AND DISCUSSION

Effects of the amino acid supplementation on growth performance and blood metabolites for weanling pigs (Exp. 1)

Results during the first 2 weeks showed that pigs fed diets supplemented with both lysine and methionine had the best feed conversion ratio ($p < 0.05$), but no significant differences ($p > 0.05$) were observed in ADG and ADFI among all dietary treatments (table 5). Pigs fed the control diet had the greatest ADG ($p < 0.05$), ADFI ($p < 0.05$), and feed conversion ratio for 2-4 wks. Therefore, pigs fed control diet obtained the optimal ADG ($p < 0.05$), ADFI ($p < 0.05$) and F/G ($p < 0.05$) than those fed other diets across the trial. Pigs performance were also improved ($p < 0.05$) with addition of amino acids. The more amino acids were added, the better growth performance was detected. However, pigs fed low protein diets with amino acids supplementation showed still lower growth rate than pigs fed the control diet.

No significant difference ($p > 0.05$) occurred in glucose and cortisol concentrations in pigs serum among dietary treatments, but the insulin concentration in serum showed an upward trend with improvement of growth performance. The lowest urea nitrogen content ($p < 0.05$) was observed in serum of pigs fed control diet.

Effects of the amino acid supplementation on growth performance and blood metabolites for growing pigs (Exp. 2 and 3)

Table 5. Effects of the amino acid supplementation on growth performance and blood metabolites for weanling pigs (Exp. 1)

Item	20% CP	18% CP + Lys	18% CP + Lys + Met	18% CP + Lys + Met + Thr	18% CP + Lys + Met + Thr + Trp	SEM
Initial Wt. (kg)	8.10	7.97	8.07	7.93	8.06	
0 – 2 weeks:						
ADG (g)	137	133	133	132	145	4.2
ADFI (g)	209	217	247	199	222	5.1
F/G	1.49^{ab}	1.57^{a}	1.43^{b}	1.51^{ab}	1.54^{ab}	0.04
2 – 4 weeks:						
ADG (g)	450^{a}	346^{c}	362^{c}	375^{c}	400^{bc}	16.0
ADFI (g)	753^{a}	587^{bc}	541^{c}	648^{b}	671^{b}	17.1
F/G	1.67	1.69	1.68	1.73	1.68	0.02
0 – 4 weeks:						
^{x}ADG (g)	294^{a}	239^{c}	247^{c}	254^{c}	273^{b}	6.5
ADFI (g)	466^{a}	404^{c}	397^{c}	421^{bc}	446^{ab}	7.2
F/G	1.58^{b}	1.68^{a}	1.61^{ab}	1.66^{ab}	1.63^{ab}	0.03
Glucose (mmol/l)	5.47	5.20	5.55	5.67	5.25	0.02
Urea N (mmol/l)	2.34^{b}	3.55^{a}	2.69^{b}	2.75^{ab}	2.94^{ab}	0.03
Insulin (ng/ml)	13.38	8.17	10.44	9.13	11.92	2.10
Cortisol (ng/mg)	97.47	95.17	89.61	91.96	99.25	2.20

n = 24 pigs/treatment.
^{a,b,c} Values with different superscript in the same row differ ($p < 0.05$).
^{x} Linear ($p < 0.01$) increase from diet 2 to 5.

Table 6. Effects of the amino acid supplementation on growth performance and serum metabolites for growing pigs (Exp. 2)

Item	16% CP	14% CP + Lys	14% CP + Lys + Met	14% CP + Lys + Met + Thr	14% CP +Lys + Met + Thr + Trp	SEM
Initial Wt. (kg)	19.90	20.15	19.93	19.98	19.92	
^{x}ADG (g)	416	390	405	422	430	12.0
ADFI (g)	1,183	1,144	1,136	1,145	1,157	4.6
^{y}F/G	2.85^{ab}	2.92^{a}	2.83^{ab}	2.71^{b}	2.69^{b}	0.04
Glucose (mmol/l)	4.95	5.48	5.15	5.85	5.33	0.05
^{y}urea, N (mmol/l)	4.95^{b}	7.30^{a}	5.88^{ab}	5.38^{ab}	5.23^{b}	0.12
^{z}Insulin (ng/ml)	8.03	11.41	12.77	14.23	15.51	0.55
Cortisol (ng/mg)	68.33	74.33	84.68	88.88	66.21	5.20

n = 16 pigs/treatment.
^{a,b,c} Values with different superscript in the same row differ ($p < 0.05$).
^{x} Linear ($p < 0.01$) increase from diet 2 to 5.
^{y} Linear ($p < 0.01$) reduce from diet 2 to 5.
^{z} Linear ($p < 0.01$) increase from diet 1 to 5.

Results from Exp. 2 (table 6) showed that pigs had no significant difference ($p > 0.05$) in ADFI among all dietary treatments, but pigs' growth rate and feed conversion ratio were (linearly, $p < 0.01$) improved with

adding lysine, methionine, threonine, and tryptophan in pigs diets. Therefore pigs fed diet supplemented with lysine, methionine, threonine, and tryptophan together obtained the optimal feed conversion ratio ($p < 0.05$) among all dietary treatments across the trial. No significant difference ($p > 0.05$) occurred in glucose and cortisol content in pigs serum among dietary treatments, but the insulin concentration in serum showed a linear ($p < 0.01$) upward trend with supplementing lysine, methionine, threonine and tryptophan in diets. There was a linear downward trend ($p < 0.01$) observed in serum urea nitrogen content of pigs due to inclusion of lysine, methionine, threonine and tryptophan in diets, and pigs receiving control diet obtained the lowest blood urea nitrogen. Results from Exp. 3 showed no significant difference ($p > 0.05$) in ADFI among all dietary treatments, but growing and finishing pigs' growth rate and feed conversion ratio were linearly ($p < 0.01$) improved by adding lysine, methionine, threonine, and tryptophan in pigs diets. Therefore pigs fed diet supple-mented with lysine, methionine, threonine, and tryptophan together obtained the optimal growth performance among all dietary treatments across the trial.

Table 7. Effects of the amino acid supplementation on growth performance for growing pigs (Exp. 3)

Item	16% CP	14% CP + Lys	14% CP + Lys + Met	14% CP + Lys + Met + Thr	14% CP +Lys + Met + Thr + Trp	SEM
Initial Wt. (kg)	29.8	29.2	29.4	29.3	29.8	0.01
[x]ADG (g)	541	509	553	605	655	11.4
ADFI (g)	1,700	1,751	1,923	1,754	1,929	13.8
[x]F/G	3.17	3.48	3.27	3.28	2.99	0.04

n = 6 pigs/treatment.
[x] Linear ($p < 0.01$) improvement from diet 2 to 5.

Effects of the amino acid supplementation on growth performance for finishing pigs (Exp. 4)

Results showed that pigs had no significant difference ($p > 0.05$) in ADFI among all dietary treatments, but growing and finishing pigs' growth rate and feed conversion ratio were linearly ($p<0.01$) improved with adding lysine, methionine, threonine, and tryptophan in pigs' diets. Therefore, pigs fed diet supplemented with lysine, methionine, threonine, and tryptophan together obtained the optimal growth performance among all dietary treatments across the trial.

Maxwell et al. (1987) reported that a substantial amount of supplemental protein (soybean meal) could be saved by lysine and threonine supplementation of wheat-based diets for growing-finishing pigs. Cervantes-Ramirez et al. (1991) found that growth rate and feed conversion ratio were improved ($p < 0.01$) and blood urea nitrogen was decreased ($p < 0.01$) with lysine and threonine additions for growing pigs, and further addition of methionine tended to improve performance and reduced plasma urea nitrogen. Cervantes-Ramires et al. (1991) also observed that increasing dietary lysine level improved daily weight gain and carcass muscle gain to a greater extent as the lean growth capacity of geno-types increased. Cromwell et al. (1983) found that tryptophan supplementation improved gain ($p < 0.1$) and feed

Table 8. Effects of the amino acid supplementation on growth performance for finishing pigs (Exp. 4)

Item	14% CP	12% CP + Lys	12% CP + Lys + Met	12% CP + Lys + Met + Thr	12% CP +Lys + Met + Thr + Trp	SEM
Initial Wt. (kg)	50.5	49.9	50.4	51.0	50.7	0.01
[x]ADG (g)	646	630	737	745	843	12.2
ADFI (g)	2,417	2,315	2,362	2,632	2,553	14.1
[y]F/G	3.77	3.67	3.48	3.51	3.02	0.05

n = 6 pigs/treatment.
[x] Linear ($p < 0.01$) increase from diet 2 to 5.
[y] Linear ($p < 0.01$) reduction from diet 1 to 5.

conversion ratio ($p < 0.05$), further impro-vements in gain and feed conversion ratio occurred with threonine addition or methionine addition for growing pigs. Recent researches have shown that one a be may limited in the amount of natural protein that can be replaced with crystalline amino acid in cereal-based pig diets to obtain optimum lean growth (Kephart and Sheritt, 1990; Cervantes- Ramirez et al., 1991; Davis et al., 1991; D' Mello, 1993; Hansen et al., 1993; Brudevold and Southern, 1994; Myer et al., 1994; Kerr et al., 1995). Non-specific nitrogen and (or) some other factors may be limiting when most or all of the supplemental protein (intact protein) is replaced with crystalline amino acids (Heger, 1990; Surisdiarto and Farrell, 1991; D'Mello, 1993; Hansen et al., 1993; Brudevold and Sourthern, 1994; Hahn and Baker, 1995). The above researchers, however, used lower protein cereal grains (corn and grain sorghum) and thus less intact protein may have been present in their diets. Results from present trials showed that supplementing lysine, methionine, threonine and tryptophan in swine diets improved linearly ($p < 0.01$) average daily gain for weanling pigs, growers and finishers, and growth rate was higher than that of control for growing and finishing pigs, this was in agreement with indication of blood urea nitrogen concentration reduction and serum insulin concentration increase. However, growth rate for weanling pigs with supplementation of amino acids was lower than that of control, the reason needs to be investigated further.

IMPLICATIONS

Reducing protein level in swine diets since weaning through supplementing the feed grade crystalline amino acids (i.e., lysine, *dl*-methionine, threonine and trypto-phan) according to ideal protein pattern would be effective to support growth rate. Obviously, This is also a way for unconventional protein resource (cottonseed meal and rapeseed meal) to be utilized efficiently for growing and finishing pigs.

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