THE OPTIMAL DIETARY THREONINE TO LYSINE RATIO FOR GROWING PIGS

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SUMMARY

The growth of 64 pigs was monitored over grower and finisher periods of 26-58 and 58-96 kg respectively, to see if the optimum dietary ratio of threonine to lysine (T/L) under *ad libitum* feeding was higher than the generally accepted ratio of 0.6. Five basal (B_1-B_5) diets were used to establish the pig's response to lysine (in the range 6.0 to 11.24 and 5.59 to 10.5 g kg^{-1} for grower and finisher periods respectively) when dietary T/L was held constant at 0.6 and other essential amino acids were supplied relative to lysine at least 20% above accepted specifications. A further three response (R_1-R_3) diets, matching the lowest three lysine diets of the B series (except for the inclusion of free l-threonine to increase T/L to 0.7) were fed to quantify response to threonine. Measurements were made of average daily gain (ADG), feed conversion ratio (FCR) and protein deposition rate (PDR). PDR was estimated from relationships between whole body protein content and P_2 backfat measurements on the live animal. The metabolism of five diets representative of the range of B (3) and R (2) diets in the grower growth assay was measured to document nutrient digestibility and nitrogen (N) retention.

In the metabolism study, differences in nutrient digestibility and N retention between companion B and R diets were not significant. Percent N retained and nutrient digestibility (except for dry matter) improved ($P<0.05$) with increasing dietary lysine content, but the magnitude of the response was small (viz: N retention, 50.2 to 56.6%; N digestibility, 86.4 to 89.7%; and digestible energy, 14.52 to 14.69 MJ kg^{-1}). For the B series diets of the growth assay, ADG, FCR and PDR improved linearly ($P<0.01$) with increasing lysine content up to the second highest level (9.62 and 8.95 g lysine kg^{-1} for grower and finisher periods respectively). Increasing the dietary T/L ratio from 0.6 to 0.7 significantly ($P<0.05$) improved ADG and PDR but not FCR in the finisher period with similar trends being apparent in the grower period. Based on the proportionality of the response to the higher T/L ratio and that to lysine for ADG and PDR, the optimum T/L ratios derived for the grower and finisher diets were 0.64 and 0.68 respectively.

INTRODUCTION

After lysine and perhaps methionine, threonine is the next most limiting amino acid in cereal based pig diets. It is also one of the most expensive amino acids when formulating diets, costing \$20 - 30/kg to supply in protein form or about \$15/kg as the free amino acid. Since protein synthesis proceeds optimally only when amino acids are available to the animal in balanced amounts and because lysine is usually the most limiting dietary amino acid, it has become accepted practice to specify the requirement of other amino acids as a ratio to lysine.

The optimal dietary threonine to lysine (T/L) ratio for growing pigs recommended by the Agricultural Research Council (ARC 1981) and adopted by the Australian Feeding Standards for Australian Livestock (SCA 1987) is 0.6. More recently, studies from the Rowett Institute (Fuller et al. 1989; Wang and Fuller 1989, 1990) and elsewhere (Cole and Bong 1990; Chung and Baker 1992) suggest that a much higher ratio - from 0.64 to 0.72 - is needed by pigs to maximise N retention.

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Using AUSPIG simulation and a What-if economic analysis, we have examined the effect of an under- or over-specification of the dietary T/L ratio for post-weaned growers in a typical 100 sow baconer production unit rearing 19 pigs/sow/year. If the true optimum dietary T/L ratio was assumed to be 0.67, an under-specification of the diet to 0.6 caused the margin over food cost (MOFC) of the piggery to fall by approximately 3% (by $19/sow/year from a base value of $816). Conversely, if the true optimum dietary T/L ratio was instead 0.6, an over-specification of the diet to 0.67 increased food costs (by $5/tonne) without any pig production benefit, causing MOFC to fall by about 3% (by $22/sow/year). Thus supplying threonine in the diet either above or below the optimum requirement induced higher food costs on the one hand or decreased production on the other and in either event, resulted in a significant decline in profitability.

The objective of the present study was to determine the optimum T/L ratio required by growing pigs fed conventional diets using growth assay procedures to measure responses to altered amino acid supply. A metabolism experiment is also reported to document nutrient digestibility and energy status of the diets

MATERIALS AND METHODS

Experimental rationale and diets

The hypothesis under test was that growing pigs required a dietary T/L ratio greater than the 0.6 ratio advocated by ARC (1981) and SCA (1987). This was examined by measuring the extent to which pig performance was altered when the dietary T/L ratio was increased from 0.6 to 0.7 under conditions demonstrated to be sub-optimal with respect only to lysine and possibly, threonine. The approach was to use growth assay procedures to evaluate the performance of pigs fed a series of five ‘basal’ (B_1-B_5) and three ‘response’ (R_1-R_3) diets. For the B series, diets were maintained at a constant T/L ratio of 0.6 while lysine content varied from 6.0 to 11.24 g kg^{-1} for the grower period and 5.59 to 10.5 g kg^{-1} for the finisher period. The purpose of the B series was to demonstrate the pig’s responsiveness to lysine under conditions in which diets were formulated to be isoenergetic and to contain all essential amino acids (other than threonine) at amounts relative to lysine that were at least 20% above SCA (1987) recommendations. A further three response (R_1-R_3) diets, matching the lowest three lysine diets of the B series (except for the inclusion of free l-threonine to increase T/L to 0.7) were fed to quantify response to threonine. Thus for each of the R diets there was a companion B diet differing in formulation only with respect to threonine content. Any improvement in performance of the R diet over that of the companion B diet would indicate a dietary T/L requirement greater than 0.6. The lysine increments of the B diets were set such that additions of free threonine not only raised the T/L ratio of the companion R diet to 0.7 but also equalled the total dietary threonine content of the next highest diet in the B series. Thus, the magnitude of any improvement in performance due to the increased T/L ratio in relation to the pig’s response (slope) to dietary lysine would quantitatively indicate the optimum T/L ratio between the range of 0.6 and 0.7. This interpretation is conditional on all other key nutrients -especially other essential amino acids and energy - being supplied in amounts that did not confound threonine responsiveness of the diets. This condition should have been satisfied in respect of other essential amino acids since diets were formulated with these being at least 20% above recommended allowances. It was necessary however, to demonstrate that the diets were isoenergetic and for this purpose complementary metabolism studies were done to define the nutrient digestibility, and specifically the digestible energy content of the growth assay diets.

It was important that the optimum dietary T/L ratio was evaluated for both grower (nominally, from 20-25 to 50-55 kg) and finisher (nominally, from 50-55 to 90-100 kg) pigs in view of the conclusions of Black and Davies (1991) that the optimum T/L ratio changes with advancing liveweight. Accordingly, pig responses were measured over discrete grower and finisher periods which necessitated diets appropriate to these growth periods being formulated (Tables 1 and 2 respectively).

Table 1. Formulation and critical amino acid content of the diets fed in the grower period

Attribute	Diet designation							
	Basal series					Response series		
	B_1	B_2	B_3	B_4	B_5	R_1	R_2	R_3
	Formulation (g kg^{-1})							
Wheat	885	855	819	782	737	885	855	819
Soybean	21	44	74	104	140	21	44	74
Fishmeal	4.5	9.5	16	22	30	4.5	9.5	16
Casein	4.5	9.5	16	22	30	4.5	9.5	16
Oil	38	36	33	30	26	38	36	33
Starch	3.0	3.0	1.7	2.2	1.5	2.4	2.3	0.9
DCP	28	28	25	23	21	28	28	25
Limestone	2	1	1	0.5	-	2	1	1
l-Lysine HCl	3	3	3	3	3	3	3	3
d/l-Methionine	-	-	0.3	0.3	0.5	-	-	0.3
l-Threonine	-	-	-	-	-	0.6	0.7	0.8
Supplement[A]	11	11	11	11	11	11	11	11
	Amino acid content							
Lysine (g kg^{-1})	6.00	7.01	8.35	9.62	11.24	6.00	7.01	8.35
Threonine (g kg^{-1})	3.57	4.18	5.01	5.78	6.76	4.17	4.89	5.80
Thr:Lys (g:g)	0.60	0.6	0.6	0.60	0.60	0.70	0.70	0.70
M+C:Lys (g:g)	0.74	0.69	0.67	0.63	0.62	0.74	0.69	0.67
Try:Lys (g:g)	0.20	0.19	0.18	0.17	0.17	0.20	0.19	0.18

[A] Provided in the mixed diet (g kg^{-1}): Sodium chloride, 2; trace mineral and vitamin premix (Williams et al. 1988), 6.5; medicaments, 2.5.

Experimental design, animals and management

A total of 64 pigs, comprising an equal number of males and females and of Duroc and Large White breeds of improved lean meat lines (pers. comm. C.P. McPhee) were used in the growth assay (Experiment 1). Pigs were selected for experimentation when approximately 8-9 weeks of age, stratified on liveweight within sex and breed into groups of eight and then distributed randomly to the eight dietary treatments. For the grower period, pigs commenced experimentation at an average (± SD) Iiveweight of 26.1 ±2.54 kg and finished when they individually attained or exceeded at the weekly weighing a liveweight of 55 kg (average, 58.0 t1.72 kg). The finisher period commenced immediately upon termination of the grower period and continued until pigs individually attained or exceeded at the weekly weighing a weight of 95 kg or after 15 weeks total experimentation (average, 96.1 ±3.23 kg). Pigs were housed in individual pens (2.1 m^2) and given water *ad libitum*. Diets were offered *ad libitum* other than on the day immediately preceding weekly weighing when feed allocation was managed so that pigs were fasted overnight (14 to 16 h); pigs were similarly fasted prior to the start of the grower period. P_2 backfat measurements were made by ultrasonic (Meritronics) scanning 45 and 65 mm lateral to the midline for grower and finisher (both start and end weights) pigs respectively. Protein deposition rate (PDR) was calculated as the rate of change in whole body protein content estimated from P_2 and liveweight relationships derived from published values (after Stranks et al. 1988). The derived relationships were:

for pigs _25 kg:- $P = LW (0.1463 - 0.0014P_2)$;
for pigs _50 kg:- $P = LW (0.1744 - 0.0017P_2)$;
for pigs _95 kg:- $P = LW (0.1843 - 0.0018P_2)$;

where P is body protein content (kg), LW is the pig's Iiveweight (kg) and P_2 is backfat (mm).

Table 2 Formulation and critical amino acid content of the diets fed in the finisher period

Attribute	Diet designation: Basal series					Response series		
	B_1	B_2	B_3	B_4	B_5	R_1	R_2	R_3
	Formulation (g kg^{-1})							
Barley	462	448.5	432.5	416	393	462	448.5	432.5
Wheat	462	448.5	432.5	416	393	462	448.5	432.5
Soybean	6.5	28	56	83	119	6.5	28	56
Fishmeal	1.5	6	12	18	25.5	1.5	6	12
Casein	1.5	6	12	18	25.5	1.5	6	12
Oil	20	18	13	9	6	20	18	13
Starch	2.7	2.2	1.9	2.2	2.7	2.1	1.5	1.1
DCP	28	28	25	23	21	28	28	25
Limestone	2	1	1	0.5	-	2	1	1
l-Lysine HCl	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
d/l-Methionine	-	-	0.3	0.5	0.5	-	-	0.3
l-Threonine	-	-	-	-	-	0.6	0.7	0.8
Supplement[A]	11	11	11	11	11	11	11	11
	Amino acid content							
Lysine (g kg^{-1})	5.59	6.52	7.75	8.95	10.50	5.59	6.52	7.75
Threonine (g kg^{-1})	3.33	3.90	4.66	5.39	6.34	3.93	4.60	5.46
Thr:Lys (g:g)	0.60	0.60	0.60	0.60	0.60	0.70	0.70	0.70
M+C:Lys (g:g)	0.71	0.67	0.66	0.65	0.61	0.71	0.67	0.66
Try:Lys (g:g)	0.18	0.18	0.17	0.17	0.16	0.18	0.18	0.17

A Provided in the mixed diet (g kg^{-1}): Sodium chloride, 2; trace mineral and vitamin premix (Williams et al. 1988), 6.5; medicaments, 2.5.

Table 3 The air dry proximate and critical amino acid content (g kg*) and gross energy (MJ kg^{-1}) of main diet ingredients[A]

Attribute	Wheat	Barley	Soybean (solv)	Fish (tuna)	Casein
Dry matter	900	903	872	926	912
Ash	14	21	61	220	32
Crude protein	109	98	448	564	859
Crude fat	-	-	12	103	-
Crude fibre	22	43	66	-	-
Amino acids					
Arginine	5.25	5.52	30.6	34.1	32.9
Histidine	2.24	1.97	9.4	15.1	21.8
Isoleucine	3.69	3.43	19.9	23.8	44.5
Leucine	7.22	6.89	34.0	42.2	81.8
Lysine	3.06	3.74	24.4	39.9	69.5
Methionine	1.60	1.41	5.3	13.2	24.1
Cystine	2.88	2.39	7.0	5.3	3.7
Phenylalanine	5.14	5.57	23.0	24.7	47.5
Tyrosine	3.39	3.36	15.7	19.8	54.1
Threonine	3.30	3.46	17.4	25.2	38.1
Tryptophan	1.18	0.94	4.2	5.2	8.6
Valine	4.59	5.03	19.9	27.2	55.9
Gross energy	16.40	16.50	17.0	18.1	21.9

A Starch composition (g kg^{-1}); dry matter, 886; ash, 3; and crude protein, 5.
Gross energy (MJ kg^{-1}) of starch and vegetable oil were 15.1 and 40.0 respectively.

A 5x5 latin square design was employed in the metabolism study (Experiment 2) to measure the nutrient digestibility and N retention of five diets (T_1, T_3, T5, RI and R_3) fed in the grower period of the growth assay (data for the finisher diets are not available for reporting at this time). Male pigs were confined individually in crates which enabled faeces and urine to be collected quantitatively. Total collections of excreta were made over 5-day periods with a similar period being allowed between diet changes; ferric oxide was used in the diet at 5 g kg^{-1} to indicate the start and end points for faecal collections. Urine was collected into covered buckets through glass wool filters and acidified with 20 ml concentrated hydrochloric acid to prevent urinary N loss. Faeces were collected twice daily and urine once daily, bulked for the entire collection period and held at -15°C pending mixing and sub-sampling for analysis. Pigs were fed 78 g food kg^{-1} metabolic weight (liveweight$^{0.75}$) daily, offered in two equal meals. Feed was moistened (1:1 by weight) and water was provided after each meal to ensure a daily allowance of not less than 200 g kg^{-1} metabolic weight. Liveweights of the pigs at the start and end of the study were 26.1 ± 0.57 and 58.0 ±0.77 kg respectively.

<u>Nutrient analyses</u>

Representative samples of feedstuffs were hammer-milled and analysed for nutrients, gross energy and amino acid composition by the methods described by Williams et al. (1988). Feedstuffs were sampled prior to and after experimentation, analysed separately and the two analyses averaged. The same analytical methods were used for faeces and urine with N being determined for the material as voided and all other analyses of faeces after drying at 60°C. Tryptophan was determined by the method of Allred and MacDonald (1988) using a Waters' high-performance liquid chromatograph (HPLC) after hydrolysis of samples with 4.2 M NaOH at 110°C under an atmosphere of N2 for 20 h. The critical nutrient composition of the main dietary ingredients is given in Table 3.

Statistical analysis

Data were subjected to analyses of variance and regression appropriate to the experimental design. Experiment 1 was initially analysed as a balanced 8x2x2x2 factorial isolating effects due to diet, sex, breed, blocks and associated interactions. The 2x3 factorial arrangement of the three companion B and R treatments was then analysed, isolating effects due to T/L ratio and lysine, using the error mean square of the original ANOVA. In the absence of an interaction between these effects, and after tests for homogeneity of variance and parallelism, the response to lysine was derived using the data pooled across T/L effect. Measurements on the live pig were adjusted by covariance analysis to remove possible effects of differences in initial/end liveweight. Average daily gain (ADG) was calculated by regression of weekly weights against time. Least square procedures (Damon and Harvey 1987) were used to analyse the latin square design of Experiment 2. Treatment means were compared using the protected l.s.d. procedure, at the five percent level of significance.

RESULTS

Experiment 1 (growth assay)

The health of the pigs during the experiment was good although four pigs (two on diet R_2 and one on each of diets T2 and R_1) were treated with injectable antibiotics to lessen effects of coughing presumed to be caused by enzootic pneumonia which is endemic in the herd. All pigs received in-feed antibiotic medication throughout the experiment to minimise effects of this organism. There were no deaths and all pigs completed experimentation.

Performance of the pigs given the eight diets in the grower and finisher periods is given in Table 4. Although there were significant ($P<0.05$) sex and breed effects, reporting at this time is confined to the effects of diets since all interactions between main effects were not significant ($P>0.05$). For the B series diets, ADG, PDR and feed conversion (FCR) improved linearly with increasing dietary lysine content up to the second highest level (9.62 and 8.95 g lysine kg^{-1} for grower and finisher periods respectively). Analysis of the effect of dietary T/L ratio and lysine responsiveness is given in Table 5. Increasing the dietary T/L ratio from 0.6 to 0.7 significantly ($P<0.05$) improved ADG and PDR but not FCR in the finisher period; similar trends were apparent for the grower period. Based on the proportional difference between the response to the higher T/L ratio and that to lysine for ADG and PDR, the derived optimum dietary T/L ratios were 0.64 and 0.68 for the grower and finisher periods respectively (Table 5).

Experiment 2 (metabolism study)

The apparent digestibility and N retention of the diets are given in Table 6. With the exception of dry matter, the nutrient digestibility and N retention improved ($P<0.05$) with increasing dietary lysine content. Differences between companion B and R diets were not significant (P>0.05) for any of the attributes.

Table 4 Performance of pigs fed basal (B) or response (R) diets in Experiment 1

Attribute[A]	Diet designation								
	Basal series					Response series			±SEM
	B_1	B_2	B_3	B_4	B_5	R_1	R_2	R_3	
				Grower period					
St wt (kg)	26.3	25.7	26.2	26.2	26.1	26.4	26.1	25.8	0.90
St P_2 (mm)	7.1	6.8	6.5	6.8	6.6	6.9	6.4	7.3	0.38
FI (kg d^{-1})	1.72	1.88	1.83	1.91	1.89	1.85	1.87	1.94	0.060
ADG (kg d^{-1})	0.66[d]	0.78[bc]	0.83[bc]	0.94[a]	0.94[a]	0.71[cd]	0.77[bc]	0.90[ab]	0.027
PDR (kg d^{-1})	0.107[e]	0.125[cd]	0.139[bc]	0.157[a]	0.157[a]	0.115[de]	0.127[cd]	0.145[ab]	0.051
FCR (g:g)	2.61[e]	2.40[d]	2.20[c]	2.04[ab]	2.02[a]	2.62[e]	2.43[d]	2.17[bc]	0.052
				Finisher period					
St wt (kg)	57.5	57.7	59.2	57.9	58.0	57.8	57.8	58.4	0.61
End wt (kg)	89.6[b]	97.1[a]	97.1[a]	98.2[a]	97.9[a]	92.6[b]	97.0[a]	98.6[a]	1.14
St P_2 (mm)	14.8[c]	14.4[c]	10.8[a]	12.0[ab]	12.2[ab]	14.3[c]	13.3[bc]	13.1[bc]	0.59
End P_2 (mm)	21.0[d]	19.5[cd]	15.4[a]	15.3[a]	16.5[ab]	19.6[cd]	17.2[abc]	18.0[bcd]	1.00
FI (kg d^{-1})	2.22	2.49	2.47	2.60	2.65	2.48	2.62	2.52	0.094
ADG (kg d^{-1})	0.62[d]	0.80[bc]	0.85[abc]	0.95[a]	0.93[a]	0.74[cd]	0.86[ab]	0.90[ab]	0.039
PDR (kg d^{-1})	0.089[e]	0.117[cd]	0.132[ab]	0.149[a]	0.145[ab]	0.109[d]	0.130[bc]	0.134[abc]	0.063
FCR (g:g)	3.61[c]	3.09[b]	2.93[ab]	2.78[a]	2.89[ab]	3.42[c]	3.08[b]	2.82[a]	0.080

[a,b,c,d,e] Where superscripting is used within attributes, the F-value of the ANOVA was significant and means not containing a common letter differ (P<0.05).

[A] P_2 - backfat measurement; FI - feed intake; ADG - average daily gain; PDR - protein deposition rate; FCR - food conversion rate.

Table 5 Effect of the threonine to lysine (T/L) ratio and lysine content of the diet on pig response and the derived optimum dietary T/L ratio

Attribute	T/L response			Lysine response (y=a+bx)			Derived optimum T/L ratio
	0.6	0.7	±SEM	a	b	SE_b	
				Grower period			
ADG (kg d^{-1})	0.76	0.79	0.017	0.257	0.073**	0.012	0.64
PDR (kg d^{-1})	0.124	0.129	0.0028	0.0325	0.0132**	0.002	0.64
FCR (g:g)	2.41	2.41	0.026	3.69	-0.180**	0.019	0.60
				Finisher period			
ADG (kg d^{-1})	0.76[x]	0.83[y]	0.025	0.225	0.086**	0.020	0.68
PDR (kg d^{-1})	0.113[x]	0.124[y]	0.0039	0.0155	0.0156**	0.0031	0.68
FCR (g:g)	3.21	3.11	0.049	5.077	-0.290**	0.039	0.64

[x,y] Where superscripting is used within attributes, the F-value of the ANOVA was significant and means not containing a common letter differ (P<0.05). ** P<0.01.

Table 6 The apparent digestibility and nitrogen (N) retention of basal (B) and response (R) diets in Experiment 2 (grower period)

Attribute	Diet designation					±SEM
	B_1	B_3	B_5	R_1	R_3	
Dry matter (%)	86.9	87.1	87.3	86.9	86.8	0.18
N (%)	87.0[c]	88.7[b]	89.7[a]	86.4[c]	89.1[ab]	0.33
Energy (%)	86.6[b]	86.9[ab]	87.2[a]	86.6[b]	86.7[ab]	0.17
Energy (MJ kg^{-1})	14.52[c]	14.61[ab]	14.69[a]	14.52[c]	14.59[bc]	0.029
N retention (%)	50.2[c]	53.5[b]	56.6[a]	49.2[c]	54.4[ab]	0.99

[a,b,c] Where superscripting is used within attributes, the F-value of the ANOVA was significant and means not containing a common letter differ ($P<0.05$).

DISCUSSION

The metabolism study confirmed that the nutrient contents of companion B and R grower diets were similar and that absolute differences between all diets were very small. Although metabolism data for the finisher period diets are not yet available, results are expected to mirror those of the grower period since dietary formulations were very similar (Tables 1 and 2). Thus, differences in pig performance between diets of the B series in the growth assay can be assumed to be due almost exclusively to differences in lysine content. Increasing the dietary T/L ratio from 0.6 to 0.7 clearly improved PDR and ADG responses and particularly for the finisher period. Based on the proportionality of the responses to the higher T/L ratio and those to lysine for ADG and PDR, the optimum ratios derived for the grower and finisher diets were 0.64 and 0.68 respectively.

This result confirms the view of Black and Davies (1991) that the T/L ratio of dietary 'ideal' protein for growth is not necessarily constant as previously advocated (see ARC 1981; SCA 1987; Fuller and Wang 1990). In respect of pig requirements for threonine and lysine, Black and Davies (1991) suggest that the optimum balance is dependent on genotype and liveweight (reflecting different requirements for maintenance and protein deposition) and on the stimulatory effect dietary fibre has on endogenous secretions into the gut (threonine being more abundant than lysine in these secretions). In the present study, the higher optimum T/L ratio for the finisher period compared with the grower period is possibly due to the increased fibre content of the diet induced by the partial replacement of wheat with barley. However, liveweight *per* se could also have been important but there is no way of separating this effect from the concomitant change in dietary fibre.

The results are also in agreement with other recent work evaluating the optimum dietary T/L ratio for growing pigs. In initial studies by the Rowett group (Wang and Fuller 1989; Fuller et al. 1989) assessing the composition of ideal dietary protein, the optimum T/L ratio was determined to be 0.69-0.72 for body protein accretion and 1.47 for maintenance. These estimates were derived from N retention responses for a series of amino acid deletion experiments wherein individual amino acids were sequentially removed from a semi-synthetic diet in which casein and free amino acids were the only N sources. In subsequent work using more practical diets based on maize and soybean, Wang and Fuller (1990) found the optimum T/L ratio to be 0.64 for pigs of _30 kg liveweight. Differences between these two studies in the optimum T/L ratio were attributed to differences in diet digestibility. In the case of the casein-amino acid diets, all dietary N was shown to be absorbed before the end of the ileum and thus the derived T/L ratio referred to the pattern of absorbed amino acids. By comparison, in the maize-soybean diet, the ileal digestibility of dietary N was only 67%. Conway et al. (1990) have drawn attention to the lack of constancy between faecal and ileal digestibility of threonine and the effect this can have on estimates of threonine requirements for pigs. Growth assays and N balance experiments with pigs _10 kg liveweight were used by Chung and Baker (1992) to evaluate the essentiality of four dietary amino acid patterns, two profiles developed by these Illinois researchers as well as that advocated by Wang and Fuller (1989) and by the National Research Council (NRC 1988). All dietary N was provided in the form of free amino acids and diets were made isonitrogenous and isoenergetic within experiments. They found the NRC pattern to result in inferior N utilisation compared to the other three patterns which were similar. On the basis of the proportion of N retained per gram of N intake from indispensable amino acids, they concluded that a T/L ratio of 0.65 was optimal for 10 kg pigs. An optimal dietary T/L ratio of 0.65-0.7 for 10-25 kg pigs was suggested by Cole and Bong (1990) who evaluated nine diets containing T/L varying at 0.05 increments from 0.5 to 0.9.

In the present metabolism study, N retention was not improved by increasing the dietary T/L ratio which contrasted with the response seen with dietary lysine (Table 6). In view of the trends evident in the growth assay that the higher T/L ratio improved ADG and PDR, the absence of similar trends for N retention was surprising. Although pigs in the metabolism study were fed restrictively as compared to *ad libitum* in the growth assay, this is not a satisfactory explanation. Protein deposition of these pigs was clearly limited by N supply and not energy since N retention improved with increasing dietary lysine content even though energy intake essentially remained constant. Furthermore, Wang and Fuller (1990) have shown that feed intake, within practical usage rates, had no effect on the lysine, threonine, methionine + cystine and tryptophan balances required by _30 kg pigs. As the requirements of threonine relative to lysine for N equilibrium in pigs are higher for maintenance than for protein deposition (Fuller et al. 1989), limiting growth by restricting feed intake is more likely to raise rather than lower the optimum ratio of threonine to lysine. A more likely explanation for the apparent lack of N retention response to higher dietary threonine is the large excess of amino acid N in the diets. This is exemplified by the low N retentions (only 49.2 to 56.6% of N intake), which could have obscured any response to the higher T/L ratio.

Based on the results of this and other cited studies, it is concluded that pigs require a dietary T/L ratio in the range of 0.64-0.7 to ensure optimal rates of lean growth, The composition and digestibility of the diet is likely to influence the optimum T/L ratio as also are animal factors including stage of growth and genotype.

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