A STUDY OF PROTEIN AND AMINO NUTRITION OF GROWING PIGS

End of Project Report ARMIS 4938

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1 Summary

Protein nutrition of the pig is concerned primarily with supplying the amino acid requirements for fast, efficient growth and development of a lean carcass. In addition, surplus protein contributes to a high level of nitrogen excretion in manure which is a problem in complying with the Nitrates Directive. Metabolism of the excess protein / nitrogen in the pig involves creation of urea and this process depresses the efficiency of energy utilisation. As the pig grows, its requirement for individual amino acids falls but the optimum ratio changes. Providing a diet with the correct levels and balance of the principal amino acids is expected to improve performance.

Improvements in genetics and changes in management such as slaughter weight require that the amino acid requirements be reassessed periodically. The objective of this study was to examine response of pigs to variation in dietary lysine in several weight ranges with the concentrations of the other principal amino acids held constant.

Entire males had superior FCR to females in all trials except 15 to 30kg, but differences in dietary lysine requirements did not occur until the finishing stage. At heavier weights, response of male and female pigs began to diverge at lysine concentrations greater than 10.7 g/kg (ADG) and 9.7 g/kg (FCR).

There appeared to be a need to increase the threonine to lysine ratio in the diet from 0.60 to 0.70 when lysine concentration was reduced from 12.0 to 9.5 g/kg as weight of the pig increased.

Providing the same mean lysine content (11.1 g/kg) to pigs from 38 to 97 kg in a series of five diets declining in lysine concentration compared with a single diet did not affect performance, or reduce N excretion. However, lowering the overall mean lysine concentration from 11g/kg to 10.0 g/kg reduced overall N excretion by 13 %, without a negative effect on pig performance. Pigs which were offered a low lysine diet in the early stage of growth exhibited a compensatory response during realimentation on a high lysine diet but it was not sufficient to equal the overall performance of pigs previously offered a lysine-adequate diet. Nitrogen excretion was reduced by 23 %

while the low lysine diet was fed in the initial period but there was no residual effect on N excretion during realimentation.

2 Introduction

The optimum balance of amino acids (ideal protein) is essential if pigs are to grow well and have a high proportion of lean meat in the carcass. Use of commercially available crystalline amino acids allows the ideal protein to be delivered within a lower total protein and amino acid concentration. Less surplus protein in the diet results in a reduced excretion of nitrogen in manure and less dietary energy lost in deaminating the surplus protein. As slaughter weight has increased in Ireland there is a need to reassess the optimum level of amino acids and in particular lysine, which is the first limiting amino acid in barley-wheat based diets.

3 Experimental - Responses of growing pigs to lysine level in the diet

The objective of this series of experiments was to determine the optimum levels of dietary lysine for pigs in the weight ranges 15 to 30kg, 20 to 40kg, 40 to 60kg, 60 to 80kg and 80 to 100kg. Pigs penned in pairs were used in all weight ranges and commercial sized groups of 15 pigs were used in the weight ranges 40 to 60kg and 80 to 100kg.

Materials and methods

In total seven feeding trials were carried out, five using pairs of pigs and two trials using groups of 15 pigs. In each trial six or eight diets varying in concentration of lysine, crude protein, methionine, methionine plus cystine, threonine and tryptophan were fed. The lower levels of lysine were chosen to be below the estimated requirement of pigs in the weight range while the higher level were expected to be above the optimum (based on maximum daily gain and minimum FCR).

Diets were formulated to the desired lysine concentration using the BESTMIX 5.02 feed formulation programme (ADIFO, Maldegem, Belgium). Constraints in the formulation were that total lysine should be not more than 6.6% of crude protein (to ensure adequate

total protein intake) and that concentrations of methionine, methionine plus cystine, threonine and tryptophan should be at least 30%, 60%, 66% and 18% of the lysine concentration.

The ingredients used were barley and wheat, Hi-Pro soyabean meal, soya oil, dicalcium phosphate, limestone flour, salt, trace minerals, L-lysine hydrochloride, DL-methionine and L-threonine. The energy concentration of the diets was 14.0 MJ DE/kg for pigs of 15 to 30kg and 13.8 MJ DE/kg for all others. At each DE concentration net energy (NE) values changed as the protein concentration of the diet changed.

Feed was manufactured in the Moorepark mill and pelleted (5 mm die), after steam-heating to 55^{o}C. Barley and wheat were ground through a 3mm screen in a hammer mill before mixing.

Feed was provided *ad libitum* from stainless steel hopper type feeders 30 cm in length and water was available *ad libitum* from nipple-in-bowl drinkers (BALP, La Buvette, Charleville Nord, France) positioned away from the feeder.

3.1 Experiment 3.1. Response of pigs in the weight range 15 to 30kg to lysine concentration in the diet

The objective of this trial was to examine the response of pigs in the weight range 15 to 30kg to variation in the lysine concentration in the diet.

3.1.1 Materials and methods

This experiment involved 192 pigs in 96 pairs in a randomised complete block design. Pigs were weaned at 26 to 28 days of age and fed commercial starter and link feeds for 19 days after which the experimental diets were applied. One pair from each block were assigned at random at weaning to each of the following treatments:

A. Very low lysine diet (Diet 3.1.1 – 10.7g/kg total lysine)
B. Medium low lysine diet (Diet 3.1.2 – 11.6g/kg total lysine)
C. Low lysine diet (Diet 3.1.3 – 12.5g/kg total lysine)
D. High lysine diet (Diet 3.1.4 – 13.4g/kg total lysine)
E. Medium high lysine diet (Diet 3.1.5 – 14.3g/kg total lysine)
F. Very high lysine diet (Diet 3.1.6 – 15.3g/kg total lysine)

The diets fed in this experiment were as shown in Table 3.1.1.

Feed was provided *ad libitum* from stainless steel hopper type feeders 30 cm in length and water was available *ad libitum* from nipple-in-bowl drinkers (BALP, La Buvette, Charleville Nord, France) positioned away from the feeder.

Table 3.1.1. Composition of experimental diets, kg/tonne

	3.1.1	*3.1.2*	*3.1.3*	*3.1.4*	*3.1.5*	*3.1.6*
Barley	376	356	340	330	310	300
Wheat	376	356	340	330	310	300
Soya HiPro	197	240	274	295	338	360
Soya oil	27	24	22	21	18	16
Lysine HCl	2.6	2.4	2.4	2.8	2.6	3.0
DL-Methionine	0.5	0.7	0.8	1.2	1.3	1.6
L-Threonine	1.2	1.2	1.2	1.5	1.5	1.7
L-Tryptophan	0	0	0	0	0	0.2
DiCal Phosphate	3.1	2.8	2.6	2.5	2.3	0
Limestone flour	13	13	12	12	12	13
Salt feed	3	3	3	3	3	3
Vit-Min	1	1	1	1	1	1
Natuphos 5000	0.1	0.1	0.1	0.3	0.1	0.1
Total	1000	1000	1000	1000	1000	1000
Nutrient content						
DE, MJ/kg	14.0	14.0	14.0	14.0	14.0	14.0
NE, MJ/kg	10.1	10.0	9.9	9.8	9.7	9.6
Crude Protein, g/kg	175	191	204	213	229	239
Lysine, g/kg	10.7	11.6	12.5	13.4	14.3	15.3
Digestible LYS, g/kg	9.1	10.0	10.8	11.6	12.4	13.2
Dig. LYS, g/MJ DE	0.65	0.71	0.77	0.83	0.89	0.95
Dig. LYS, g/MJ NE	0.90	1.0	1.09	1.18	1.28	1.38

NE values are according to values for ingredients in Sauvant et al. (2002). True ileal digestible LYS values are from the CVB database (various years, 2001 to 2004).

3.1.2 Results

Results of experiment 3.1 are shown in Table 3.1.2. For the entire period from 15kg to c. 32kg, the highest daily feed intake and highest daily gain were achieved at the highest lysine level (15.3g/kg) though there was little difference between pig performance on the highest three lysine levels (13.4, 14.3 and 15.3g/kg). FCR was also similar on these three lysine levels.

3.1.3 Conclusion

The total lysine concentration of a diet for pigs from 15 to 32kg should be about 12.5g/kg or 10.8g/kg digestible lysine.

Table 3.1.2. Performance of pigs fed experimental diets

Diet	*3.1.1*	*3.1.2*	*3.1.3*	*3.1.4*	*3.1.5*	*3.1.6*	*Sem*	*Lin*	*Quad*
Lysine, g/kg	*10.7*	*11.6*	*12.5*	*13.4*	*14.3*	*15.3*			
Pig weights, kg									
Day 19	15.2	15.8	15.0	15.6	15.3	15.2	0.33	0.74	0.74
Day 33	22.2	22.8	22.7	23.7	23.8	24.0	0.25	**	**
Day 47	31.0	32.5	32.0	34.0	33.7	34.2	0.49	**	**
Period day 19 to 33									
Daily gain, g	492	536	527	600	600	620	17.3	**	**
Daily feed, g	934	889	912	896	920	926	23.6	0.85	0.85
Feed con. Ratio	1.93	1.67	1.74	1.51	1.59	1.50	0.058	**	**
Period day 33 to 47									
Daily gain, g	594	677	654	721	693	715	23.5	**	**
Daily feed, g	1175	1240	1275	1220	1176	1217	35.9	0.91	0.91
Feed con. Ratio	2.00	1.84	1.96	1.70	1.72	1.73	0.050	**	**
Period day 19 to 47									
Daily gain, g	548	607	590	661	647	668	16.2	**	**
Daily feed, g	1054	1070	1058	1062	1048	1072	26.1	0.90	0.90
Feed con. Ratio	1.95	1.76	1.80	1.61	1.64	1.61	0.042	**	**

[2] **P<0.05, **P<0.01, Lin=linear and Quad=quadratic effect of lysine concentration*

3.2 Experiment 3.2. Response of pigs in the weight range 20 to 40kg to lysine concentration in the diet

The objective of this trial was to examine the response of pigs in the weight range 20 to 40kg to variation in the lysine concentration in the diet.

3.2.1 Materials and methods

Ninety-six single sex (boars and gilts) pairs of pigs were arranged in blocks of six based on sex and initial weight. Initial weight was 20.8 ± 2.1 (sd) kg and final weight was 41.0 ± 4.3 (sd) kg. The pigs were penned in fully slatted pens (plastic slats, FAROEX, Manitoba, Canada), measuring 1.1m x 0.9m in rooms of 24 pens.

Pigs were weaned at 26 to 28 days of age and fed commercial starter feed (Startrite 88, Nutec Ltd, Monread Rd., Naas, Co. Kildare) and link feed (Vigour, Nutec Ltd, Monread Rd., Naas, Co. Kildare) for 19 days from weaning, and then fed a weaner diet (Diet 3.1.3 in Table 3.1.1) until 20kg, after which the experimental diets were applied. One pair from each block were assigned at random at weaning to each of the following six treatments:

A. Very low lysine diet (Diet 3.2.1 – 9.7g/kg total lysine)
B. Medium low lysine diet (Diet 3.2.2 – 10.7g/kg total lysine)
C. Low lysine diet (Diet 3.2.3 – 11.6g/kg total lysine)
D. High lysine diet (Diet 3.2.4 – 12.5g/kg total lysine)
E. Medium high lysine diet (Diet 3.2.5 – 13.5g/kg total lysine)
F. Very high lysine diet (Diet 3.2.6 – 14.4g/kg total lysine)

Table 3.2.1. Ingredient composition of experimental diets, g/kg (Experiment 2)

Diet number	*3.2.1*	*3.2.2*	*3.2.3*	*3.2.4*	*3.2.5*	*3.2.6*
Barley	404	384	364	345	327	306
Wheat	404	384	364	345	327	306
Soya HiPro	151	194	236	276	316	356
Soya oil	19	17	15	12	10	10
Lysine HCl	3	3	2	2	2	2
DL-Methionine	0.4	0.5	0.7	0.8	0.9	1.1
L-Threonine	1.2	1.2	1.2	1.2	1.2	1.2
Limestone flour	13	13	13	13	12	13
Salt feed	3	3	3	3	3	3
Vitamin-Mineral mix	1	1	1	1	1	1
Natuphos 5000[1]	0.1	0.1	0.1	0.1	0.1	0.1
Nutrient content g/kg						
DE, MJ/kg	13.8	13.8	13.8	13.8	13.8	13.8
NE, MJ/kg	10.0	9.9	9.8	9.7	9.6	9.5
Crude Protein	159	175	191	206	221	236
Total lysine	9.7	10.7	11.6	12.5	13.5	14.4
Digestible lysine	8.2	9.1	10.0	10.8	11.6	12.4
Dig. LYS, g/MJ DE	0.59	0.66	0.72	0.78	0.84	0.90
Dig. LYS, g/MJ NE	0.82	0.92	1.02	1.11	1.21	1.31

3.2.2 Results

The effects of dietary lysine concentration on performance is presented in Table 3.2.2. Dietary lysine content had a quadratic effect on ADG ($P<0.01$), which was highest for pigs fed the diet containing 12.5 g lysine/kg and lowest for those fed 9.7 g lysine/kg. There was no statistically significant improvement in FCR above a lysine concentration of 12.5 g/kg (Quadratic, $P<0.05$).

3.2.3 Conclusion

Diets for pigs in the weight range 20 to 40kg should contain about 12.5g/kg lysine (10.8g/kg digestible lysine) for maximum growth rate or higher for minimum FCR.

Table 3.2.2. Main effects of dietary lysine concentration and sex on growth performance of pairs of pigs from 20 to 40 kg (LSmeans and standard errors of means)

	Lysine concentration, g/kg							*Sex*[1]			*Significance*[2]		
	9.7	*10.7*	*11.6*	*12.5*	*13.5*	*14.4*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Daily gain, g/d	621	587	718	789	746	743	25.4	717	716	14.7	**	**	
Daily feed intake, g/d	1261	1338	1339	1354	1233	1266	37.5	1275	1322	21.6		*	
Feed conversion ratio, kg/kg	2.04	1.96	1.87	1.72	1.68	1.70	0.04	1.80	1.86	0.02	**	*	*

[1] *M=Male, F=Female pigs*

[2] **P<0.05, **P<0.01, Lin=linear and Quad=quadratic effect of lysine concentration*

3.2.4 Regression equations

Table 3.2.3 shows the regression equations used to describe the relationship between dietary lysine concentration and pig growth rate and FCR for experiment 3.2.

Table 3.2.3 Quadratic equations used to predict dietary lysine concentration required for maximum daily gain or minimum feed conversion ratio

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG	y = -1436(s.e. 589) + 336x(s.e. 98.8) – 12.85x^2(s.e. 4.09)	0.91	*	13.1
FCR	y = 4.77(s.e. 1.12) – 0.41x(s.e. 0.19) + 0.014x^2(s.e. 0.008)	0.95	*	14.6

[1] **P<0.05, **P<0.01*

[2] *Opt. x = optimum dietary lysine concentration*

3.3 Experiment 3.3. Response of pigs in the weight range 40 to 60kg to lysine concentration in the diet – pairs

The objective of this trial was to examine the response of pigs (penned in pairs) in the weight range 40 to 60kg to variation in the lysine concentration in the diet.

3.3.1 Materials and methods

Sixty single sex pairs of pigs were arranged in blocks of five according to sex and weight. Initial weight was 41.8 ± 3.3 (sd) kg and final weight was 68.0 ± 4.7 (sd) kg. Pigs were penned in fully slatted pens (concrete slats, 80 mm wide with 20 mm slot), measuring 1.4 m x 1.2 m, in rooms of 18 pens.

One pair from each block were assigned to each of the following five treatments in a randomised complete block design:

A. Very low lysine diet (Diet 3.3.1 – 9.0g/kg total lysine)
B. Medium low lysine diet (Diet 3.3.2 – 9.9g/kg total lysine)
C. Low lysine diet (Diet 3.3.3 – 12.1g/kg total lysine)
D. High lysine diet (Diet 3.3.4 – 13.1g/kg total lysine)

E. Medium high lysine diet (Diet 3.3.5 – 14.1g/kg total lysine)

Composition of the diets is shown in Table 3.3.1. A treatment with 11g/kg total lysine had to be omitted due to an error in the formulation.

3.3.2 Results

Table 3.3.2 shows the effect of increasing dietary lysine concentration on the liveweight growth performance of growing pigs from 40 to 68 kg housed in pairs. Increasing lysine concentration above 12.1 g/kg did not improve FCR (Quadratic, $P<0.05$). Male pigs had better FCR than female pigs ($P<0.01$), and a lower daily feed intake ($P<0.01$).

3.3.3 Conclusion

Diets for pigs in the weight range 40 to 60kg should contain about 12.1g/kg lysine (10.4g/kg digestible lysine) for maximum growth rate and minimum FCR.

Table 3.3.1. Ingredient composition of diets, g/kg (Experiment 3)

Diet	*3.3.1*	*3.3.2*	*3.3.3*	*3.3.4*	*3.3.5*
Barley	427	409	369	348	327
Wheat	427	409	369	348	327
Soya HiPro	112	149	233	273	314
Soya oil	16	15	10	10	10
Lysine HCl	3	3	3	3	3
DL-Methionine	0.5	0.5	0.6	0.8	0.9
L-Threonine	1.1	1.1	1.2	1.2	1.2
Limestone flour	10	10	10	11	12
Salt feed	3	3	3	3	3
Vitamin-Mineral mix	1	1	1	1	1
Natuphos 5000[1]	0.1	0.1	0.1	0.1	0.1
Nutrient content, g/kg					
DE, MJ/kg	13.8	13.8	13.8	13.8	13.8
NR, MJ/kg	10.1	10.0	9.8	9.7	9.6
Crude Protein	145	159	191	206	221
Total lysine	9.0	9.9	12.1	13.1	14.1
Digestible Lysine	7.6	8.5	10.4	11.3	12.2
Dig. LYS, g/MJ DE	0.55	0.61	0.75	0.82	0.89
Dig. LYS, g/MJ DE	0.75	0.84	1.07	1.17	1.28

Table 3.3.2. Main effects of dietary lysine concentration and sex on growth performance of pairs of pigs from 40 to 68 kg (LSmeans and standard errors of means)

	Lysine concentration, g/kg						*Sex*[1]			*Significance*[2]		
	9.0	*9.9*	*12.1*	*13.1*	*14.1*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Daily gain, g/d	903	939	963	968	960	23.8	952	941	15.1	0.07		
Daily feed intake, g/d	2025	1967	1852	1967	1948	41.6	1890	2004	26.3		0.06	**
Feed conversion ratio, kg/kg	2.25	2.10	1.99	2.05	2.06	0.05	2.01	2.17	0.03	**	*	**

[1] *M=Male, F=Female pigs*

[2] **P<0.05, **P<0.01, Lin=linear and Quad=quadratic effect of lysine concentration*

3.3.4 Regression equations

Table 3.3.3 shows the regression equations used to describe the relationship between dietary lysine concentration and pig growth rate and FCR. The relationship for males and females is graphically illustrated in figure 3.3.1.

Table 3.3.3. Quadratic equations used to predict dietary lysine concentration required for maximum daily gain or minimum feed conversion ratio

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG	y = 230(s.e. 133) + 116x(s.e. 23.8) – 4.60x^2(s.e. 1.03)	0.98	*	12.7
FCR	y = 5.42(s.e. 0.73) – 0.56x(s.e. 0.13) + 0.023x^2(s.e. 0.006)	0.95	*	12.2

[1] **P<0.05,*

[2] *Opt. x = optimum dietary lysine concentration*

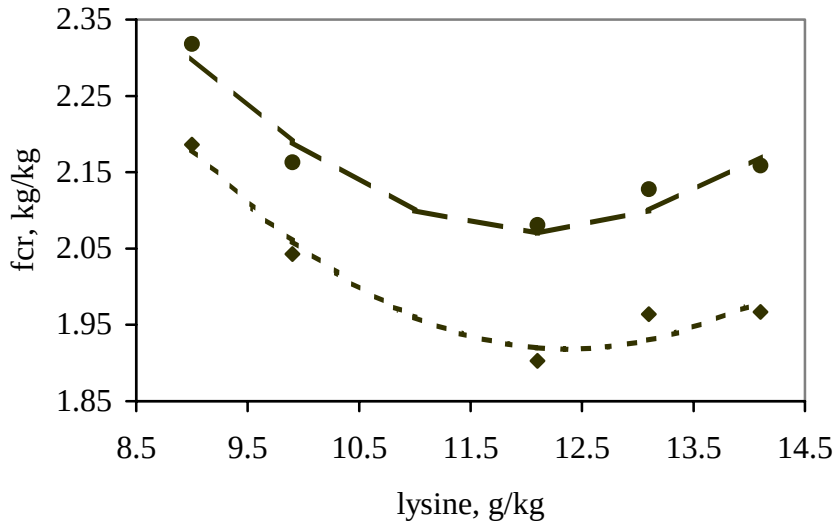

Figure 3.3.1. Quadratic response curves fitted to observed values of FCR of male (-♦-) and female (-●-) pigs (40-68 kg pairs)

Regression equations: Males: $y = 5.40\ (0.76) - 0.56x\ (0.14) + 0.023x^2\ (0.006)$, $R^2 = 0.96$, $P<0.05$; **Females**: $y = 5.46\ (0.73) - 0.56x\ (0.13) + 0.023x^2\ (0.006)$ $R^2 = 0.94$, $P=0.06$. Each point represents the mean of six pairs of pigs. Optimum lysine concentration was 12.2 g/kg for both male and female pigs.

3.4 Experiment 3.4. Response of pigs in the weight range 40 to 60kg to lysine concentration in the diet - groups

The objective of this trial was to examine the response of pigs in the weight range 40 to 60kg to variation in the lysine concentration in the diet.

3.4.1 Materials and methods

Forty-two single sex groups of 14 crossbred pigs (meatline sires x (Large White x Landrace) dams) of similar weight (40.4 ± 2.3 (sd) kg) were formed into seven blocks of six. Final weight was 62.3 ± 4.1 (sd) kg. Pens measured 4.8m x 2.4m and were fully slatted (concrete slats 80 mm wide with 20 mm slot). The diets fed were those used in Experiment 3.3 and the composition is shown in Table 3.3.1.

3.4.2 Results

Table 3.4.1 shows the effect of increasing dietary lysine concentration on the liveweight growth performance of growing pigs from 40 to 62 kg housed in groups.

Increasing dietary lysine concentration resulted in a quadratic effect on FCR, with no further improvement in FCR above 12.1 g lysine/kg ($P<0.05$). Male pigs had better FCR than female pigs ($P<0.05$).

3.4.3 Regression equations

Table 3.4.2 shows the regression equations used to describe the relationship between dietary lysine concentration and pig growth rate and FCR for experiment 3.4. The relationship for males and females is graphically illustrated in figure 3.4.1.

Table 3.4.1. Main effects of dietary lysine concentration and sex on growth performance of groups of pigs from 40 to 60 kg (LSmeans and standard errors of means)

	Lysine concentration, g/kg						*Sex*[1]			*Significance*[2]		
	9.0	*9.9*	*12.1*	*13.1*	*14.1*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Daily gain, g/d	781	840	833	792	789	30.4	801	814	19.2			
Daily feed intake, g/d	1971	1975	1922	1837	1850	73.3	1868	1953	46.4			
Feed conversion ratio, kg/kg	2.52	2.44	2.31	2.32	2.34	0.04	2.34	2.45	0.03	**	*	*

[1] *M=Male, F=Female pigs*

[2] **P<0.05, **P<0.01, Lin=linear and Quad=quadratic effect of lysine concentration*

Table 3.4.2. Quadratic equations used to predict dietary lysine concentration required for maximum daily gain or minimum feed conversion ratio

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG	y = -161(s.e. 558) + 175x(s.e. 99.5) – 7.76x^2(s.e. 4.32)	0.63	0.37	11.3
FCR	y = 4.78(s.e. 0.21) – 0.38x(s.e. 0.04) + 0.015x^2(s.e. 0.002)	0.99	**	12.7

[1] ***P<0.01*

[2] *Opt. x = optimum dietary lysine concentration*

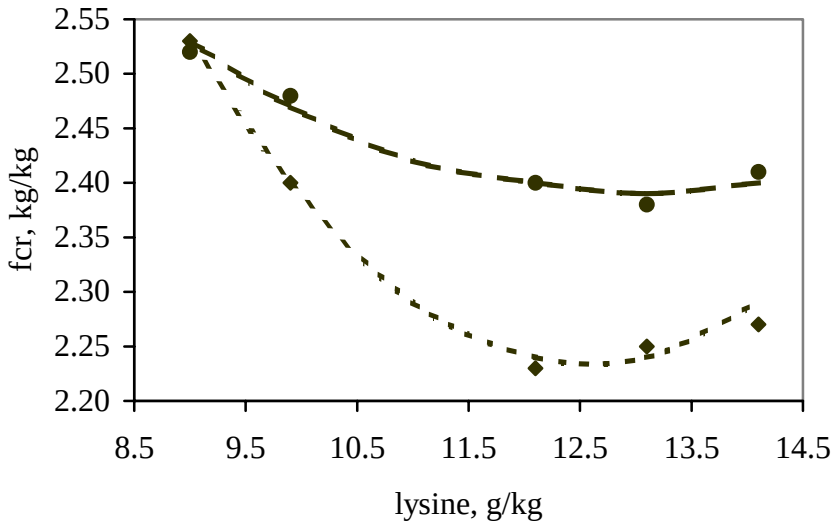

Figure 3.4.1. Quadratic response curves fitted to observed values of FCR of male (-♦-) and female (-●-) pigs (40-60 kg groups)

Regression equations: Males: y = 5.88 (0.25) – 0.58x (0.05) + 0.023x^2 (0.002), R^2 = 0.99, P<0.01; **Females**: *y = 3.85 (0.29) – 0.23x (0.05) + 0.009x^2 (0.002), R^2 = 0.98, P<0.05.* Each point represents the mean of four (male) or three (female) groups of pigs. Optimum lysine concentration was 12.6 and 12.8 g/kg for male and female pigs respectively.

3.5 Experiment 3.5. Response of pigs in the weight range 60 to 90kg to lysine concentration in the diet - pairs

The objective of this trial was to examine the response of pigs in the weight range 60 to 90kg penned in pairs to variation in the lysine concentration in the diet.

3.5.1 Materials and methods

Ninety pairs of pigs were arranged into fifteen blocks (based on sex and weight) and allocated to one of six treatments. Initial weight was 60 ± 3.2 kg and final weight was 91 ± 5.2 kg. Pigs were on trial for an average of 33.7 ± 5.6 days. Pens were fully slatted (concrete slats, 80 mm wide with 20 mm slot), and measured 1.4 m x 1.2 m with eighteen pens per room.

Pigs were allocated to the following treatments in an RCB design.

A. Very low lysine diet (Diet 3.5.1 – 7.9g/kg total lysine)
B. Medium low lysine diet (Diet 3.5.2 – 8.8g/kg total lysine)
C. Low lysine diet (Diet 3.5.3 – 9.7g/kg total lysine)
D. High lysine diet (Diet 3.5.4 – 10.7g/kg total lysine)
E. Medium high lysine diet (Diet 3.5.5 – 11.7g/kg total lysine)
F. Very high lysine diet (Diet 3.5.6 – 12.5g/kg total lysine)

Composition of the diets is shown in Table 3.5.1.

Table 3.5.1. Ingredient composition of experimental diets, g/kg

Diet identity	*3.5.1*	*3.5.2*	*3.5.3*	*3.5.4*	*3.5.5*	*3.5.6*
Barley	440	421	404	384	364	345
Wheat	440	421	404	384	364	345
Soya HiPro	75	114	151	194	236	276
Soya oil	24	22	19	17	15	12
Lysine HCl	3	3	3	3	3	2
DL-Methionine	0.2	0.3	0.4	0.5	0.7	0.8
L-Threonine	1.2	1.2	1.2	1.2	1.2	1.2
Limestone flour	14	13	13	13	13	13
Salt feed	3	3	3	3	3	3
Vitamin-Mineral mix	1	1	1	1	1	1
Di Cal Phosphate	0.3	0.05	0	0	0	0
Natuphos 5000[1]	0.1	0.1	0.1	0.1	0.1	0.1
Nutrient content						
D.E., MJ/kg	13.8	13.8	13.8	13.8	13.8	13.8
N.E., MJ/kg	10.2	10.1	10.0	9.9	9.8	9.7
Crude Protein, g/kg	130	145	159	175	191	206
Total lysine, g/kg	7.9	8.8	9.7	10.7	11.7	12.5
Dig. LYS., g/kg	6.6	7.5	8.2	9.1	9.8	10.8
Dig. LYS, g/MJ DE	0.48	0.54	0.59	0.66	0.72	0.78
Dig. LYS, g/MJ NE	0.65	0.74	0.82	0.92	1.02	1.12

[1] *Phytase: Natuphos – BASF; 5000 FTU/gm equal to 500 FTU per kg finished feed*

3.5.2 Results

Main effects of lysine concentration and sex in Experiment 3.5 are shown in Table 3.5.2.

Table 3.5.2. Main effects of dietary lysine concentration and sex on liveweight growth performance of pairs of pigs from 60 to 90 kg (LSmeans and standard errors of means)

	Dietary lysine concentration, g/kg							*Sex*			*Significance*[1]		
Liveweight performance	*7.9*	*8.8*	*9.7*	*10.7*	*11.7*	*12.5*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Days	35.5	34.0	33.5	32.6	34.2	32.7	1.36	32.3	35.2	0.79			*
Daily gain, g/d	849	919	948	980	953	935	27.0	993	869	15.6	*	**	***
Daily feed intake, g/d	2348	2423	2353	2427	2287	2403	64.5	2405	2343	37.2			
Feed conversion ratio, kg/kg	2.78	2.66	2.53	2.42	2.39	2.56	0.05	2.44	2.68	0.03	***	***	***
Daily lysine intake, g/d	18.6	21.3	22.8	26.0	26.8	30.0	0.66	24.5	24.0	0.39	***		
Lysine conversion ratio, g/kg	21.9	23.4	24.6	26.8	28.8	32.0	0.70	25.0	27.5	0.42	***	0.08	***
Carcass characteristics													
Cold weight, kg	69.5	70.0	70.0	69.0	68.9	69.2	0.41	69.0	70.0	0.24			**
Lean content, g/kg	592	591	592	595	598	593	2.18	590	597	1.26			***
Fat depth, mm	10.8	11.0	10.8	10.6	9.9	10.6	0.30	10.9	10.4	0.17	0.06		*
Muscle depth, mm	54.8	55.2	54.8	55.4	53.5	54.1	0.98	53.6	55.7	0.57			**
Kill-out, g/kg	766	766	762	758	758	763	2.82	756	768	1.63	0.06		***

[1] *Lin = linear, Quad = quadratic *P<0.05, **P<0.01, ***P<0.001*

3.5.3 Regression equations

Table 3.5.3 shows the regression equations used to describe the relationship between dietary lysine concentration and pig growth rate and FCR for experiment 3.5. These relationships are graphically illustrated in figure 3.5.1.

Table 3.5.3. Quadratic regression equations used to predict optimum dietary lysine concentration for maximum ADG or minimum FCR

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG, g/d	$y = -698\ (167.2) + 309x\ (33.3) - 14.3x^2\ (1.629)$	0.98	**	10.8
FCR, kg/kg	$y = 7.14\ (1.09) - 0.85x\ (0.22) + 0.039x^2\ (0.011)$	0.92	*	10.9

[1] *Significance level * P<0.05, ** P<0.01*

[2] *Opt. x = optimum dietary lysine concentration for maximum ADG or minimum FCR*

Table 3.5.4 Regression equations used to predict daily lysine intake for maximum daily gain[1]

	Regression equation	R^2	*Sig.*[2]	*Opt. x, g/d*[3]	*Max. ADG*[4]
Exp. 3.5 Boars	$y = -797\ (415) + 139.8x\ (34.2) - 2.67x^2\ (0.69)$	0.91	*	26.2	1034
Exp. 3.5 Gilts	$y = -329\ (122) + 96.3x\ (10.4) - 1.88x^2\ (0.22)$	0.98	**	25.6	904

[1] *M = male pairs, F = female pairs*

[2] *Significance level *P<0.05, **P<0.01*

[3] *Opt. x = optimum daily lysine intake for maximum ADG*

[4] *ADG = g/d*

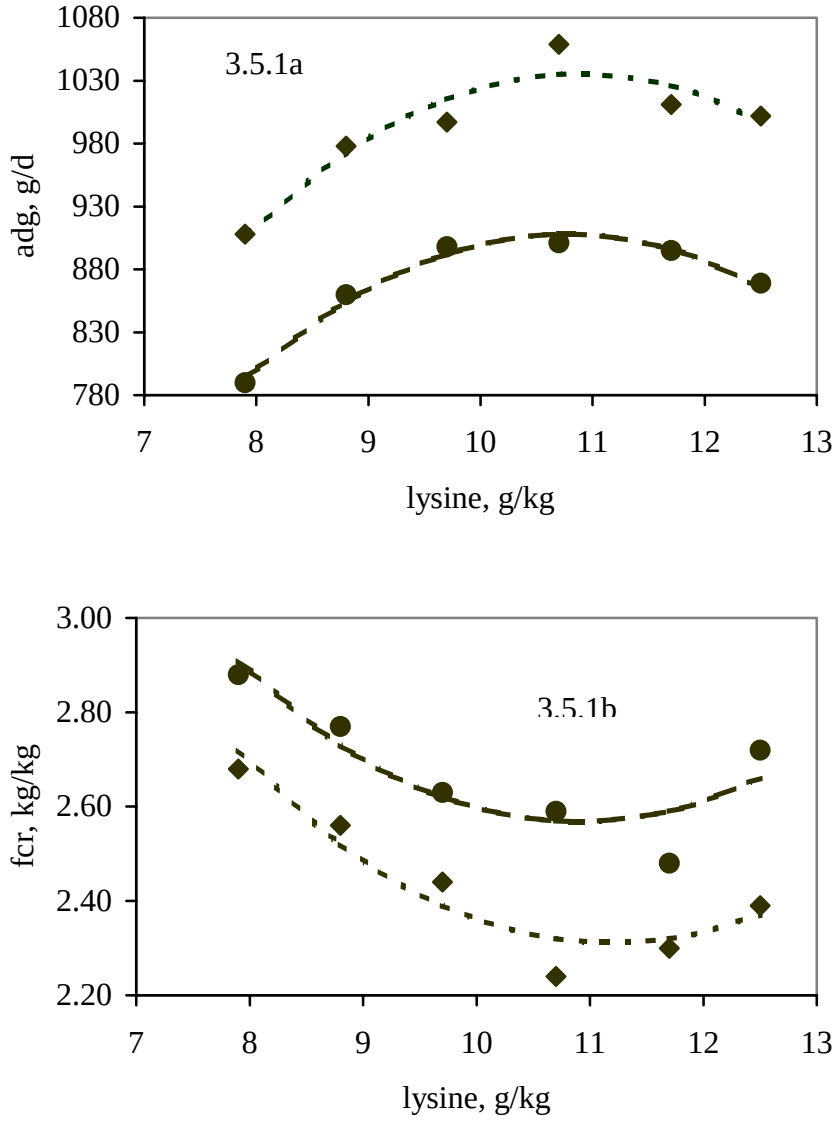

Figure 3.5.1 a and b. **Quadratic response curves fitted to observed values of ADG and FCR of boars (-♦-) and gilts (-●-) (60-90 kg pairs)**

Regression equations: Boars ADG: y = -663 (398.3) + 312.1x (79.4) – 14.34x^2 (3.88), R^2 = 0.90, P<0.05, optimum lysine concentration = 10.9 g/kg; **Gilts** ADG: y = -715 (135.5) + 301.8x (27.0) – 14.03x^2 (1.32), R^2 = 0.98, P<0.01, optimum lysine concentration = 10.8 g/kg; **Boars** FCR: y = 7.03 (1.24) – 0.84x (0.25) + 0.038x^2 (0.012), R^2 = 0.91, P<0.05, optimum lysine concentration = 11.1 g/kg; **Gilts** FCR: y = 7.16 (1.56) – 0.84x (0.31) + 0.039x^2 (0.015), R^2 = 0.82, P=0.08, optimum lysine concentration = 10.8 g/kg.

3.6 Expt 3.6. Response of pigs in the weight range 80 to 100kg to lysine concentration in the diet - pairs

The objective of this trial was to examine the response of pigs in the weight range 80 to 100kg penned in pairs to variation in the lysine concentration in the diet.

3.6.1 Materials and methods

One hundred and forty four pairs of pigs were allotted to eight treatments in an RCB design. Initial weight was 81 ± 3.8 kg and final weight was 102 ± 4.0 kg. Pigs were on trial for 24.4 ± 4.8 days. Housing and management of the pigs were as used in Experiment 3.5.

Treatments were:

A. Very low lysine diet (Diet 3.6.1 – 7.0g/kg total lysine)
B. Medium low lysine diet (Diet 3.6.2 – 7.9g/kg total lysine)
C. Low lysine diet (Diet 3.6.3 – 8.8g/kg total lysine)
D. High lysine diet (Diet 3.6.4 – 9.7g/kg total lysine)
E. Medium high lysine diet (Diet 3.6.5 – 10.7g/kg total lysine)
F. Very high lysine diet (Diet 3.6.6 – 11.7g/kg total lysine)
G. Medium high lysine diet (Diet 3.6.7 – 12.5g/kg total lysine)
H. Very high lysine diet (Diet 3.6.8 – 13.5g/kg total lysine)

Table 3.6.1. Ingredient composition of experimental diets, g/kg

Diet identity	*3.6.1*	*3.6.2*	*3.6.3*	*3.6.4*	*3.6.5*	*3.6.6*	*3.6.7*	*3.6.8*
Barley	458	440	421	404	384	364	345	327
Wheat	458	440	421	404	384	364	345	327
Soya HiPro	35	75	114	151	194	236	276	316
Soya oil	26	24	22	19	17	15	12	10
Lysine HCl	3	3	3	3	3	3	2	2
DL-Methionine	0.2	0.2	0.3	0.4	0.5	0.7	0.8	0.9
L-Threonine	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Limestone flour	14	14	13	13	13	13	13	13
Salt feed	3	3	3	3	3	3	3	3
Vitamin-Mineral mix	1	1	1	1	1	1	1	1
Di Cal Phosphate	0.5	0.3	0.05	0	0	0	0	0
Natuphos 5000[1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nutrient content g/kg								
DE, MJ/kg	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
NE, MJ/kg	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6
Crude Protein	115	130	145	159	175	191	206	221
Total lysine	7.0	7.9	8.8	9.7	10.7	11.7	12.5	13.5
Digestible lysine	5.8	6.6	7.4	8.2	9.1	9.8	10.8	11.6
Digestible LYS, g/MJ DE	0.42	0.48	0.54	0.60	0.66	0.72	0.78	0.84
Digestible LYS, g/MJ NE	0.56	0.65	0.74	0.82	0.92	1.02	1.12	1.22

[1] *Phytase: Natuphos – BASF; 5000 FTU/gm equal to 500 FTU per kg finished feed*

3.6.2 Results

Results of experiment 3.6 are shown in Table 3.6.2. Males grew faster ($P<0.05$) and more efficiently ($P<0.01$) than females while females had leaner carcasses ($P<0.05$).

3.6.3 Conclusions

Males grew faster and more efficiently than females on similar feed intake. Growth rate was maximised at 11.7g/kg lysine. Feed conversion ratio was similar from 9.7 to 12.5 g/kg lysine.

Table 3.6.2. Main effects of dietary lysine concentration and sex on liveweight growth performance of pairs of pigs from 80 to 100 kg (LSmeans and standard errors of means)

	Dietary lysine concentration, g/kg									*Sex*			*Significance*[1]		
	7.0	*7.9*	*8.8*	*9.7*	*10.7*	*11.7*	*12.5*	*13.5*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Days	21.9	23.9	25.4	24.9	23.5	24.7	24.5	25.6	0.90	23.5	25.1	0.45		0.07	*
Daily gain, g/d[2]	770	883	904	883	905	922	784	759	21.0	950	800	10.5	***	*	***
Daily feed intake, g/d	2469	2408	2547	2402	2525	2505	2398	2394	56.9	2481	2431	28.5			
Feed conversion ratio, kg/kg[3]	3.25	2.87	2.86	2.78	2.84	2.79	2.77	2.89	0.07	2.64	3.12	0.04	***	**	***
Carcass characteristics															
Cold weight, kg	78.3	78.3	78.8	78.2	78.3	78.3	78.4	78.6	0.29	77.7	79.1	0.14			***
Lean content, g/kg	588	592	594	601	600	596	592	595	2.26	592	597	1.13	***	*	**
Fat depth, mm	11.7	11.3	11.1	10.4	10.4	10.7	11.2	10.9	0.29	11.1	10.8	0.15	**		
Muscle depth, mm	56.5	57.5	57.5	58.4	57.6	57.0	56.7	57.3	0.95	56.4	58.3	0.48			**
Kill-out, g/kg	772	768	769	767	769	767	771	771	2.74	762	777	1.37			***

*[1] Lin = linear, Quad = quadratic *P<0.05, **P<0.01, ***P<0.00, [2] Treatment x sex interaction, P<0.01, [3] Treatment x sex interaction, P<0.05, [4] Treatment x sex interaction, P<0.01*

Table 3.6.3. Quadratic regression equations used to predict optimum dietary lysine concentration for maximum ADG or minimum FCR

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG Boar, g/kg	$y = -24.3\ (377.2) + 171x\ (76.0) - 7.2x^2\ (3.69)$	0.78	*	11.8
ADG Gilt, g/kg	$y = -25.1\ (323.2) + 175x\ (65.1) - 8.8x^2\ (3.17)$	0.64	0.08	9.9
FCR Boar	$y = 6.26\ (1.44) - 0.64x\ (0.29) + 0.027x^2\ (0.014)$	0.76	*	11.9
FCR Gilt	$y = 5.33\ (0.54) - 0.46x\ (0.11) + 0.023x^2\ (0.005)$	0.79	*	10.0

[1] *Significance level * P<0.05,*

[2] *Opt. x = optimum dietary lysine concentration for maximum ADG or minimum FCR*

Table 3.6.4 Regression equations used to predict daily lysine intake for maximum daily gain[1]

	Regression equation	R^2	*Sig.*[2]	*Opt. x, g/d*[3]	*Max. ADG*[4]
Exp. 3.6 Boars	$y = -79\ (370) + 73.5x\ (29.8) - 1.24x^2\ (0.58)$	0.79	*	29.6	1008
Exp. 3.6 Gilts	$y = -259\ (431) + 94.3x\ (37.5) - 2.00x^2\ (0.79)$	0.57	ns	23.6	854

[1] *M = male pairs, F = female pairs*

[2] *Significance level *P<0.05, **P<0.01*

[3] *Opt. x = optimum daily lysine intake for maximum ADG*

[4] *ADG = g/d*

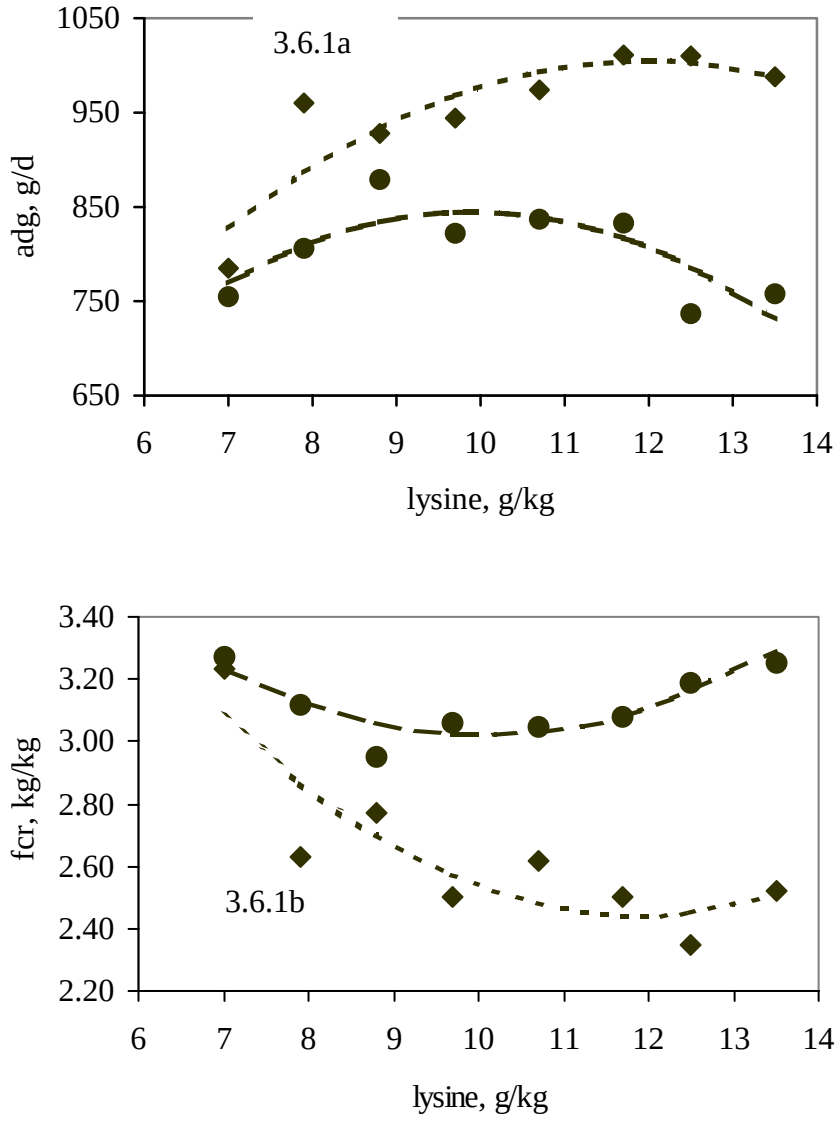

Figure 3.6.1 a and b. Quadratic response curves fitted to observed values of ADG and FCR of boars (-♦-) and gilts (-●-) (80-100 kg pairs)

Regression equations: Boars ADG: y = -24.3 (377.2) + 171.9x (76.0) – 7.18x^2 (3.69), R^2 = 0.78, P<0.05, optimum lysine concentration = 11.8 g/kg; **Gilts** ADG: y = -25.1 (323.2) + 175.4x (65.1) – 8.84x^2 (3.17), R^2 = 0.64, P=0.08, optimum lysine concentration = 9.9 g/kg; **Boars** FCR: y = 6.26 (1.44) – 0.64x (0.29) + 0.027x^2 (0.014), R^2 = 0.76, P<0.05, optimum lysine concentration = 11.9 g/kg; **Gilts** FCR: y = 5.33

(0.54) – 0.46x (0.11) + 0.023x^2 (0.005), R^2 = 0.79, P<0.05, optimum lysine concentration = 10.0 g/kg.

3.7 Experiment 3.7. Response of pigs in the weight range 80 to 100kg to lysine concentration in the diet - groups

The objective of this trial was to examine the response of pigs in the weight range 80 to 100kg penned in groups to variation in the lysine concentration in the diet.

3.7.1 Materials and Methods

Groups of 13 pigs (n=42) were arranged into seven blocks and allocated to one of six treatments. Initial weight (pen average) was 80 ± 3.2 kg and final weight was 99 ± 2.4 kg. This trial lasted for 23.9 ± 4.1 days. Pens measured 4.8 m x 2.4 m and were fully slatted (80 mm wide concrete slats with 20 mm slot).

Groups were allocated to the following six treatments in an RCB design.
Treatments were:

A. Very low lysine diet (Diet 3.6.1 – 7.0g/kg total lysine)
B. Medium low lysine diet (Diet 3.6.2 – 7.9g/kg total lysine)
C. Low lysine diet (Diet 3.6.3 – 8.8g/kg total lysine)
D. High lysine diet (Diet 3.6.4 – 9.7g/kg total lysine)
E. Medium high lysine diet (Diet 3.6.5 – 10.7g/kg total lysine)
F. Very high lysine diet (Diet 3.6.6 – 11.7g/kg total lysine)

The diets fed were those also fed in Experiment 3.6 and shown in Table 3.6.1.

Table 3.7.1. Main effects of dietary lysine concentration and sex on liveweight growth performance of groups of pigs from 80 to 100 kg (LSmeans and standard errors of means)

	Dietary lysine concentration, g/kg							*Sex*			*Significance*		
	7.0	*7.9*	*8.8*	*9.7*	*10.7*	*11.7*	*s.e.*	*M*	*F*	*s.e.*	*Lin*	*Quad*	*Sex*
Days	26.0	25.7	22.7	22.0	24.0	23.3	0.83	23.3	24.6	0.48	**	*	0.07
Daily gain, g/d	768	817	870	880	804	755	33.3	882	750	19.2		**	***
Daily feed intake, g/d	2576	2486	2616	2451	2428	2453	90.0	2494	2509	52.0			
Feed conversion ratio, kg/kg	3.37	3.19	2.95	2.91	3.05	3.19	0.08	2.92	3.30	0.05	0.06	***	***
Carcass characteristics													
Cold weight, kg	78.0	78.2	77.0	77.0	77.4	77.1	0.45	76.7	78.3	0.26			***
Lean content, g/kg	585	591	594	592	598	596	1.88	592	594	1.09	***		
Fat depth, mm	11.8	11.1	10.8	11.0	10.4	10.6	0.27	11.0	10.9	0.15	**		
Muscle depth, mm	55.8	56.1	56.2	55.7	56.3	56.2	0.84	55.6	56.6	0.49			
Kill-out, g/kg	783	784	777	780	782	780	3.57	774	788	2.06			***

[1] *Lin = linear, Quad = quadratic *P<0.05, **P<0.01, ***P<0.001*

Table 3.7.2. Quadratic regression equations used to predict optimum dietary lysine concentration for maximum ADG or minimum FCR

	Regression equation	R^2	*Sig.*[1]	*Opt. x, g/kg*[2]
ADG	$y = -864\ (293.6) + 374x\ (64.1) - 20.2x^2\ (3.42)$	0.92	*	9.3
FCR	$y = 8.87\ (0.79) - 1.23x\ (0.17) + 0.064x^2$ (0.009)	0.95	*	9.6

[1] *Significance level * P<0.05*

[2] *Opt. x = optimum dietary lysine concentration for maximum ADG or minimum FCR*

Table 3.7.3 Regression equations used to predict daily lysine intake for maximum daily gain

	Regression equation	R^2	*Sig.*[2]	*Opt. x, g/d*[3]	*Max. ADG*[3]
Boars	$y = -1109\ (359) + 170.6x\ (31.1) - 3.55x^2\ (0.66)$	0.91	*	24.0	939
Gilts	$y = -1279\ (621) + 187.4x\ (54.9) - 4.22x^2\ (1.19)$	0.84	0.07	22.2	799

[1] *Significance level *P<0.05*

[2] *Opt. x = optimum daily lysine intake for maximum ADG*

[3] *ADG = g/d*

4 Response of growing pigs to phase feeding of diets of decreasing amino acid concentration

4.1 Experiment 4.1. Effect of feeding decreasing levels of protein and amino acids with a declining lysine: DE ratio on the performance of grower-finisher pigs

As pigs mature, their requirement for nutrients declines. If a single diet is fed throughout the growing-finishing period then nutrients will be either under- supplied in the early stage or over-supplied in the later stages of growth. Phase feeding a sequence of diets decreases the amount of over- or under-supply. Campbell et al. (1988) demonstrated that feeding a continually declining dietary protein and lysine concentration as live weight increases can lead to an increase in efficiency.

The objective of this experiment was to test the hypothesis that feeding a decreasing level of protein and amino acids with a declining lysine: DE ratio will have no adverse effect on performance of growing-finishing pigs.

4.1.1 Materials and Methods

Thirty-six pigs (18 males and 18 females), crossbred progeny of meatline sires out of F1 (i.e. Landrace * Large White) sows were used. Initial weight was 31.6 ± 3.4 kg, final weight was 98.6 ± 4.9 kg, with carcass weight of 74.8 ± 4.3 kg. Pigs were blocked (12 blocks of 3) on the basis of sex and weight and assigned at random to one of three treatments: high lysine sequence (HL), medium lysine sequence (ML) and low lysine sequence (LL) (Table 4.1.1). As lysine levels were decreased, the protein content and other amino acids also decreased, while DE content remained constant (13.5 MJ/kg). Diets were formulated from wheat, barley and soyabean meal with minerals, vitamins and synthetic amino acids. Ratios of methionine, methionine plus cystine and threonine to lysine were maintained at minima of 0.30, 0.60 and 0.65, respectively. Composition of the diets is shown in Table 4.1.2. Phases were sequential with phases 1 and 2 lasting 21 days each and phase 3 continuing until

slaughter (36 ± 6.5 days). Pigs were penned individually in fully slatted concrete pens (1.4 m * 1.2 m) in temperature controlled rooms of 18 pens. Carcass lean, backfat depth and muscle depth were measured on the hot carcasses by the Hennessy Grading Probe.

Statistical analysis was by the GLM procedure of SAS Inc., Cary, N. Carolina for a randomised complete block design with single degree of freedom comparisons to compare HL with ML and HL with LL.

Table 4.1.1. Dietary treatments in experiment 4.1

	HL	*ML*	*LL*
Phase 1			
Diet number	*4.1.1*	*4.1.2*	*4.1.3*
Crude Protein, g/kg	173	165	157
Lysine conc., g/kg	11.5	11.0	10.5
Lysine:DE, g/MJ	0.84	0.81	0.77
Phase 2			
Diet number	*4.1.2*	*4.1.3*	*4.1.4*
Crude Protein, g/kg	165	157	149
Lysine conc., g/kg	11.0	10.5	10.0
Lysine:DE, g/MJ	0.81	0.77	0.74
Phase 3			
Diet number	*4.1.3*	*4.1.4*	*4.1.5*
Crude Protein, g/kg	157	149	142
Lysine conc., g/kg	10.5	10.0	9.5
Lysine:DE, g/MJ	0.77	0.74	0.70

Table 4.1.2. Composition of experimental diets, kg/tonne

	Diet 4.1.1	*Diet 4.1.2*	*Diet 4.1.3*	*Diet 4.1.4*	*Diet 4.1.5*
Barley	362.5	383.5	402.8	422.9	441.2
Wheat	404	404	404	404	404
Soya Hi-Pro	200	179	160	140	122
Fat lard	10	10	10	10	10
Lysine Synthetic	3.7	3.7	3.7	3.7	3.7
Methionine Synthetic	0.9	0.9	0.7	0.6	0.5
Threonine	1.8	1.8	1.7	1.7	1.5
Limestone Flour	13	13	13	13	13
Salt	3	3	3	3	3
Vit-Mins	1	1	1	1	1
Natuphos	0.1	0.1	0.1	0.1	0.1
Total	**1000**	**1000**	**1000**	**1000**	**1000**
Nutrient content g/kg					
DE, MJ/kg	13.7	13.6	13.6	13.5	13.5
NE, MJ/kg	9.4	9.4	9.4	9.4	9.5
Crude Protein	173	165	157	149	142
Total lysine	11.5	11.0	10.5	10.0	9.5
Digestible lysine	10.1	9.6	9.1	8.7	8.3
Digestible LYS, g/MJ DE	0.74	0.71	0.67	0.64	0.61
Digestible LYS, g/MJ NE	1.07	1.02	0.97	0.93	0.87

4.1.2 Results and Discussion

Results are shown in Table 4.1.3. There were no significant differences between HL and ML treatments for any of the performance and carcass traits measured. HL pigs tended to have better average daily gain and carcass average daily gain ($P = 0.08$, $P = 0.09$) than LL. Carcass feed conversion efficiency was also significantly better for HL ($P < 0.05$) than LL pigs. No other significant differences were observed between these treatments.

Table 4.1.3. Effect of treatment on performance in Experiment 4.1

	HL	*ML*	*LL*	*s.e.*	*P-values*[1]		
					Overall	*HL vs ML*	*HL vs LL*
Average daily liveweight gain, g	882	884	823	23.1	0.12	0.94	0.08 +
Average daily feed intake, g	2227	2293	2209	78.4	0.73	0.56	0.87
Feed conversion ratio, kg/kg	2.54	2.60	2.70	0.08	0.36	0.56	0.16
Lean meat, %	60.7	59.6	59.9	0.47	0.26	0.11	0.25
Fat depth, mm	9.5	10.7	10.9	0.57	0.19	0.15	0.10 +
Muscle depth, mm	55.4	54.7	56.5	1.37	0.67	0.73	0.59
Carcass average daily gain, g	709	699	658	0.02	0.19	0.74	0.09 +
Carcass FCR, kg/kg	3.63	3.76	4.14	0.18	0.12	0.60	0.05 *

[1] *+ P < 0.10 * P < 0.05*

4.1.3 Conclusion

While lowering the lysine concentration and lysine: DE ratio from the high level to the medium level in each phase did not result in significant adverse effects on the performance of the pigs, feeding diets at the lowest level of lysine should be approached with caution.

4.2 Experiment 4.2. Effect of phase feeding diets declining in digestible Lysine: digestible energy (DE) compared to a single diet throughout the growing-finishing period

As pigs mature their requirements for amino acids decline. Phase feeding a series of diets of reducing protein and amino acid content has the potential to increase growth rate and improve feed conversion efficiency because less surplus nitrogen (N) is excreted. This experiment was carried out to assess the response of group penned growing-finishing pigs to feeding a single diet throughout or a sequence of five diets of high, medium or low amino acid content.

4.2.1 Materials and methods

Four hundred and forty six crossbred pigs (progeny of meatline sires out of F1 LW*LR dams) were used in the study. Initial weight of pigs was 38.3 ± 3.8 (mean ± s.d.) kg. Groups (n=32) of 14 pigs of similar weight were assigned at random to one of four dietary regimes: single diet throughout (SD), high lysine sequence (HL), medium lysine sequence (ML) and low lysine sequence (LL). Composition of the diets is shown in Table 4.2.1.

There were eight blocks of four treatments:

1) single diet, C-11.1 g lysine/kg (SD),
2) high lysine series (HL: A-12.2, B-11.6, C-11.1, D-10.5 and E-10.0 g lysine/kg),
3) medium lysine series (ML: C-11.1, D-10.5, E-10.0, F-9.5 and G-8.9 g lysine/kg) and
4) low lysine series (LL: E-10.0, F-9.5, G-8.9, H-8.4 and I-7.8 g lysine/kg).

Table 4.2.1. Ingredient composition of experimental diets, kg/tonne

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Barley	368	376	385	396	406	415	426	427	445
Wheat	368	376	385	396	406	415	426	427	445
Soya Hi-Pro	229	214	196	175	156	135	112	111	73
Soya oil	10	10	10	10	11	12	13	13	16
Lysine HCl	3.4	3.2	3.1	3.1	3.0	3.0	3.0	2.5	3.0
DL-Methionine	1.0	0.9	0.7	0.6	0.5	0.5	0.3	0.2	0.2
L-Threonine	1.5	1.4	1.3	1.3	1.2	1.2	1.1	0.8	1.0
L-Tryptophan	0.10	0.07	0.05	0.05	0.03	0.02	0.03	0	0
Limestone flour	14	14	14	14	13	13	14	14	14
Salt feed	3	3	3	3	3	3	3	3	3
Vit-Min mix	1	1	1	1	1	1	1	1	1
Natuphos 5000[1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nutrient content									
DE, MJ/kg	190	184	177	169	162	154	145	144	130
NE, MJ/kg	9.7	9.7	9.8	9.8	9.8	9.9	10.0	10.1	10.1
Lysine, g/kg	12.2	11.6	11.1	10.5	10.0	9.4	8.9	8.4	7.8
Dig. LYS, g/kg	10.5	10.0	9.5	9.0	8.5	8.0	7.5	7.0	6.5
Dig. LYS, g/MJ DE	0.77	0.73	0.70	0.66	0.63	0.59	0.55	0.52	0.48
Dig. LYS, g/MJ NE	1.08	1.03	0.97	0.92	0.86	0.81	0.75	0.71	0.65

[1] *Phytase: Natuphos – BASF; 5000 FTU/gm equal to 500 FTU per kg finished feed*

The trial period consisted of five phases of two weeks each. Digestible lysine: digestible energy (DE) ratio was 0.70 g/MJ throughout for SD, and declined in increments of 0.035 g/MJ for HL (from 0.77 to 0.63 g/MJ), for ML (from 0.70 to 0.55 g/MJ) and for LL (from 0.63 to 0.48 g/MJ). Crude protein ranged from 190 to 130 g/kg and digestible lysine from 10.5 to 6.5 g/kg.

Margin over feed cost (MOF) was calculated by subtracting the feed cost per pig plus the value of the pig at the start of the experiment from the carcass value at slaughter. MOF

of SD was used as a base (100) with MOF of HL, ML and LL expressed as a percentage of this.

N excreted was calculated by subtracting N gain (carcass N at slaughter minus carcass N at the start of the experiment) from N intake (protein intake*0.16). Carcass lean at the start was estimated by multiplying initial weight by 0.675 and 0.65 (to adjust to carcass weight and lean content of the pig). Carcass lean at slaughter was calculated by multiplying the cold weight by the lean proportion. Carcass N was then estimated by multiplying the carcass lean by 0.22 and 0.16 (protein has 0.16 nitrogen and is 0.22 of lean). Carcass N gain was calculated as carcass N at slaughter minus carcass N at the start of the experiment. Proportion of N retained was estimated by dividing the N gain by the N intake.

Statistical analysis was by the GLM procedures of SAS Inc., Cary, N. Carolina for a randomised complete block design. Single degree of freedom contrasts were used to compare the effects of SD against HL, ML and LL.

4.2.2 Results

Data is presented in Table 4.2.2 for the entire trial period. No differences were observed between SD and HL or ML for growth rate, feed intake, feed conversion ratio (FCR), carcass growth rate or carcass FCR ($P>0.05$). LL pigs grew slower than SD pigs ($P<0.05$), but had similar feed intakes ($P>0.05$), which resulted in poorer FCR ($P<0.05$). Similarly LL pigs had lower carcass growth rates than SD pigs ($P<0.05$) and higher carcass FCR ($P<0.05$). Margins over feed, when compared to the base (SD), increased with HL and ML but decreased with LL, though these effects were not significant ($P>0.05$). ML and LL pigs excreted less N than SD pigs ($P<0.05$, $P<0.001$), who excreted similar quantities to HL pigs ($P>0.05$). ML and LL pigs retained a higher proportion of consumed N than SD pigs ($P<0.001$) but HL pigs did not ($P>0.05$).

Table 4.2.2. Effect of treatment on pig performance (least square means)

	Treatment					*P-values*[1]		
	SD	*HL*	*ML*	*LL*	*Sem*	*SD v HL*	*SD v ML*	*SD v LL*
Average daily gain, g	852	840	860	817	10.7	0.50	0.66	*
Average daily feed intake, g	2119	2089	2144	2093	32.9	0.57	0.64	0.62
Feed conversion ratio, kg/kg	2.49	2.49	2.50	2.59	0.03	0.91	0.93	*
Carcass daily gain, g	729	713	742	696	9.0	0.28	0.38	*
Carcass FCR, kg/kg	2.91	2.93	2.89	3.01	0.03	0.73	0.70	*
Margin over feed cost (% of SD)	100	106	108	98	5.08	0.48	0.35	0.81
Nitrogen excreted, kg/pig	3.13	3.15	2.81	2.46	0.07	0.83	*	***
Proportion of nitrogen retained	0.24	0.25	0.27	0.28	0.003	0.33	***	***

[1]* P<0.05 *** P<0.001

4.2.3 Conclusions

Compared to using a single diet, feeding a sequence of diets declining in digestible lysine: DE ratio improved N retention and reduced N excretion at the ML and LL levels but not at the HL level. However, reducing the digestible lysine: DE ratios to those used in LL had a negative effect on growth rate and feed conversion efficiency.

5 Response of growing pigs to variation in dietary level of amino acids other than Lysine

5.1 Expt 5.1. Response of growing pigs to dietary threonine:lysine ratio and protein level

Pigs perform best when diets contain adequate amount of the essential amino acids in a combination close to the composition of "ideal protein". The requirement of the heavy growing pig is for threonine (THR) and lysine (LYS) in a THR:LYS ratio of at least 0.6:1. Formulation of dietary protein with an amino acid profile close to the ideal allows for a lesser concentration of crude protein, less nitrogen in the excreta and less wastage of energy in metabolising the excess protein.

The objective of this trial was to assess the response of pigs from 50 to 95kg to variation in THR:LYS ratio in diets of high (160g/kg) and low (140g/kg) crude protein content.

5.1.1 Materials and methods

Fifty single sex (gilts and boars) groups of 14 crossbred pigs (mean = 50kg), blocked on sex and weight were assigned at random to the following diets:

A. Low protein with THR:LYS ratio of 0.5 (LP/0.5)
B. Low protein with THR:LYS ratio of 0.6 (LP/0.6)
C. Low protein with THR:LYS ratio of 0.7 (LP/0.7)
D. High protein with THR:LYS ratio of 0.6 (HP/0.6) and
E. High protein with THR:LYS ratio of 0.7 (HP/0.7).

The diets contained 13.5 MJ/kg digestible energy and 9.0g/kg total lysine. Lysine was set at a limiting level on purpose to assess ratio response and the other essential amino acids were at nutritionally adequate levels. Pigs were fed the dry pelleted diets ad libitum. Composition of the diets is shown in Table 5.1.1.

Table 5.1.1. Composition of Experimental diets, kg/tonne

	LP/0.5	*LP/0.6*	*LP/0.7*	*HP/0.6*	*HP/0.7*
Barley	150	150	150	150	150
Wheat	480.9	480	479.1	401.5	400.6
Soya Hi Pro	76	76	76	132	132
Molasses	30	30	30	30	30
Pollard	225	225	225	243	243
Fat Lard	12	12	12	20	20
Lysine Synthetic	3.9	3.9	3.9	1.7	1.7
Methionine Syn	0.2	0.2	0.2	0	0
Threonine	0.0	0.9	1.8	0	0.9
Di Cal Phos	2	2	2	0.8	0.8
Limestone Flour	16	16	16	17	17
Salt	2.5	2.5	2.5	2.5	2.5
Vit-Mins	1.5	1.5	1.5	1.5	1.5
Total	**1000**	**1000**	**1000**	**1000**	**1000**
Nutrient content					
Lysine, g/kg	9.0	9.0	9.0	9.0	9.0
MET + CYS, g/kg	5.0	5.0	5.0	5.5	5.5
THR, g/kg	4.5	5.4	6.3	5.4	6.3
Dig Lysine, g/kg	7.6	7.6	7.6	7.6	7.6

5.1.2 Results

Results of experiment 5.1 are shown in Table 5.1.2.

Table 5.1.2. Effect of protein level and THR:LYS ratio on pig performance

	LP/0.5	*LP/0.6*	*LP/0.7*	*HP/0.6*	*HP/0.7*	s.e.	F-test, P%
Initial weight, kg	50.6	49.8	50.5	50.4	50.6	0.5	NS
Final wt, kg	93.1	97.2	96.4	94.3	96.3	1.0	*
Carcass wt, kg	70.9	74.1	73.6	72.1	73.6	0.8	+
Daily gain, g	708	792	806	755	773	16	**
Daily feed, g	2338	2377	2389	2310	2333	37	NS
FCE live	3.32	3.01	2.97	3.07	3.03	0.05	**
Carcass gain, g/d	612	677	695	654	666	14	**
Carcass FCE	3.83	3.52	3.45	3.54	3.51	0.06	**
Kill out %	76.1	76.3	76.3	76.4	76.4	0.3	NS
Backfat depth, mm	11.5	11.0	11.4	11.0	10.5	0.35	NS
Muscle depth mm	51.8	53.0	53.0	52.3	53.6	0.9	NS
Carcass lean %	58.1	59.0	58.4	58.6	59.4	0.30	*

*+ = P<0.10; * = P<0.05; ** P<0.01*

On the LP diets (A, B and C), there was a significant linear response (P<0.01) in daily gain to increasing the THR:LYS ratio and a tendency towards a quadratic effect (P=0.09). In FCR both linear (P<0.01) and quadratic (P<0.05) effects were significant.

Feeding a lower protein diet (treatments B and C v. D and E) resulted in improved growth rate (P<0.05) and a tendency towards increased feed intake (P=0.11) with no effect on FCR (P>0.10).

The small numerical improvement in FCR at the lower dietary protein is consistent with the energy sparing effect of low protein diets combined with the higher digestibility of lysine, threonine and methionine in these diets.

5.1.3 Conclusion

Heavy finishing pigs respond to increasing the THR:LYS ratio in the diet up to 0.7:1.

5.2 Experiment 5.2. Assessment of the methionine requirement of pigs in the weight range 11 to 20kg

There is little recent information on the optimum ratio of methionine to lysine in diets for pigs. The objective of this trial was to determine the optimum ratio of Methionine (MET) to Lysine (LYS) for nursery pigs in the weight range 11 to 23kg.

5.2.1 Materials and Methods

A total of 192 pigs were used, with a pair of pigs of the same sex penned together (n = 96 pairs) as the experimental unit in a randomised complete block design. Pigs were fed a commercial starter diet for 11 days after weaning at 26 to 28 days of age and fed the test diets for 24 days. The basal diet was (g/kg) wheat 231, barley 120, heated full fat soybeans 200, field peas 240, corn starch 120, soy oil 25, L-lysine HCl 3.5, L-threonine 2.0, L-tryptophan 0.5, L-valine 0.5 and L-isoleucine 0.5, minerals and vitamins. The digestible energy content of the diet was 14.9 MJ/kg, crude protein was 166g/kg, total LYS was 12.0g/kg and true ileal digestible (TID) LYS was 10.0g/kg. The basal diet (2.2g/kg total MET) was supplemented with DL-MET in increments of 0.4g/kg to give seven diets ranging from 2.2 to 4.6g/kg total MET. The ratio total MET:total LYS varied from 0.183 to 0.383 and TID MET:TID LYS from 0.17 to 0.37. The ratio of total sulphur amino acids (methionine :LYS ranged from 0.41 to 0.61. Statistical analysis was by the GLM procedure of SAS Inc. with the linear and quadratic components tested for significance.

5.2.2 Results

MET supplementation increased the average daily feed intake (quadratic – $P<0.01$) and average daily gain (linear – $P<0.01$; quadratic – $P<0.01$) and improved feed to gain ratio (linear – $P<0.01$; quadratic – $P<0.01$). Exponential response curves were fitted and showed the optimum level of MET (95% of the asymptote) to be 4.1g/kg for daily gain and 3.7g/kg for feed:gain.

5.2.3 Conclusions

It is concluded that the optimum ratio of MET:LYS for pigs in the weight range 11 to 20kg is 0.31 for feed:gain and 0.34 for average daily gain.

Table 5.2.1. Pig performance on control and test diets

Treatment	*T-1*	*T-2*	*T-3*	*T-4*	*T5*	*T-6*	*T-7*	*s.e.*	*Linear*	Quadratic
Added DL-METH, g/kg	*0*	*0.4*	*0.8*	*1.2*	*1.6*	*2.0*	*2.4*			
METH:LYS	0.18	0.22	0.25	0.28	0.32	0.35	0.38			
Pig weights, kg										
Weaning	8.3	8.3	8.3	8.4	8.3	8.4	8.3	0.23	95	84
Day 11	11.3	11.4	11.4	11.3	11.3	11.8	11.8	0.18	5 *	15
Day 35	18.6	20.4	22.3	22.5	23.6	23.8	22.5	0.43	<1 **	<1 **
Stage 1 (day 0 to 11) – starter diet										
Daily gain, g	268	276	275	261	261	312	307	16	5 *	14
Daily feed, g	315	320	311	319	310	346	328	14	22	53
FCE	1.19	1.19	1.17	1.30	1.24	1.12	1.08	0.06	24	5 +
Experimental period (day 11 to 35)										
Daily gain, g	297	372	453	457	507	515	459	18	<1 **	<1 **
Daily feed, g	748	734	775	840	775	829	707	31	70	1 *
FCE	2.55	2.00	1.74	1.75	1.54	1.60	1.55	0.09	<1 **	<1 **

[1] *+ = P<0.10; * = P<0.05; ** P<0.01.*

5.3 Experiment 5.3. Response of growing pigs to phase feeding of diets decreasing in amino acid content

The nutrient requirements of growing pigs decrease with increasing body weight. Feeding diets of lower nutrient content will result in lower feed costs and reduced manure nutrients provided pig performance is not adversely affected.

The objective of this trial was to assess the response of pigs in the weight range 60-95 kg to variation in the level of lysine in the diet and in the ratios of total threonine (THR), methionine (MET) and cystine (CY) to total lysine (LYS) in the diet.

5.3.1 Materials and methods

Forty single-sex groups of 14 pigs were selected at about 35kg live weight and assigned at random to the following treatments.

A. Control diet 1.1% lysine to slaughter
B. Diet A to c. 60 kg followed by 0.95% lysine and low THR/MET/CY ratio
C. Diet A to c. 60 kg followed by 0.95% lysine and high THR/MET/CY ratio
D. Diet A to c. 60 kg followed by 0.8% lysine and low THR/MET/CY ratio
E. Diet A to c. 60 kg followed by 0.8% lysine and high THR/MET/CY ratio.

Diets B and D were formulated so that THR and Met + CY were at least 65% and 55% respectively of LYS. Diets C and E were formulated so that THR and Met + CY were at least 70% and 60% respectively of LYS. Diets were formulated to contain 13.6 MJ/kg DE and contained barley, wheat, soyabean meal, synthetic amino acids, minerals and vitamins. Soyabean and cereal inclusion levels were varied to achieve the target levels of amino acids.

5.3.2 Results

Results of this trial are shown in Table 5.3.1. There was some depression in pig performance (growth rate, feed conversion efficiency and carcass leanness) when the diets of reduced nutrient content were fed.

Table 5.3.1. Effect of phase feeding on performance of finishing pigs

	A	*B*	*C*	*D*	*E*	*sem*	*P %*
No / pen	13.6	13.6	13.9	14.0	13.5	0.18	27
Initial Wt.	38.5	38.7	37.5	37.7	36.6	0.62	15
Final Wt.	96.8	93.4	96.7	91.5	91.4	1.46	3*
Daily Gain g	780	727	771	695	730	15.6	<1**
Daily Feed g	2017	1964	2053	1955	1963	32.7	18
FCE	2.59	2.70	2.66	2.81	2.69	0.029	<1**
Daily Gain Carcass g	660	623	653	591	618	12.7	<1**
FCE Carcass	3.06	3.15	3.14	3.31	3.18	0.035	<1**
Cold Wt. Kg	73.3	72.1	74.5	70.1	70.2	1.02	<1*
KO %	76.8	77.2	77.1	76.7	76.8	0.32	81
Carcass Lean %	59.6	59.3	59.6	59.3	59.0	0.18	22
Backfat mm	10.9	11.1	11.2	10.7	11.3	0.29	79
Muscle depth mm	55.5	54.7	56.1	53.9	54.4	0.72	24

5.3.3 Conclusion

Caution should be exercised in reducing dietary nutrient density in the final stages of finishing pigs.

6 Dietary protein and nitrogen excretion

6.1 Effect of feeding a single diet or phase feeding a series of diets on nitrogen excretion

The environmental impact of pig production is also important, with emphasis on strategies that reduce the output of nitrogen and phosphorus. Some producers tend to over supply nutrients (e.g. protein and lysine) to finishing pigs by feeding a single or perhaps two diets throughout the growing-finishing period. Not only does protein oversupply result in increased nitrogen excretion but it can also lead to a decline in feed efficiency.

In order to efficiently realise the growth potential of the pig, the protein (lysine) to energy ratio of the diet should be continually decreased. This feeding strategy can also lead to a reduction in the amount of nutrients excreted. The objectives of this study was to determine the effect of these feeding strategies on estimated nitrogen excretion and retention,

6.1.1 Materials and Methods

Data from the pigs in experiment 4.2 was used to estimate nitrogen balance. Nitrogen intake (NINTAKE) was calculated from overall protein intake i.e. feed intake and crude protein content. Nitrogen deposition rate (NDR) was calculated from estimated daily carcass nitrogen gain plus an additional 3 g/d for blood and organ gain (de Greef and Verstegen, 1993). Daily carcass nitrogen gain was calculated as [carcass weight gain*0.17 (de Greef and Verstegen, 1993; Friesen et al., 1994)*0.16 (nitrogen content of protein)]/days on trial. Total nitrogen gain (NGAIN) was calculated as [nitrogen deposition rate*days on trial]. Nitrogen excretion (NEXCR) was estimated from NINTAKE minus NGAIN. Nitrogen retained (NRET) was calculated as the percentage of nitrogen intake that was retained by the pig.

Statistical analysis

All data were analysed using the PROC GLM procedure of SAS (SAS Inst., Inc., Cary. N. Carolina).

6.1.2 Results

The effect of treatment on the estimated nitrogen deposition, excretion and retention of pigs is shown in Table 6.1.1. Nitrogen deposition rate was lower for pigs on the LL compared to the SD treatment ($P<0.05$). Pigs on the ML treatment excreted less ($P<0.01$) and retained a higher percentage of consumed nitrogen ($P<0.001$) than those on the SD treatment. Pigs on the LL treatment consumed less ($P<0.001$), excreted less ($P<0.001$) and retained a higher percentage ($P<0.001$) of nitrogen than those on the SD treatment. Nitrogen deposition rate was greater for pigs on SD compared to those on LL ($P<0.01$). Female pigs had higher nitrogen intakes ($P<0.05$), and excreted more nitrogen ($P<0.01$) than male pigs. Percentage of nitrogen retained was lower for female pigs compared to male pigs ($P<0.001$).

6.1.3 Discussion

When providing a single diet throughout the growing finishing period, the lysine content is either adequate initially and becomes excessive as lysine requirement declines with increase in liveweight, or it is below initial requirements, with the expectation that pigs will be able to compensate in later stages (of diet adequacy) for the initial effects of dietary restriction.

In this study, the lysine content of the single diet was 11.1 g total lysine per kg of feed. Lysine titration studies described earlier indicate that pigs in groups could respond positively to diets with total lysine contents of up to 12.4 g/kg between 40 and 60 kg, declining to 9.7 g/kg from 80 to 100 kg, although there was no increase in response of pigs to lysine content above 11.0 g/kg when fed as a single diet from 35 to 95 kg (unpublished data). Therefore, it was assumed that the lysine content of SD was initially limiting.

Increased retention of consumed nitrogen caused a 12.6 % reduction in nitrogen excretion for ML compared to SD pigs. The combined increase in percentage of consumed nitrogen retained, and decrease in nitrogen intake and nitrogen deposition rate caused nitrogen excretion to be 25.1 % lower for pigs on the LL treatment compared to those on the SD treatment. When protein retention reaches a constant rate and lysine intake increases, lysine conversion ratio deteriorates. The excess lysine is deaminated and excreted as urea, which is also part of the reason why SD pigs had greater nitrogen excretion than ML and LL pigs. Lee et al., (2000) report a 12 % decrease in nitrogen excretion for pigs on a three phase feeding program compared to those on a

single-phase program although the mean crude protein content of the three phase program was 14 % compared to 16 % for the single phase program. Reduction in nitrogen excretion and improvement in percentage of nitrogen retained were not the result of phase feeding per se since no differences between HL and SD were observed, but rather were the result of reduced overall dietary nitrogen content.

The percentage of consumed nitrogen that was retained ranged from 38 to 46 %. Whittemore et al. (2001) suggest that two thirds of nitrogen consumed is excreted, implying that approximately 34 % is retained. Higher nitrogen retention percentages found here can be attributed to reduced excretion of nitrogen when overall dietary nitrogen content was reduced. Although estimated nitrogen gain was similar for pigs on all treatments, nitrogen deposition rate was lower for pigs on LL compared to SD. This supports the theory that a mean overall lysine content of 8.9 g/kg is below requirements for these pigs. The estimated mean nitrogen deposition rate (from 38.3 to 97.3 kg) of pigs in this study was 22.9 ± 1.09 g/d.

Increased nitrogen consumption by female pigs is the result of females exhibiting a tendency towards increased overall feed intake. Although males had lower nitrogen intakes than females they retained a higher percentage of this nitrogen. Since there was no difference in overall nitrogen gain and overall mean nitrogen deposition rate between the sexes, this illustrates a greater efficiency of utilization of dietary nitrogen by male pigs and results in greater nitrogen excretion by female pigs.

6.1.4 Conclusions

Phase feeding resulted in no improvement in pig performance, nitrogen deposition rate, nitrogen excretion or percentage of nitrogen retained compared to a single diet when the mean overall lysine content was 11.1 g/kg (from 38 to 98 kg). Reducing the overall mean lysine content (ML and LL) improved lysine utilization and percentage of nitrogen retained and reduced nitrogen excretion compared to SD. It is more likely that the positive effects on nitrogen excretion and percentage retained are due to a reduction in the overall mean lysine content of the diet rather than to phase feeding. Reducing the overall mean lysine content to 8.9 g/kg depressed growth rate and feed efficiency of the pigs, with particular effect on male pigs.

Table 6.1.1. **The effect of treatment on estimated nitrogen excretion and retention[1] (LSmeans and standard errors of means)**

	Treatment					Sex			Significance[2]		
Treatment	SD	HL	ML	LL	s.e.	M	F	s.e.	SDvML	SDvLL	Sex
Total nitrogen intake, kg	4.03	4.19	3.80	3.45	0.10	3.75	3.99	0.07		***	*
Nitrogen gain, kg	1.56	1.66	1.64	1.59	0.04	1.60	1.63	0.03			
Nitrogen deposition rate, g/d	23.2	22.7	23.4	22.3	0.24	23.0	22.8	0.17		*	
Nitrogen excreted, kg	2.47	2.53	2.16	1.85	0.07	2.15	2.35	0.05	**	***	**
Nitrogen retained, %[1]	38.9	39.5	43.3	46.3	0.38	42.8	41.2	0.27	***	***	***

[1]*Nitrogen retention = (nitrogen gain/nitrogen intake)x100*

[2]*P>0.05 for all SD v HL comparisons *P<0.05, **P<0.01, ***P<0.001*

7 Response of weaned pigs to dietary protein level

There is some evidence that weaned pig fed lower protein levels have a lower incidence of diarrhoea. Furthermore, the energy sparing effect of low protein diets is expected to apply to weaned pigs as to heavier pigs.

The objective of this trial was to assess the response of pigs in the weight range 12 to 30kg to variation in the level of crude protein in the diet when all diets contained equal amounts of the principal essential amino acids.

7.1.1 Materials and methods

Forty eight pairs of crossbred pigs, progeny of meat-line sires out of F1 (i.e. Landrace* Large White) sows were used. They were weaned at 24 to 30 days of age (mean =28.1 days and 8.1 kg). Two pigs, one male and one female from different litters and close in weight were placed in each pen. Pairs were formed into blocks of three on the basis of weight. One pair from each block was assigned at random to each of the following treatments:

A. Low protein diet (190g/kg)
B. Medium protein diet (210g/kg)
C. High protein diet (230g/kg)

All pigs were fed a commercial starter diet (Startrite 88, SCA, Nass, Co. Kildare) for 11 days from weaning followed by the test diets (Table 7.1.1) for 30 days.

Table 7.1.1. Composition of experimental diets, g/kg

Diet No.	Low CP	Medium CP	High CP
Barley	225	225	225
Wheat	355.6	299	242.4
Maize	100	100	100
Soya Full Fat	100	100	100
Soya Hi-Pro	180	240	300
Fat Tallow/Lard	10	10	10
L- Lysine HCl	4.0	2.0	
DL-Methionine	1.5	1.0	0.5
L-Threonine	1.5	0.75	
L-Trypophan	0.3		
Di Cal Phos	5.0	5	5.0
Limestone Flour	11	11.15	11
Salt	3.0	3.0	3.0
Vit-Mins	3.0	3	3.0
Phytase 5000 iu/g	0.1	0.1	0.1
Total	**1000**	**1000**	**1000**
DE, MJ/kg	14.1	14.2	14.2
NE, MJ/kg	10.0	9.9	9.9
Crude protein, g/kg	195	211	231
Lysine, g/kg	13.0	12.9	12.9
Dig. LYS, g/kg	11.3	11.1	10.9
Dig. LYS, g/MJ DE	0.80	0.77	0.77
Dig. LYS, g/MJ NE	1.13	1.12	1.10

7.1.2 Results

Results of this trial are shown in Table 7.1.2. Differences between treatments were not significant. Nevertheless, there was a tendency towards better performance on the low protein diets.

Table 7.1.2. Effect of protein level on performance of weaned pigs

	Low	*Medium*	*High*	*Sem*	*F test*	
					Linear	*Quadratic*
Weight on d. 9, kg	10.3	10.1	10.1	0.11	44	63
Weight on d. 39, kg	26.3	25.4	25.3	0.47	17	45
Daily gain, g	535	508	507	14.5	19	48
Daily feed, g	825	850	834	23.8	81	49
FCE	1.55	1.69	1.65	0.044	12	9

7.1.3 *Conclusions*

Feeding a lower protein level to weaned pigs resulted in a small but statistically non significant increase in growth rate and improvement in feed conversion ratio.

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9 Publications this project

Refereed papers

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2005). A note on the response of growing-finishing pigs to increasing the threonine to lysine ratio of diets with reduced lysine content. *The Pig Journal 55:19-26.*

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2005). Determination of the optimum dietary lysine concentration for growing pigs housed in pairs and in groups. *Animal Science (accepted)*

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2005). A comparison between feeding a single diet or phase feeding a series of diets, with either the same or reduced crude protein content, to growing finishing pigs. *Animal Science (accepted).*

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2005). Determination of the optimum dietary lysine concentration for boars and gilts penned in pairs and in groups in the weight range 60 to 100 kg. *Animal Science (submitted).*

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2005). The effect of dietary lysine restriction during the grower phase and subsequent dietary lysine concentration during the realimentation phase on the performance, carcass characteristics and nitrogen balance of growing-finishing pigs. *Livestock Production Science (submitted)*

Conference presentations

Lynch, P.B. and Rademacher, M. (2004). Assessment of the methionine requirement of pigs in the weight range 11 to 20kg. *Proceedings Annual meeting American Society of Animal Science, St. Louis.*

Lynch, P.B., Rademacher, M. and Lawlor, P (2004). Assessment of the methionine requirement of pigs in the weight range 11 to 23kg. *Proceedings EAAP Annual meeting, Bled, Slovenia.*

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2004). Comparison of feeding grower-finisher pigs sequences of multiple diets declining in digestible Lysine: DE. *Proceedings Midwest meeting of the American Society of Animal Science, Des Moines, Iowa.*

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