Developing Model Equation to Subdivide Lysine Requirements into Requirements for Growth and Maintenance in Pigs

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ABSTRACT : Purified diets containing 5 graded levels of lysine were fed to young and growing pigs to determine the lysine requirement for growth and maintenance. A model was developed to subdivide the lysine requirement for the maintenance from requirement for growth. From this model, the lysine requirement for growth was 18.018 and 19.431 g/kg live weight gain and the maintenance requirement was 0.115 and 0.033 g per unit of metabolic body size at each stage of growth, respectively. In the young pigs, the lysine requirement for growth was 0.950 g /g N gain and the maintenance requirement was 0.114 g per unit of metabolic body size. The breakpoint of plasma lysine concentrations was 8.695 and 13.464 g/d, respectively. Expected requirements obtained from these formulae were in general agreement with previous estimates. Based on weight gain vs N gain equation, about 7.92% of the retained protein was comprised of lysine as compared to 7.11%, the mean lysine content of pig muscle CP.

(**Key Words** : Lysine, Requirement, Maintenance, Growth, Body Composition, Plasma Concentration, Purified Diets, Pigs)

INTRODUCTION

The amino acid requirements of a growing pig can be divided into two components, a requirement for maintenance and a requirement for growth. If amino acid requirements should represent one proportion for maintenance and a second proportion for growth, requirements at any specified levels of production can be calculated. In addition to changes in absolute requirements with level of production, ratios of amino acids needed may differ with level of production as suggested by results of Bunce and King (1969). There is evidence from studies with other species (Shin et al., 1994a,b) that the pattern of amino acids required for each of these is quite different, and the animal's total requirement must, therefore, depend on the relative contributions of maintenance and growth to its total needs.

The lysine requirement for young, growing and finishing pigs suggested by NRC (1988) was 0.95% for 10-20 kg, 0.75% for 20-50 kg and 0.60% for 50-110 kg of live weight. The lysine requirement determined by plasma urea N concentrations were 1.04% for 19 kg, 0.85 % for 32 kg, 0.70% for 44 kg and 0.69% for 70 kg (Coma et al., 1995). Lin et al. (1986) reported that the oxidation rate of lysine was increased markedly above 0.65% of diet for a 30-40 kg growing pig.

The dietary lysine requirement for the accretion of 1 g body protein in the growing pig was 0.068 g. From the relationship between N retention and amino acid intake the daily lysine maintenance requirements for N equilibrium were estimated to be 36 mg/$W_{kg}^{0.75}$ (Fuller et al., 1989). The maintenance requirements for lysine estimated in N balance studies were 25 mg/$W_{kg}^{0.75}$ per day in nongravid gilts averaging 145 kg weight by Baker et al. (1966). However, these studies seemed to use diets containing inadequate amino acids for maximum growth and protein accretion, and protein turnover (Chung and Baker, 1992).

The growth and maintenance requirements of lysine can vary with weight differences, response criterion and mathematical models. Nutrient limitations, environmental conditions, or performance potentials influencing feed intake also should be considered as important factors which affect requirement. It seems desirable to express amino acid requirements for maintenance, like energy requirements, on metabolic body size because daily N loss should be a result of surface and intestinal protein losses

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and, basal metabolic rate should be proportional to body weight. The objective of this study was to determine the lysine requirement for maintenance and growth, in young (10 kg) and growing (40 kg) pigs.

MATERIALS AND METHODS

Animals and general procedures

Four-week-old, male weanling, pure bred (Landrace) pigs were used in all experiments. Individual pigs based on ancestry and weight, were initially fed standard corn-soybean meal diets, which were followed by gradual introduction of a chemically defined, amino acid diets for 7 days as shown in table 1 until they attained an average weight of 10 kg (experiment 1) and 40 kg (experiment 2). In all experiments, pigs were housed individually in 1.2 × 2.5 m pens installed with a self-feeder and nipple waterer in an environmentally controlled room (20℃ to 24℃) in which a 24 h constant light schedule was maintained. Before the beginning and the end of each experiment, the pigs were weighed after overnight fasting. All animals were meal-fed to satiation twice daily, once in the morning and once in the evening. Fresh (refrigerated) diet was provided at every feeding. Diets were fed dry without moistening. Feed intakes were monitored daily and body weights were recorded weekly.

Experimental diets

The composition of the basal diet for pigs of an average weight of 10 kg (experiment 1) and 40 kg (experiment 2), respectively is shown in table 1. Experimental diets were formulated to contain either 25, 50, 75, 100 or 125% of lysine requirement suggested by NRC (1988); all amino acids except lysine were formulated to meet or exceed 100% of NRC nutrient requirements (1988). To make the experimental diets isocaloric, L-lysine was substituted for L-glutamic acid in the basal diet. The methyl-donor compounds (choline, folate and vitamine B_{12}) were included to meet the requirement. Pigs had ad libitum access to water and their test diet, which were kept at −20℃ throughout the experimental period to prevent spoilage or any other change after mixing and during storage.

Blood amino acid analysis

On the final day of the experiment, blood plasma samples were collected from three pigs in each treatment of all experiments. Samples were centrifuged at 3,000 rpm for 20 min to obtain plasma samples. The plasma was frozen in two aliquots. One aliquot was analyzed for plasma urea N and total plasma protein concentration by

Table 1. Composition of the chemically defined amino acid diets (% of diet)

	Young	Growing
Ingredients :		
Cornstarch	37.24	50.44
Amino acid mixture	18.00	15.00
Lactose	15.00	−
Sucrose	15.00	20.00
Mineral mixture[a]	5.28	5.28
Corn oil	5.00	5.00
Cellulose	3.00	3.00
$NaHCO_3$	1.20	1.00
Vitamin mixture[b]	0.04	0.04
Choline chloride	0.20	0.20
Antibiotic mixture[c]	0.03	0.03
DL-α-tocopheryl acetate	(20 mg/kg)	(20 mg/kg)
Ethoxyquin	(125 mg/kg)	(125 mg/kg)
Total	100.00	100.00
Amino acid mixture :		
L-Arginine	0.40	0.25
L-Histidine HCl H_2O	0.35	0.31
L-Isoleucine	0.53	0.46
L-Leucine	0.70	0.60
L-Lysine HCl	1.19	0.94
L-Methionine	0.24	0.21
L-Cystine	0.24	0.21
L-Phenylalanine	0.46	0.40
L-Tyrosine	0.31	0.26
L-Threonine	0.56	0.48
L-Tryptophan	0.14	0.12
L-Valine	0.56	0.48
L-Proline	0.40	0.33
L-Glycine	1.20	1.00
L-Glutamic acid	10.72	8.96
Total	18.00	15.00

[a] Mineral mixture provided per kilogram of diet: $CaCO_3$, 3 g; $Ca_3(PO_4)_2$, 28 g; K_2HPO_4, 9 g; NaCl, 8.8 g; $MgSO_4 \cdot H_2O$, 2.6 g; $MnSO_4 \cdot H_2O$, 0.65 g; $FeSO_4$, 0.5 g; $ZnCO_4$, 0.15 g; $CuSO_4 \cdot H_2O$, 15 mg; H_3BO_3 9 mg; $Na_2MoO_4 \cdot 2H_2O$, 9 mg; KI, 40.6 mg; $CoSO_4 \cdot 7H_2O$, 1 mg; Na_2SeO_3 0.66 mg.

[b] Vitamin mixture provided per kilogram of diet: thiamin HCl, 20 mg; niacin, 50 mg; riboflavin, 10 mg; D-calcium pantothenate, 30 mg; vitamin B_{12}, 0.04 mg; pyridoxine HCl, 6 mg; D-biotin, 0.6 mg; folic acid, 4 mg; menadione, 2 mg; ascorbic acid, 250 mg; retinyl acetate, 5,200 IU; cholecalciferol (200,000 IU per g), 600 IU.

[c] Antibiotic mixture provided per kilogram of diet: chlortetracycline, 110 mg; sulfamethazine, 110 mg; procaine penicillin, 55 mg.

blood analyzer (Ciba-Corning Model, Express Plus, Ciba Corning Diagnostics Co.). The other aliquot was deproteinized with the sulfosalicylic acid and analysed for plasma free amino acid concentration with ion-exchange chromatography (Hitachi Model 835, Amino Acid Analyzer, Hitachi Ltd, Tokyo, Japan).

Preparation of carcass sample

In experiment 1, the pigs were weighed before they were transported to the Meat Laboratory. They were killed by hammer stunning, after which the blood was allowed to clot inside the body before evisceration. An incision through the abdominal wall was made between both hams to facilitate removal of the gastrointestinal tract, which was emptied of its contents and rinsed with a minimal amount of water. The intact whole carcass including head and all organs and the washed gastrointestinal tract were combined, weighed, packaged in a heavy-duty plastic bag and frozen at −20℃. The weight obtained before freezing was recorded as empty body weight.

After deep freezing, whole carcasses and gastrointestinal tract were cut while frozen into 2.5 × 2.5 × 5 cm shape and after mixing, ground two times through a 1 cm die and ground two times again through a 0.5 cm die, with hand mixing between grindings to obtain homogenous samples. Subsamples (~4 kg) were taken and frozen again. After deep freezing, samples were sliced while frozen into 0.5 cm strips and ground through a 0.1 cm die until a homogeneous, finely minced paste was obtained. One subsample was taken and frozen at −20℃ for dry matter and ash determination. The other subsample was freeze-dried at −40℃ for 36 h and frozen at −20℃ until chemical analyses.

Analysis of body composition

Dry matter obtained by drying wet samples for 24 h at 105℃. The dried samples were then extracted in ether for determination of whole-body lipid. For ash determination wet carcass samples were dry-ashed for 24 h at 550℃. Whole-body nitrogen was analyzed on wet samples by the Kjeldahl procedure (AOAC 1990).

Development of model equation and statistical analysis

The lysine requirement for growth and maintenance was calculated using a model based on metabolic body size ($W_{kg}^{0.75}$). The mathematical equation for this model was:

$$y = ax + b \quad \cdots\cdots (1)$$

where $y = R/W_{kg}^{0.75}$; $x = I/W_{kg}^{0.75}$; a = upslope to plateau; b = y intercept; I = amino acid intake in g/day; R = response (weight gain in kg/day or nitrogen gain in g /day). By incorporating these variables into equation (1), the following new model was generated.

$$I = 1/a \cdot (R - bW_{kg}^{0.75}) \quad \cdots\cdots (2)$$

$-b/aW_{kg}^{0.75}$ is the maintenance requirement of lysine (g/day) at maintenance. The upslope, 1/a, represents the growth requirement (g/day) per 1 kg live weight gain or 1 g nitrogen gain. Two linear regression equations, one for some of the upslope portion and the other one for upslope plus some plateau portion, were determined as intersecting at the point at which the residual sum of square is minimized by the nonlinear least square method (SAS, 1985). The data points covering the plateau portion beyond 100% of lysine requirement by NRC (1988) was excluded form the equations because, by definition, some nutrient or energy other than lysine was limiting response in that region.

All experimental data were subjected to ANOVA procedures appropriate for completely randomized design. Orthogonal single degree of freedom comparisons were made to test for linear and quadratic lysine effects and for other treatment differences of interest (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Growth responses of young pigs fed diets containing graded levels of lysine are shown in table 2. Weight gain and nitrogen gain increased rapidly by supplementing up to 0.95% lysine. Responses beyond 0.95% lysine were minor. Between 0.10 and 0.15% lysine in the diet was required to maintain both body weight and nitrogen retention. Feed intake reached the plateau at 0.95%, and gain/feed ratio continued to increase up to 1.19% lysine levels.

Responses of growing pigs fed diets containing graded levels of lysine are presented in table 3. Weight gain increased by supplementing rapidly up to 0.56% lysine. Changes in weight gain were minor beyond 0.56%. Feed intake reached to the plateau at 0.56% and then tended to decrease. Gain/feed ratio was reached to the maximum at 0.56 and 0.75%.

Water content of young pig carcasses increased in the same manner as protein content of young pig carcasses increased up to 0.95% lysine as described table 4. However, the ratio of protein to water content decreased by increasing the lysine level up to 0.95%. This means that body composition of pigs can be changed by deficiency or excess of lysine in the diet. Serious deficiency of lysine in the diet decreased water content of the pig carcass in this study.

Table 2. Responses of young pigs fed diets containing five graded levels of lysine for 14 days[1]

Lysine	Mean[2] $W^{0.75}$	Feed intake	Weight[3] gain	Lysine intake	Body nitrogen retention	Gain / Feed
(%)	(kg)	(kg/d)	(kg/d)	(g/d)	(g/d)	
0.24	6.22 ± 0.34	0.42 ± 0.04	0.04 ± 0.01	1.00 ± 0.08	0.64 ± 0.09	0.09 ± 0.04
0.48	7.22 ± 0.12	0.81 ± 0.06	0.37 ± 0.05	3.85 ± 0.30	6.07 ± 0.92	0.45 ± 0.03
0.71	7.45 ± 0.17	1.05 ± 0.06	0.51 ± 0.05	7.50 ± 0.45	10.27 ± 0.78	0.48 ± 0.02
0.95	7.83 ± 0.22	1.11 ± 0.06	0.59 ± 0.04	10.54 ± 0.55	10.20 ± 0.91	0.53 ± 0.00
1.19	7.66 ± 0.19	0.97 ± 0.02	0.53 ± 0.02	11.54 ± 0.23	9.76 ± 0.66	0.55 ± 0.01

[1] Values are mean ± S.E. of 3 pigs of each treatment.
[2] $W^{0.75}$ is (initial weight + final weight)/2)$^{0.75}$.
[3] Average initial weight was 11.27 ± 0.78 kg.

Table 3. Responses of growing pigs fed diets containing five graded levels of lysine for 13 days[1]

Lysine	Mean[2] $W^{0.75}$	Feed intake	Weight[3] gain	Lysine intake	Gain / Feed
(%)	(kg)	(kg/d)	(kg/d)	(g/d)	
0.19	16.45 ± 0.18	1.61 ± 0.05	0.31 ± 0.03	3.01 ± 0.10	0.19 ± 0.01
0.38	17.69 ± 0.26	2.43 ± 0.02	1.08 ± 0.04	9.10 ± 0.05	0.45 ± 0.02
0.56	17.86 ± 0.40	2.54 ± 0.08	1.18 ± 0.03	14.30 ± 0.45	0.47 ± 0.01
0.75	18.08 ± 0.13	2.49 ± 0.06	1.16 ± 0.02	18.70 ± 0.46	0.47 ± 0.02
0.94	17.74 ± 0.05	2.39 ± 0.10	1.11 ± 0.06	22.37 ± 0.97	0.46 ± 0.02

[1] Values are mean ± S.E. of 3 pigs of each treatment.
[2] $W^{0.75}$ is (initial weight + final weight)/2)$^{0.75}$.
[3] Average initial weight was 39.38 ± 1.22 kg.

Table 4. Body composition of young pigs fed five graded levels of lysine for 14 days

Lysine	Live weight gain	Dry weight gain	Water gain	Protein gain	Protein gain / water gain
(%)	(kg/14 days)	(g/14 days)	(g/14 days)	(g/14 days)	
0.24	0.54^{c}	0.36^{c}	0.17^{c}	0.64^{c}	0.320^{a}
0.48	5.12^{b}	2.77^{b}	2.36^{b}	6.07^{b}	0.228^{b}
0.71	7.14^{a}	2.99^{b}	4.15^{a}	0.90^{a}	0.218^{b}
0.95	8.28^{a}	4.05^{a}	4.22^{a}	0.89^{a}	0.211^{b}
1.19	7.47^{a}	3.41^{ab}	4.06^{a}	0.85^{ab}	0.211^{b}

^{abc} Means in a column with different superscripts are different ($p < 0.05$).

Table 5 shows plasma amino acid, urea N and protein concentrations of young pigs fed five graded levels of lysine. Plasma isoleucine, leucine and lysine concentrations changed in a linear pattern as the dietary lysine level increased, while valine and cystine concentrations in plasma followed in a quadratic pattern. Plasma urea N concentration showed a quadratic pattern with increasing lysine. The pattern was smilar to plasma urea N conentrations of pigs fed diets containing graded levels of lysine in the study by Coma et al. (1995).

Plasma amino acids, urea N and protein concentration of growing pigs fed five graded levels of lysine are presented in table 6. Plasma lysine and cystine concentrations changed in a linear pattern as dietary lysine increased. Urea N concentrations in plasma decreased in a linear pattern. However, protein concentrations in plasma did not change as dietary lysine level increased (table 5 and 6).

The predicted equation for lysine requirement of young pigs (10 kg of body weight) for maintenance and for growth is shown in figure 1. The estimated lysine requirement for growth was 18.018 g per unit of kg weight gain while the estimated requirement for maintenance was 0.115 g/d per unit of metabolic body size. The total lysine requirement is the sum of growth and maintenance requirement. For example, if a young pig weighing 15 kg and gaining at a rate of 0.45 kg per day, the growth requirement would be 8.108 g per day and the maintenance requirement would be 0.876 g per day. Thus,

Table 5. Plasma amino acid, urea N and protein concentrations of young pigs fed five graded levels of lysine (mg / 100 ml)

AA	Lysine (%)					Mean	SE
	0.24	0.48	0.71	0.95	1.19		
ARG	1.48	1.80	1.81	1.45	1.00	1.51	0.17
HIS	1.85	2.03	1.46	1.09	1.10	1.51	0.11
ILE[l]	1.38^{b}	1.94^{b}	4.32^{a}	3.76^{a}	3.16^{ab}	2.91	0.36
LEU[l]	1.55^{ab}	1.83^{a}	1.56^{ab}	1.11^{ab}	0.97^{a}	1.40	0.12
LYS[l]	1.30^{b}	1.83^{b}	1.99^{b}	4.26^{a}	5.44^{a}	2.96	0.45
MET	0.62	0.71	0.92	0.66	0.53	0.69	0.06
PHE	1.47	0.89	1.66	2.23	1.47	1.54	0.20
THR	10.23^{a}	16.10^{a}	14.64^{ab}	6.51^{c}	9.70^{bc}	11.44	1.11
VAL[q]	2.55^{b}	3.33^{b}	6.56^{a}	3.92^{b}	4.19^{b}	4.11	0.42
Total Ess.[q]	22.43^{b}	30.45^{ab}	34.91^{a}	24.99^{b}	27.55^{ab}	28.07	1.52
ALA	7.26	12.17	12.28	13.51	13.94	11.84	1.09
ASP	0.52	0.91	1.14	0.89	0.95	0.88	0.09
CYS[q]	0.13^{b}	0.22^{ab}	0.32^{a}	0.21^{ab}	0.16^{b}	0.21	0.02
GLU	5.16^{b}	9.02^{ab}	13.73^{a}	7.03^{ab}	10.16^{ab}	9.21	0.12
GLY	6.35^{b}	9.93^{ab}	11.67^{a}	9.19^{ab}	9.57^{ab}	9.34	0.69
PRO	2.89	4.10	4.03	3.10	3.76	3.58	0.30
SER	2.04	2.52	2.55	1.96	1.86	2.19	0.15
TYR	1.21	1.22	1.18	1.38	0.84	1.17	0.11
Total Noness.	25.56	40.09	46.91	37.29	41.25	38.22	3.10
Grand total	48.00^{b}	70.55^{ab}	81.82^{a}	62.27^{ab}	68.79^{ab}	66.29	4.36
PUN (mg/dl)[q]	14.80^{a}	11.37^{b}	9.30^{bc}	7.27^{c}	10.17^{b}	10.58	0.74
Protein (g/dl)	3.57^{a}	2.17^{c}	2.73^{abc}	2.23^{bc}	3.47^{ab}	2.83	0.21

^{abc} Means in a row with different superscripts are different ($p < 0.05$).
[l] Linear relationship among treatment means ($p < 0.05$).
[q] Quadratic relationship among treatment means ($p < 0.05$).

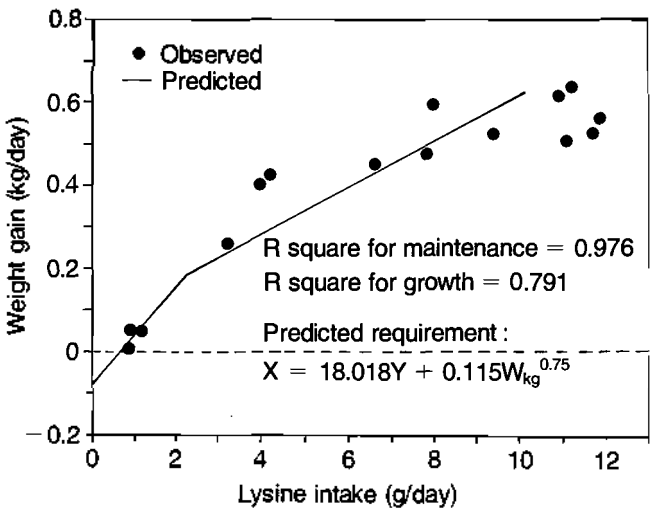

Figure 1. Weight gain response to graded lysine intake in young pigs.

the total requirement for lysine needed by this young pig would be 8.984 g per day. This means that about 9.75% of the total requirement would be utilized for maintenance. If feed intake is 0.95 kg per day, the dietary level of lysine required for growth would be 0.85%, for maintenance would be 0.09% and therefore, total requirement would be 0.94%. This value is similar to previously reported lysine requirements for total (0.95% ± 0.09) as shown in table 7.

The predicted equation for lysine requirement of growing pigs (40 kg of body weight) for maintenance and for growth is shown in figure 2. The estimated lysine requirement for growth was 19.431 g per unit of kg weight gain while the estimated requirement for maintenance was 0.033 g/d per unit of metabolic body size. For example, if a growing pig weighs 45 kg and gains 0.7 kg per day, the growth requirement would be

Table 6. Plasma amino acid, urea N and protein concentrations of growing pigs fed five graded levels of lysine (mg / 100 ml)

AA	Lysine (%)					Mean	SE
	0.19	0.35	0.56	0.75	0.94		
ARG	0.90	0.43	0.73	0.87	0.98	0.78	0.11
HIS	1.07	1.08	1.13	1.61	4.23	1.82	0.61
ILE	1.23	1.56	2.11	2.27	2.32	1.90	0.26
LEU	1.20	1.41	1.77	1.58	1.59	1.51	0.22
LYS[1]	1.54[c]	0.74[c]	1.24[c]	3.69[b]	5.55[a]	2.35	0.53
MET	0.45	0.48	0.71	0.63	0.63	0.58	0.09
PHE	1.37	1.16	1.43	1.20	1.33	1.30	0.17
THR	5.46	5.08	5.09	5.91	5.97	5.50	0.59
VAL	1.49	1.51	3.37	3.49	3.54	2.68	0.43
Total Ess.	13.72	13.45	17.58	21.24	26.13	18.42	2.28
ALA	4.52	5.53	6.00	7.45	7.96	6.29	0.83
ASP	0.36	0.37	0.30	0.19	0.23	0.29	0.04
CYS[1]	0.08[b]	0.15[b]	0.18[b]	0.20[b]	0.34[a]	0.19	0.03
GLU	3.52	4.50	3.85	5.05	4.16	4.22	0.49
GLY	5.72	5.86	7.53	8.14	8.38	7.13	0.79
PRO	2.21	2.38	2.69	2.39	2.27	2.39	0.32
SER	1.15	0.96	1.10	1.06	1.15	1.09	0.10
TYR	0.96	0.82	0.81	0.89	0.89	0.87	0.10
Total Noness.	18.53	20.57	22.46	25.38	25.37	22.46	2.47
Grand total	32.24	34.01	40.04	46.61	51.50	40.88	4.65
PUN (mg/dl)[1]	16.63[a]	14.87[ab]	10.04[bc]	8.30[c]	9.43[bc]	11.91	1.11
Protein (g/dl)	5.60	6.13	4.07	4.87	6.03	5.34	0.59

[abc] Means in a row with different superscripts are different ($p < 0.05$).
[1] Linear relationship among treatment means ($p < 0.05$).

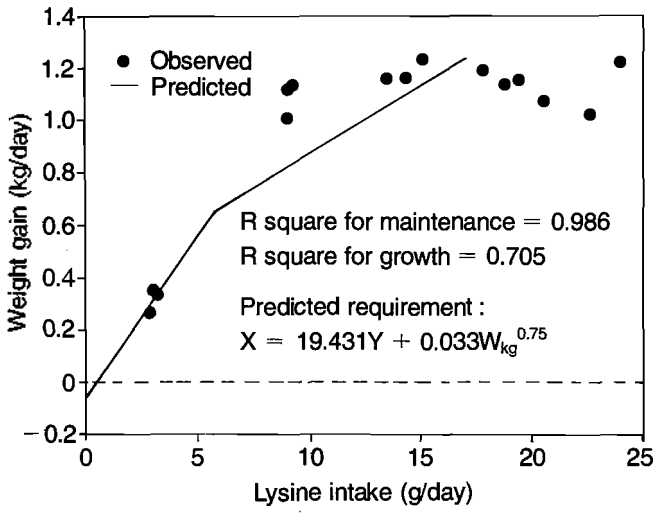

Figure 2. Weight gain response to graded lysine intake in growing pigs.

13.602 g per day and the maintenance requirement would be 0.567 g per day. Thus, the total requirement for lysine needed by this growing pig would be 14.169 g per day. This means that about 4.00% of the total requirement would be utilized for maintenance. If feed intake is 1.9 kg per day, the dietary level of lysine required for growth would be 0.72%, for maintenance would be 0.06% and therefore, total requirement would be 0.78%. This value is almost the same as the previously reported lysine requirements (0.77% ± 0.09) in total as listed in table 7.

Daily lysine intake of young pigs are plotted against daily nitrogen gains in figure 3; the prediction line and equation are also included. The estimated lysine requirement for growth was 0.950 g per g nitrogen gain and the estimated requirement for maintenance was 0.114 g per unit of metabolic body size. For instance, a pig weighing 15 kg and gaining N at a rate of 8.5 g N/day

Table 7. Previously published lysine requirements for young, growing and finishing pigs

Dietary lysine	Live weight	Response parameters	Lysine requirement	Sources
(%)	(kg)		(%)	
	10-20	Growth	0.95	NRC (1988)
0.60-1.20	19	N retention, PUN	1.03	Coma et al. (1995)
0.54-0.94	20	Growth	0.86	Martinez and Knable (1990)
Mean			0.95	
STD			0.09	
	20-50	Growth	0.75	NRC (1988)
0.60-1.00	32	PUN	0.85	Coma et al. (1995)
0.60-0.75	17-54	Growth	0.70	Asche et al. (1985)
0.25-1.50	30-40	$^{14}CO_2$ Oxidation	0.65	Lin et al. (1986)
0.60-1.00	44	PUN	0.70	Coma et al. (1995)
0.60-0.90	25-55	Growth, Carcass	0.86	Williams (1984)
0.83-0.96	25-45	Growth	0.86 (D)	Lenis et al. (1992)
Mean			0.77	
STD			0.09	
	50-110	Growth	0.60	NRC (1988)
0.60-0.90	35-99	Growth	0.60	Cromwell et al. (1993)
0.35-0.75	50-90	Growth, PUN	0.58	Hahn et al. (1995)
0.45-0.60	54-101	Growth	0.50	Asche et al. (1985)
0.47-0.77	55-105	Growth, Carcass	0.74	Williams (1984)
0.50-0.90	70	PUN	0.69 (B)	Coma et al. (1995)
0.50-0.90	70	PUN	0.75 (G)	Coma et al. (1995)
Mean			0.62	
STD			0.08	
Maintenance requirement				
	145	N balance	25 $mg/W_{kg}^{0.75}$	Baker et al. (1966a)
	46	Growth	36 $mg/W_{kg}^{0.75}$	Fuller (1989)

PUN : plasma urea nitrogen, D : digestible requirement, B : barrow, G : gilt.

would require 8.076 g of lysine per day for growth. The maintenance requirement for lysine for this young pig would be 0.872 g per day. Thus, the total daily amount needed by this growing pig would be 8.948 g per day. This means that about 9.75% of the total requirement would be utilized for maintenance in young pigs. When total requirement expressed as daily intake basis is converted to the dietary percentage assuming a feed intake of 0.95 kg per day, the requirement would be 0.94%.

Previously determined lysine requirement for the accretion of 1 g body N (protein × 6.25) in growing pigs (46 kg) was 425 mg. In contrast, from the relationship between N retention and amino acid intake the daily lysine maintenance requirements for N equilibrium were estimated to be 36 $mg/W_{kg}^{0.75}$ per day (Fuller et al., 1989). The maintenance requirements for lysine estimated in N balance studies were 25 $mg/W_{kg}^{0.75}$ per day in nongravid gilts averaging 145 kg weight by Baker et al. (1966). These requirements are generally close to requirements for growing pig's (40 kg) values. Adjusting to young pigs, these requirement would underestimate lysine requirement for the maintenance and accretion of 1 g body N. In contrast, if these requirements adjust finishing pigs, predicted equation would overestimate the lysine requirement for the maintenance and the accretion of 1 g body N.

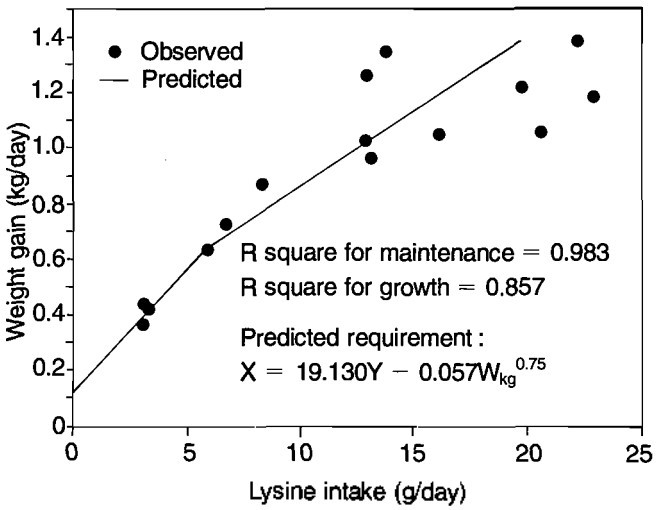

Figure 3. Nitrogen gain as influenced by lysine intake in young pigs.

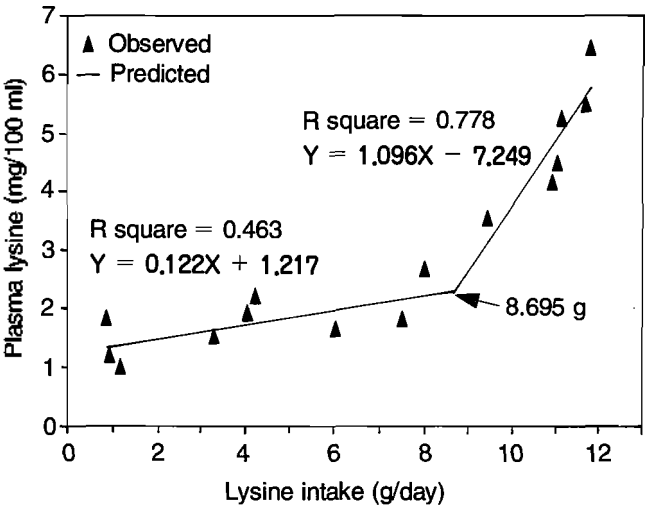

Figure 4. Plasma lysine concentration as influenced by lysine intake in young pigs.

From the relationship of weight gain to N gain, the N percentage of retained body weight was 1.76% (8.736/495). Multiplied by 6.25, the protein content of weight gained was 11.03%. Based on N retention and weight gain responses, as a proportion of CP (N × 6.25) gained, lysine content in muscle protein calculated to be 7.92%. This can be compared with mean lysine content 7.11% of muscle protein in pig (Zhang et al., 1986).

The daily level of net protein synthesis increases in a curvilinear fashion until a genotypic maximum rate is obtained, and then it begins to decline (Tullis, 1980). As a result, dietary amino acid requirements for protein accretion also increase in a curvilinear fashion as metabolic body size increases. Dietary amino acid requirements for maintenance, in contrast, respond linearly with increases in metabolic body size until mature body weight is achieved (Hahn and Baker, 1995).

Plasma lysine concentrations of young pigs fed diets containing these 5 graded levels of lysine are presented in figure 4. Plasma lysine content remained constant up to the inflection point and then rose up abruptly. The inflection point (8.695 g/d intake) could be regarded as lysine requirement for growth. If the lysine intake at that inflection point is converted to a dietary percentage assuming that feed intake is 0.95 kg per day, the requirement is 0.92% of diet. This value is near the previously shown lysine requirements for growth expressed as a percentage of the diet 0.95 ± 0.09% as shown in table 7. Plasma amino acid concentrations to 5 graded levels of lysine are presented in table 5. Plasma lysine concentration changed in the linear fashion as dietary lysine supply was elevated.

Plasma lysine concentrations of growing pigs fed diets containing these 5 graded levels of lysine are presented in figure 5. Plasma lysine content showed the same trend as shown with young pigs. The inflection point (13.464 g/d intake) could be regarded as lysine requirement for growth. If the lysine intake at that inflection point is converted to a dietary percentage assuming that feed intake is 1.9 kg per day, the requirement is 0.71% of diet. This value is near the previous lysine requirements for growth expressed as a percentage of the diet 0.77 ± 0.09 % as shown in table 7. Plasma amino acid concentrations to 5 graded levels of lysine are presented in table 6. Plasma lysine concentration changed in the linear fashion as dietary lysine supply was elevated.

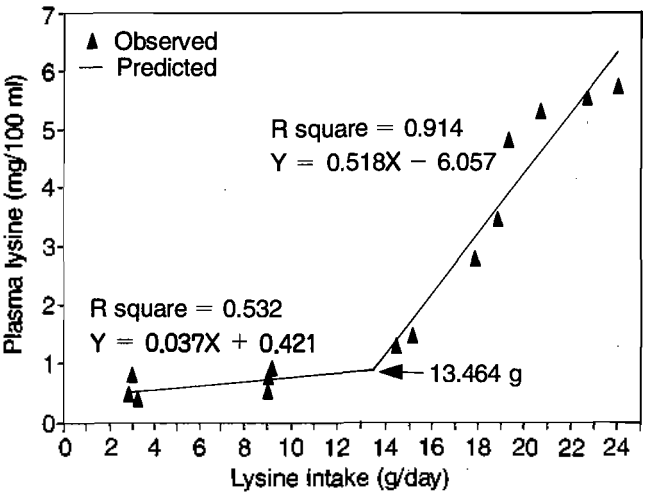

Figure 5. Plasma lysine concentration as influenced by lysine intake in growing pigs.

Table 8 shows estimated lysine requirement based on model equations for respective 10 and 40 pigs and lists of lysine requirements calculated from NRC (1988) nutrient requirements for each of the corresponding pigs. Total lysine requirements summing growth and maintenance are in close agreement with NRC (1988) requirements. The proportion of lysine needs for maintenance were greater for young than for growing pigs. Pigs with very rapid growth rate and 20 to 50 kg body weight tended to need less lysine for maintenance compared to smaller or larger body weight of pigs as suggested by Hahn and Baker (1995). However, the direct comparison between our estimates derived from purifed diets and previous requirements derived from semi-purified diets or corn-soybean meal based diets should be illogical because there are some discrepancies in digestibility between natural forms of amino acids and synthetic amino acids.

Table 8. Requirement estimates derived from model equations for 10, 40 and 70 kg pigs

Body weight	Weight gain	Feed intake	Requirement		Total needs	NRC needs	Maintenance/ Total
			Growth	Maintenance			
(kg)	(kg/d)	(kg/d)	(g/d)	(g/d)	(g/d)	(g/d)	(%)
3.0	0.20	0.25	3.604	0.262	3.866	3.500	6.8
7.5	0.25	0.46	4.505	0.521	5.026	5.300	10.4
15.0	0.45	0.95	8.108	0.877	8.985	9.000	9.8
45.0	0.70	1.90	13.602	0.573	14.175	14.300	4.0
80.0	0.70	3.11	15.687	−1.534	14.153	18.700	−10.8

IMPLICATIONS

Based upon growth rate, the lysine requirement for young pigs weighing 15 kg and gaining 0.45 kg/d is 0.94 % of the diet. From the data of N gain, the requirement was estimated as 0.94% of the diet. Similar requirement (0.92%) for lysine was obtained from the plasma lysine breakpoint. About 9 to 10% of these requirements were utilized for maintenance.

Based upon growth rate, the lysine requirement for growing pigs weighing 45 kg and gaining 0.7 kg/d is 0.78 % of the diet. Similar requirement (0.71%) for lysine was obtained from plasma lysine breakpoint. About 4 to 5% of these requirements were utilized for maintenance.

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