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Comparison of Synthetic Lysine Sources on Growth Performance, Nutrient Digestibility and Nitrogen Retention in Weaning Pigs

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ABSTRACT : We compared the effects of supplementing L-lysine·SO_4 to L-lysine·HCl on growth performance, nutrient digestibility and nitrogen retention in weaning pigs. A total of 96 crossbred pigs, weaned at 21±3 days of age and with an average initial body weight (BW) 6.23±0.01 kg, were given one of 4 treatments, which translated into 6 replicates of 4 pigs in each pen. The animals were randomly assigned to four dietary treatments according to a randomized completely block design (RCBD) as follows: 1) control-no synthetic lysine, lysine deficient (0.80% total lysine); 2) L-C (= 0.2% L-lysine·HCl); 3) K-L-S (= 0.332% L-lysine·SO_4, A company); 4) C-L-S (= 0.332% L-lysine·SO_4, B company). Diets were formulated with corn, soy bean meal, and corn gluten meal as the major ingredients, and all nutrients except the lysine met or exceeded NRC requirements (1998). The lysine content of supplemented synthetic lysine was the same in all treatment groups except the control. No clinical health problems associated with the dietary treatments were observed. During the entire experimental period, body weight, average daily gain (ADG) and feed efficiency (G:F ratio) increased ($p<0.01$) in pigs fed the experimental diets supplemented with L-lysine·HCl or L-lysine·SO_4 produced by A company, irrespective of the two synthetic lysine sources. Although the supplementation of L-lysine·SO_4 produced by B company tended to improve the ADG and G:F ratio, significant differences were not seen among all treatments and tended to be lower than the L-C (L-lysine·HCl) and K-L-S (L-lysine·SO_4 groups using the product from A company). The digestibility of crude protein (CP) was increased by the supplementation of synthetic lysine ($p<0.05$), irrespective of the L-lysine source (L-C, K-L-S, C-L-S). The results of this study showed that ADG, G:F ratio, and CP digestibility improved when L-lysine·SO_4 or L-lysine·HCl was supplemented into the weaning pigs' diet. There was a clear difference in efficacy between the two lysine·SO_4 products based upon the growth performance of weaning pigs. Consequently, the bioavailability of lysine·SO_4 products should be evaluated before supplementation of synthetic lysine in swine diets. (**Key Words :** L-lysine·HCl, L-lysine·SO_4, Growth Performance, Nutrient Digestibility, Weaning Pigs)

INTRODUCTION

The importance of limiting amino acids in a corn-soybean diet for the growth and muscle protein metabolism of pigs has been examined in several studies (Sharda et al., 1976; Russell et al., 1983; Chang and Wei, 2005; Cheng et al., 2006). Lysine is clearly recognized as the first limiting amino acid in pig and poultry diets (Tang et al., 2007), and the requirements for pigs have been precisely defined (NRC, 1998). With the demand to reduce nitrogen and phosphorus waste and maximize producer net income, synthetic L-lysine becomes increasingly important for pig diets, including its use as a tool to optimize dietary amino acid profiles. Furthermore, with current environmental concerns over nitrogen excretion, interest has increased in the use of synthetic amino acids in the formulation of swine diets. Between 1991 and 1997, the global market for L-lysine experienced explosive growth from 45.3 thousand to 340.2 thousand tons/year, primarily as a result of increased swine and poultry production around the world. Although recent growth has leveled off, its market is still projected to increase by approximately 7% annually. The greatest potential for their use is in the formulation of nursery rations, since many of the protein sources in these diets are expensive. Normally, L-lysine·HCl is widely used as a source of synthetic lysine in animal feed. However, a new form, L-lysine·SO_4, has been recently developed and introduced. Both are products of bacterial fermentation, but L-lysine·SO_4 is produced by a different post-fermentation

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Table 1. Formula and chemical composition of experimental diets, diet I (0-7 d)

Item	Control	L-C	K-L-S and C-L-S
Ingredients (%)			
Corn	38.30	39.31	39.49
SBM-46	13.72	17.10	17.20
Dried whey	2.55	2.78	2.70
Whey yeast	8.31	6.04	5.79
Corn gluten meal	14.00	-	-
SPC[a]	-	11.51	11.51
Lactose	20.00	20.00	20.00
Soy oil	0.32	0.43	0.35
DCP	1.36	1.11	1.11
Limestone	0.68	0.68	0.68
Synthetic lysine	-	0.200[b]	0.332[c]
DL-methionine	0.04	0.12	0.12
Vitamin mix.[d]	0.12	0.12	0.12
Mineral mix.[e]	0.10	0.10	0.10
Salt	0.20	0.20	0.20
Neomycin[f]	0.10	0.10	0.10
ZnO	0.10	0.10	0.10
Choline-chloride	0.10	0.10	0.10
Total	100	100	100
Chemical compositions[g]			
ME (kcal/kg)	3,293.83	3,290.82	3,290.81
CP (%)	23.00	23.00	23.00
Lysine (%)	0.80	1.35	1.35
Methionine (%)	0.44	0.44	0.44
Ca (%)	0.80	0.80	0.80
P (%)	0.65	0.65	0.65

[a] Soy Protein Concentrate manufactured by ADM.
[b] L-lysine·HCl: supplemented with 13.57% of lysine.
[c] L-lysine·SO_4: supplemented with 13.57% of lysine.
[d] Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64 g; riboflavin, 3.2 mg; calcium pantothenic acid, 8 mg; niacin, 16 mg; vitamin B_{12}, 12 g; vitamin K, 2.4 mg.
[e] Provided the following per kilogram of diet: Se, 0.1 mg; I, 0.3 mg; Mn, 24.8 mg; Cu·SO_4, 54.1 mg; Fe, 127.3 mg; Zn, 84.7 mg; Co, 0.3 mg.
[f] Antibiotics: Neomycin sulfate 110 g/kg.
[g] Calculated value.

Table 2. Formula and chemical composition of experimental diets, diet II (7-21 d)

Item	Control	L-C	K-L-S and C-L-S
Ingredients (%)			
Corn	38.56	40.24	40.36
SBM-46	13.33	13.33	13.67
Dried whey	10.97	10.49	10.25
Whey yeast	11.13	10.48	10.28
Corn gluten meal	7.58	-	-
SPC[a]	-	6.94	6.78
Lactose	13.00	13.00	13.00
Soy oil	3.00	3.00	3.00
DCP	1.00	0.85	0.86
Limestone	0.66	0.66	0.66
Synthetic lysine	-	0.200[b]	0.332[c]
DL-methionine	0.05	0.09	0.09
Vitamin mix.[d]	0.12	0.12	0.12
Mineral mix.[e]	0.10	0.10	0.10
Salt	0.20	0.20	0.20
Neomycin[f]	0.10	0.10	0.10
ZnO	0.10	0.10	0.10
Choline-chloride	0.10	0.10	0.10
Total	100	100	100
Chemical compositions[g]			
ME (kcal/kg)	3,267.43	3,267.46	3,267.40
CP (%)	21.00	21.00	21.00
Lysine (%)	0.80	1.15	1.15
Methionine (%)	0.37	0.37	0.37
Ca (%)	0.75	0.75	0.75
P (%)	0.63	0.63	0.63

[a] Soy protein concentrate manufactured by ADM.
[b] L-lysine·HCl: supplemented with 13.57% of lysine.
[c] L-lysine·SO_4: supplemented with 13.57% of lysine.
[d] Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64 g; riboflavin, 3.2 mg; calcium pantothenic acid, 8 mg; niacin, 16 mg; vitamin B_{12}, 12 g; vitamin K, 2.4 mg.
[e] Provided the following per kilogram of diet: Se, 0.1 mg; I, 0.3 mg; Mn, 24.8 mg; Cu·SO_4, 54.1 mg; Fe, 127.3 mg; Zn, 84.7 mg; Co, 0.3 mg.
[f] Antibiotics: Neomycin sulfate 110 g/kg.
[g] Calculated value.

process. Unlike the process for L-lysine·HCl, the fermentation broth of L-lysine·SO_4 is not separated from the bacterial biomass and not transferred to the hydrochloric acid salt (Schutte and Pack, 1994). As such, the process of L-lysine·SO_4 production is less complex and generates less waste. L-lysine·SO_4 has been shown to be as efficacious as L-lysine·HCl in studies with chicken, pigs (Schutte and Pack, 1994) and rainbow trout (Rodehutscord et al., 2000). Smiricky-Tjardes et al. (2004) and Liu et al. (2007) demonstrated that the relative bioavailability (RBV) of lysine in L-lysine·SO_4 was not significantly different from that of lysine in L-lysine·HCl, which was assumed to be 100% (Izquierdo et al., 1988). Although there are few studies of L-lysine·SO_4 in the swine diet, all of the studies have shown that L-lysine·SO_4 could be used as a source of synthetic lysine in place of L-lysine·HCl to fortify lysine-deficient corn-soybean meal based diets. The object of this study was to compare the efficiency of supplementation of L-lysine·SO_4 versus L-lysine·HCl, and to determine the efficacy of two L-lysine·SO_4 products on growth performance, nutrient digestibility, amino acid digestibility and nitrogen retention in weaning pigs.

MATERIALS AND METHODS

Animals and experimental design

A total of ninety six crossbred pigs ((Landrace×Large White Yorkshire)×Duroc) averaging 6.23±0.01 kg in body weight (BW) and weaned at 21±3 days of age were segregated into one of 4 treatments in 6 replicates of 4 pigs

Table 3. Formula and chemical composition of the experimental diets, diet III (21-35 d)

Item	Control	L-C	K-L-S and C-L-S
Ingredients (%)			
Corn	63.69	64.34	64.34
SBM-46	13.30	13.30	13.30
Dried whey	5.10	5.10	5.10
Whey yeast	5.70	5.42	5.34
Corn gluten meal	4.12	0.24	0.17
SPC[a]	3.00	6.35	6.37
Lactose	-	-	-
Soy oil	3.00	3.00	3.00
DCP	1.15	1.08	1.08
Limestone	0.30	0.30	0.30
Synthetic lysine	-	0.200[b]	0.332[c]
DL-methionine	0.02	0.05	0.05
Vitamin mix.[d]	0.12	0.12	0.12
Mineral mix.[e]	0.10	0.10	0.10
Salt	0.20	0.20	0.20
Neomycin[f]	0.10	0.10	0.10
ZnO	-	-	-
Choline-chloride	0.10	0.10	0.10
Total	100	100	100
Chemical compositions[g]			
ME (kcal/kg)	3,274.37	3,274.38	3,274.38
CP (%)	19.00	19.00	19.00
Lysine (%)	0.80	1.05	1.05
Methionine (%)	0.34	0.34	0.34
Ca (%)	0.70	0.70	0.70
P (%)	0.60	0.60	0.60

[a] Soy protein concentrate manufactured by ADM.
[b] L-lysine·HCl: supplemented with 13.57% of lysine.
[c] L-lysine·SO_4: supplemented with 13.57% of lysine.
[d] Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64 g; riboflavin, 3.2 mg; calcium pantothenic acid, 8 mg; niacin, 16 mg; vitamin B_{12}, 12 g; vitamin K, 2.4 mg.
[e] Provided the following per kilogram of diet: Se, 0.1 mg; I, 0.3 mg; Mn, 24.8 mg; Cu . SO_4, 54.1 mg; Fe, 127.3 mg; Zn, 84.7 mg; Co, 0.3 mg.
[f] Antibiotics: Neomycin sulfate 110 g/kg.
[g] Calculated value.

per pen in a randomized completely block design (RCBD) by body weight and sex. The treatments were: 1) control-no synthetic lysine, lysine deficient (0.80% total lysine); 2) L-C (= 0.2% L-lysine·HCl); 3) K-L-S (= 0.332% L-lysine·SO_4, A company); 4) C-L-S (= 0.332% L-lysine·SO_4, B company). The lysine content in all treatment groups was the same except for the control group. The feeding trial lasted 5 weeks.

Experimental diets and feeding

Diets were formulated with corn, soy bean meal and corn gluten meal as their major components (Table 1). Three different experimental diets were formulated and provided to weaning pigs according to phase feeding programs. The basal diets contained approximately 3,265 ME kcal/kg for the youth period (d 0-35). The three experimental diets were fed during phase I (diet I, d 0-7), phase II (diet II, d 7-21), and phase III (diet III, d 21-35), and were formulated to contain 23, 21, 19% crude protein, and 1.35, 1.15, 1.05% lysine, respectively. All nutrients except the lysine in the control diet met or exceeded NRC requirements (1998). Corn gluten meal, with its relatively low lysine concentration (1.02%) compared to its high crude protein concentration (60.2%), was used as the protein source to achieve low basal lysine levels. The total lysine concentration in the control diets over all periods was 0.8%, and the other basal diets of L-C, K-L-S, C-L-S were supplemented with the same lysine concentration as L-lysine·HCl (0.2% of diet) or two kinds of L-lysine·SO_4 products (0.332% of diets) to meet the requirement. Total lysine levels in all diets except for the control were the same after supplementation with L-lysine·HCl or L-lysine·SO_4 products. Although L-lysine·SO_4 made by A company and L-lysine·SO_4 made by B company contained approximately 52% and 47% total lysine, respectively (Table 4), the amounts of the two L-lysine·SO_4 products supplemented were the same to facilitate comparison. The formula and chemical composition of the experimental diets are presented in Table 1, 2, and 3.

Table 4. Amino acid compositions of L-lysine·HCl and two products of L-lysine·SO_4, as fed basis (%)[a]

Item	L-lysine·HCl	L-lysine·SO_4	
	L-C	K-L-S	C-L-S
DM (%)	96.91	97.26	96.04
Crude protein (%)	69.74	65.35	64.47
Threonine	0.00	0.22	0.76
Valine	0.00	0.47	1.03
Methionine	0.03	0.06	0.18
Isoleucine	0.00	0.27	0.74
Leucine	0.00	0.33	1.37
Phenylalanine	0.00	0.33	0.98
Lysine	76.11	52.17	47.66
Histidine	0.00	0.17	0.45
Arginine	0.00	0.34	0.95
EAA[b]	76.14	54.36	54.12
Asparagine	0.00	0.41	1.62
Serine	0.00	0.17	0.69
Cystein	0.09	0.17	0.31
Glutamic acid	0.00	2.46	3.17
Proline	0.00	0.14	2.09
Glycine	0.00	0.31	0.87
Alanine	0.00	0.74	2.71
Tyrosine	0.00	0.15	0.53
NEAA[c]	0.09	4.55	11.99
TAA[d]	76.23	58.91	66.11

[a] Analyzed composition. [b] Essential amino acids.
[c] Non essential amino acids. [d] Total amino acids.

Housing and blood sampling

All pigs were housed in half-slotted concrete floor pens

Table 5. Effects of L-lysine·SO_4 as substitution for L-lysine·HCl on growth performance of weaning pigs[c]

Item	Control	L-C	K-L-S	C-L-S	SEM[d]
Body weight (kg)					
Initial	6.24	6.22	6.23	6.23	-
3 week	9.45	10.13	9.87	9.60	0.21
5 week	15.51[b]	17.78	17.82[a]	16.93[ab]	0.28
Average daily gain[e] (g)					
0-3 week	160	184	169	159	7.86
3-5 week	420[b]	532[a]	551[a]	511[a]	14.01
0-5 week	264[b]	329[a]	328[a]	304[ab]	7.73
Average daily feed intake[ef] (g)					
0-3 week	294	317	293	288	8.23
3-5 week	799	891	890	831	16.82
0-5 week	496	547	533	507	9.62
Gain:feed ratio[e]					
0-3 week	0.553	0.580	0.575	0.537	0.02
3-5 week	0.527[b]	0.597[a]	0.619[a]	0.616[a]	0.01
0-5 week	0.535[b]	0.601[a]	0.616[a]	0.600[a]	0.01

[a, b] Mean within rows with different superscripts differ, $p<0.05$.
[c] A total of 96 crossbred pigs was fed from average initial body weight 6.32±0.01 kg and the average of final weight was 17.01 kg.
[d] Standard error of mean. [e] Values are means for six pens of four pigs per pen.
[f] Not significantly different ($p>0.19$).

(0.90×2.15 m^2 for four pigs) and fed *ad libitum* through feeders and nipple water throughout the entire experimental period. The temperature in experimental house was maintained at 30°C in the first week and decreased 1°C every week to a final value of 26°C in the last week. Body weight and feed intake were recorded weekly to calculate the average daily gain (ADG), average daily feed intake (ADFI) and gain/feed ratio (feed efficiency).

Blood samples were collected from the anterior vena cava of each pig weekly during the entire experimental period for blood urea nitrogen (BUN) analysis. After the blood sample was collected in disposable glass tubes, the samples were centrifuged for 15 min at 3,000 rpm and 4°C (Eppendorf centrifuge 5810R, Germany). The serum was carefully transferred to plastic vials and stored at -20°C until BUN analyses. Total BUN concentration was analyzed using a blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning Diagnostics Co.).

Digestibility trial

To investigate nutrient digestibility, nitrogen retention, and apparent amino acid digestibility, sixteen barrows (4 pigs per treatment) averaging 10.64±0.37 kg BW were each housed in individual metabolic crates at 2 weeks. Each pig was fed a total of 130 g of the experimental diet twice a day. After a 4 day adaptation period, pigs were subjected to a 5 day collection period. The total amount of feed consumed and excreta produced were recorded daily. Collected excreta from each pig were pooled, sealed in plastic bags and dried in an air-forced drying oven at 60°C for 72 h, and ground into 1 mm particles in a Wiley mill for chemical analysis.

Chemical analysis

Analysis of the experimental diets and excreta was conducted according to AOAC methods (1995). The amino acid contents of the experimental feed and excreta were determined by amino acid analyzer (Biochrom 20, Pharmacia Biotech, England), after acid hydrolysis with 6 N HCl at 110°C for 24 h (Mason, 1984). The concentrations of calcium and phosphorus in the experimental diets and excreta were measured on an atomic absorption spectrophotometer (Shimadzu, AA6145F, Japan).

Statistical analysis

The means for ADG, ADFI, and G:F were separated using the PDIFF protocol of SAS and were analyzed as a randomized complete block design using the General Linear Model (GLM) protocol of SAS. The experimental pen was used as the experimental unit for the performance data, whereas individual pig data served as the experimental unit in nutrient digestibility calculations carried out by comparing means according to the least significant difference (LSD) multiple range tests, using the GLM protocol of SAS (SAS Institute, 2004).

RESULTS AND DISCUSSION

Growth performance

Table 5 showed the effects of L-lysine·SO_4 substituting for L-lysine·HCl on the growth performance of weaning pigs. Over the 35 day trial, body weight and ADG increased ($p<0.01$) when diets were supplemented with either L-lysine·HCl or L-lysine·SO_4 produced by A company. Supplementation of L-lysine·HCl or two kinds of L-

Table 6. Effect of L-lysine·SO_4 as substitution for L-lysine·HCl on nutrient digestibility of weaning pigs with diet II (%)[c]

Item	Control	L-C	K-L-S	C-L-S	SEM[d]
Dry matter[e]	91.46	91.86	91.90	92.23	3.08
Crude protein	56.94[b]	74.96[a]	73.28[a]	80.92[a]	0.91
Crude fat[e]	85.05	83.06	85.76	85.25	1.05
Crude ash[e]	73.90	75.75	75.63	76.91	0.42
Ca[e]	71.19	73.13	70.97	73.12	1.36
P[e]	80.15	80.21	78.71	80.05	0.99

[a, b] Mean within rows with different superscripts differ, $p<0.05$.
[c] Sixteen pigs were used from an average initial BW of 10.64±0.37 kg to an average final BW of 11.15±0.68 kg.
[d] Standard error of mean. [e] Not significantly different ($p>0.80$).

Table 7. Effect of L-lysine·SO_4 as substitution for L-lysine·HCl on nitrogen retention of weaning pigs with diet II (g/day)[a]

Item	Control	L-C	K-L-S	C-L-S	SEM[b]
N intake	7.93	7.93	7.93	7.93	-
Fecal N[c]	1.00	1.08	1.00	0.98	0.37
Urinary N[c]	2.54	2.14	2.35	1.65	0.97
N retention[cd]	4.39	4.71	4.58	5.30	1.05

[a] Sixteen pigs were used from an average initial BW of 10.64±0.37 kg to an average final BW of 11.15±0.68 kg.
[b] Standard error of mean. [c] Not significantly different ($p>0.25$). [d] N retention = N intake (g)-fecal N (g)-urinary N (g).

lysine·SO_4 improved feed efficiency ($p<0.01$). Although the supplementation of L-lysine·SO_4 produced by B company (C-L-S) tended to improve ADG, it did not yield any significant differences among the treatments and tended to be lower than the groups of L-C (L-lysine·HCl) and K-L-S (L-lysine·SO_4 of A company product). As L-lysine·SO_4 is produced by bacterial fermentation (Nhan et al., 1976), the biomass is not separated from the fermentation broth, and the end product after fermentation contains small amounts of other nutrients remaining from the bacterial growth media, such as amino acids other than lysine, and phosphorus. To explain the differences between two L-lysine·SO_4 sources, the chemical composition, lysine content, and composition of other amino acids, calcium, and phosphorus of the two sources were analyzed and compared (Table 4).

By supplementing the lysine deficient diet with synthetic lysine, ADG increased 19.8%, 19.5% and 13.2% with L-C, K-L-S, C-L-S, respectively. Moreover, the gain:feed ratio (feed efficiency) improved 12.5%, 15.1% and 12.2% with L-C, K-L-S, C-L-S, respectively, compared to the control. Supplementation of synthetic lysine resulted in increases in ADG and G:F ratio with the exclusion of ADFI. These improved growth performance parameters were observed regardless of the lysine source. Kirchgessner and Roth (1996) reported that supplementation of the lysine in a lysine deficient basal diet improved gain and feed efficiency, irrespective of the lysine source, which closely resembles the findings of this experiment. A preliminary comparison of L-lysine·HCl and L-lysine·SO_4 showed no difference in their efficacy in pigs (Schutte and Pack, 1994). In addition, Neme et al. (2001) demonstrated no difference in the relative bioavailability of L-lysine·SO_4 compared to L-lysine·HCl in broiler chickens, and the average bioavailability of L-lysine·SO_4 was determined to be 100.19% of L-lysine·HCl. So, the bioavailability of lysine in L-lysine·SO_4 in promoting growth in young pigs may not differ from the lysine supplied by L-lysine·HCl. Smiricky-Tjardes (2004) also demonstrated that the bioavailability of lysine in L-lysine·HCl is not different from that of lysine in L-lysine·SO_4. Based on this data, it was suggested that there was a clear difference in efficacy between the two lysine·SO_4 products in the growth performance of weaning pigs.

Nutrient digestibility

The effects of L-lysine·SO_4 as a substitute for L-lysine·HCl on nutrient digestibility are presented in Table 6. There were no significant differences in the digestibility of most of the nutrients (dry matter, crude fat, crude ash, calcium and phosphorus) among all treatments with the exception of crude protein (CP), which was improved by supplementation with synthetic lysine ($p<0.05$). However, the different sources of lysine (L-C, K-L-S, C-L-S) did not affect the digestibility of other nutrients. This result is in agreement with the report of Rodhouse (1992), and similar to the study conducted by Neme et al. (2001) where no differences were seen in the true digestibility of L-lysine·SO_4 when compared with L-lysine·HCl in cecectomized roosters.

Nitrogen retention

The nitrogen intake and excretion were calculated for nitrogen retention in the experimental diets and excreta (Table 7). There were no significant differences in the nitrogen retention values among the various forms of synthetic L-lysine supplemented, but tended to decrease the excreted urinary nitrogen and improve the nitrogen

Table 8. Effect of synthetic lysine products on apparent amino acids digestibility in weaning pigs with diet II, as fed basis (%)[a, b]

Item	Control	L-C	K-L-S	C-L-S	SEM[c]
Threonine	87.65	89.56	88.80	89.83	0.63
Valine	87.86	89.91	91.59	90.08	0.95
Methionine	87.58	88.90	89.81	89.17	0.77
Isoleucine	88.00	90.50	89.28	90.13	0.69
Leucine	91.51	90.64	93.69	90.97	0.78
Phenylalanine	90.92	89.99	91.18	91.24	0.51
Lysine	89.17	91.95	92.58	92.66	0.73
Histidine	91.61	93.17	93.34	93.59	0.48
Arginine	91.34	94.38	93.20	94.41	0.61
EAA[d]	89.52	91.00	91.50	91.34	0.59
Asparagine	89.27	992.16	91.45	92.15	0.66
Serine	90.32	91.65	91.19	92.02	0.52
Cystein	84.00	86.84	87.46	87.79	0.87
Glutamic acid	92.92	93.79	93.51	93.99	0.42
Proline	92.30	91.83	92.10	91.24	0.47
Glycine	85.33	88.37	87.98	88.52	0.87
Alanine	89.20	88.61	89.60	88.76	0.72
Tyrosine	90.12	89.10	89.72	90.54	0.62
NEAA[e]	89.78	90.29	90.37	90.63	0.59
TAA[f]	89.35	90.65	90.94	90.98	0.59

[a] Sixteen pigs were used from an average initial BW of 10.64±0.37 kg to an average final BW of 11.15±0.68 kg.
[b] Not significantly different (p>0.24). [c] Standard error of mean. [d] Essential amino acids.
[e] Non essential amino acids. [f] Total amino acids.

Table 9. Effect of the different sources of synthetic lysine on feed cost per gain in weaning pigs[c].

Item	Control	L-C	K-L-S	C-L-S	SEM[d]
Total weight gain (kg)	9.27[b]	11.56[a]	11.59[a]	10.70[ab]	0.25
Total feed cost/pig (US $)[e]	12.38	13.77	13.24	12.74	0.27
Feed cost/kg weight gain (US $)	1.33[c]	1.20[d]	1.12[d]	1.19[d]	0.02

[a, b] Mean within rows with different superscripts differ, p<0.01.
[c] A total of 96 crossbred pigs was fed from average initial body weight 6.32±0.01 kg and the average of final weight was 17.01 kg.
[d] Standard error of mean. [e] Not significantly different (p>0.19).

retention. Rodhouse (1992) reported that increasing the concentration of lysine in the diet using L-lysine·HCl or extruded soybean meal improved N and energy utilization in diets that were deficient in lysine. In this experiment, N retention was improved by the supplementation of synthetic lysine.

Apparent digestibility of amino acids

Table 8 showed the amino acid compositions of L-lysine·HCl and two products of L-lysine·SO_4. The effects of these three synthetic lysine products on apparent amino acid digestibility in weaning pigs with diet II were presented in Table 8. As the total lysine content in L-lysine·SO_4 products differed in percentage (52.17% and 47.66%, respectively), the amount of supplementation with two L-lysine·SO_4 products was adjusted to the same total lysine content to facilitate comparison. There were no significant differences among treatments for amino acid digestibility. These results agreed with the results of Bae et al. (1998), in which there were no trends between the sexes nor among dietary lysine levels for amino acid digestibility.

Cost benefit analysis

The cost benefits of supplementation of different sources of synthetic lysine on feed cost per kg weight gain in weaning pigs (US $/kg) are presented in Table 9. As the production of L-lysine·SO_4 is less complex and generates less waste, the price of L-lysine·SO_4 is lower than that of L-lysine·HCl. Generally, synthetic lysine prices vary with the price of soybean meal and it is hard to establish a stable price for synthetic lysine. The average price of the L-lysine·HCl in 2004 was about $2,100/ton, and generally, the price of the L-lysine·SO_4 accounts for 40-65% of that of L-lysine·HCl. Therefore, the calculation of the feed cost per kg weight gain in this experiment was based on a tentative standard price.

The feed cost/kg weight gain of the control treatment (US $/kg) was higher than that for the other treatments (p< 0.01). Generally, it is cheaper to use a grain source protein to provide most of the amino acid needs of the animals, but synthetic amino acids (i.e., lysine, methionine, tryptophan, and threonine) should be supplemented when the diets are deficient in amino acids. In addition, synthetic amino acids have the potential to decrease the cost of rations by decreasing the amount of protein ingredients in the diet. Although there were no significant differences in total feed cost/pig and feed cost/kg weight gain among synthetic lysine treatments, the L-lysine·SO_4 group showed the lowest feed cost/kg weight gain. This result suggests that an economical benefit could be obtained by using L-lysine·SO_4 instead of L-lysine·HCl. Based on the similar bioavailabilities of lysine in L-lysine·SO_4 and L-lysine·HCl for promoting growth in young pigs and its guaranteed quality, the cost of feed production can be lowered.

IMPLICATIONS

Two kinds of synthetic lysine sources, L-lysine·HCl or L-lysine·SO_4, are available for animal feed. The results of this study demonstrated that ADG, G:F ration, CP digestibility and nitrogen retention were improved when either L-lysine·SO_4 or L-lysine·HCl was used in weaning pigs' diets. As there were no growth performance differences between the two different L-lysine·SO_4 products, L-lysine·SO_4 can be safely substituted for L-lysine·HCl in the animal diet without any retardation in weaning pigs' diets as long as its quality can be guaranteed.

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