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Dietary Lysine Requirements and Feeding Regimes for Finisher Pigs

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Executive Summary

Experiment 1

The response to lysine of the modern PIC genotype from 50 to 100 kg liveweight (LW) was determined by Moore *et al.* (2012a) in 2009. The results indicated that the suggested requirement for lysine in this weight range was higher by approximately 10% than that currently being used by industry (0.55 g av lys/MJ DE). However the application of the results commercially has been questioned by some in the industry as not being relevant to commercial piggeries because of the superior performance seen at Medina. The objective of this experiment was to confirm the optimal available lysine/MJ DE ratio for a modern genotype from 60-100 kg LW.

The optimum SID lysine requirement for male and female pigs between 63 and 103 kg LW was assessed using linear plateau, quadratic plateau and quadratic models. When the results from the models were combined, the optimum estimated SID lysine levels for females and males from 63 to 103 kg LW were 0.61 and 0.64 g/MJ DE, respectively.

This experiment was also conducted with female pigs at three other sites in Australia. The results from each site were reanalysed both individually and for all of the sites using linear plateau, quadratic plateau and quadratic models to determine the optimum lysine level. An estimate of the optimal lysine requirement for female pigs from 60-100 kg LW for the Australian pork industry to maximise growth performance is 0.64 g Av Lys/MJ DE. This is approximately 10% higher than the level than was previously used by industry.

Experiment 2

Moore *et al.* (2012b) found that blend feeding and feeding a single diet reduced diet costs by approximately $3/pig compared to the conventional three-phase feeding regime with no impact on growth performance or conventional measures of carcass quality. Edwards (2011) then explored this concept in a commercial environment. They also found little difference in overall growth performance between the single diet and the conventional three-phase feeding program from 25 kg LW (Edwards, 2011). However there was some concern that the lysine requirement in the diet was not sufficient and as a result the true effect of feeding the single diet was not realised. The single diet has the advantage of simplifying the feeding of pigs and could possibly offer a means to improve the decrease in feed efficiency found in the late finishing stage (Edwards, 2011). Therefore, this experiment aimed to compare the effects of three different feeding strategies (conventional three-phase feeding, blend feeding and single diet feeding) on growth performance, carcass composition, economic analysis and meat quality using lysine levels determined from the first experiment.

There were no differences in daily gain, feed intake, feed to gain, feed costs per pig and objective meat quality between feeding strategies. Pigs on the blend or single feeding strategy deposited 38 g/day more fat than phase fed pigs with no difference in the amount of lean or ash deposited per day between feeding strategies. In addition, pigs receiving the blend feeding strategy had nearly twice as much intramuscular fat compared to the phase feeding or single diet.

In conclusion, although there was no cost benefit to a single diet in this experiment using a single diet is a very practical alternative to phase feeding and has several advantages for feed manufacture, storage and delivery. Its success will depend on the diet specifications that are chosen, which will vary depending on the genetic potential of the herd and the weight range over which the pigs are to be fed. Although blend feeding requires significant initial infrastructure, it has the ease of only 2 diets on hand at any time and may also be a practical alternative to phase feeding.

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1. Background to Research

The response to lysine of the modern PIC genotype from 50 to 100 kg LW was determined by Moore *et al.* (2012a) in 2009. The results indicated that the suggested requirement for lysine in this weight range was higher by approximately 10% than that currently being used by industry (0.55 g Av lys/MJ DE). However the application of the results commercially has been questioned by some in the industry as not being relevant to commercial piggeries because of the superior performance seen at Medina. Therefore, to validate the results three commercial piggeries and Medina will conduct an experiment using similar diets and lysine levels. The aim is to confirm the optimal available lysine/MJ DE ratio for a modern genotype from 60-100 kg LW. This will help to ensure the optimum growth performance of pigs.

This research will also re-examine the three feeding strategies, phase-feeding, blend feeding or feeding a single diet from 30 to 100 kg LW. Moore *et al.* (2012b) found that blend feeding and feeding a single diet reduced diet costs by approximately $3/pig compared to the conventional three-phase feeding regime with no impact on growth performance or conventional measures of carcass quality. Edwards (2011) then explored this concept in a commercial environment. They also found little difference in overall growth performance between the single diet and the conventional three-phase feeding program from 25 kg LW (Edwards, 2011). However there was some concern that the lysine requirement in the diet was not sufficient and as a result the true effect of feeding the single diet was not realised. The single diet has the advantage of simplifying the feeding of pigs and could possibly offer a means to improve the decrease in feed efficiency found in the late finishing stage (Edwards, 2011). Therefore, this experiment aimed to compare the effects of three different feeding strategies (conventional three-phase feeding, blend feeding and single diet feeding) on growth performance, carcass composition, economic analysis and meat quality using lysine levels determined from the first experiment.

2. Objectives of the Research Project

The objectives of this project were:

1. To confirm the optimal Av Lys/MJ DE ratio for a modern genotype from 60-100 kg LW.

2. To determine if feeding a single diet during the grower-finisher phase can reduce the cost of production compared to the conventional three-phase feeding system without adversely affecting pig growth performance or carcass quality.

3. Experiment 1: Introductory Technical Information

Prior to 2009 it had been a number of years since the amino acid requirements of the modern pig were determined. In 2009 an experiment to determine the lysine requirements of the modern PIC genotype from 50 to 100 kg liveweight (LW) was conducted by Moore *et al.* (2012a) at the Medina Research Station. The results indicated that the suggested requirement of lysine in this weight range was higher by approximately 10% than that currently being used by industry (0.55 g Av lys/MJ DE). In addition the performance of the pigs greatly exceeded that being seen in commercial situations.

The application of the results commercially has been questioned by some in the industry as not being relevant to commercial piggeries because of the superior performance seen at Medina. For example, Figure 1 shows a comparison by the growth performance experienced at Medina compared to that at a commercial piggery in Queensland using the same genotype. This shows the pigs at Medina considerably outperforming those in the commercial facility. However, based on projected weights and growth rates at Week 10 and Week 15 the pigs followed a similar shaped growth curve to those at Medina. After Week 15, growth rate dropped considerably due possibly to the effect of over-stocking in the commercial piggery.

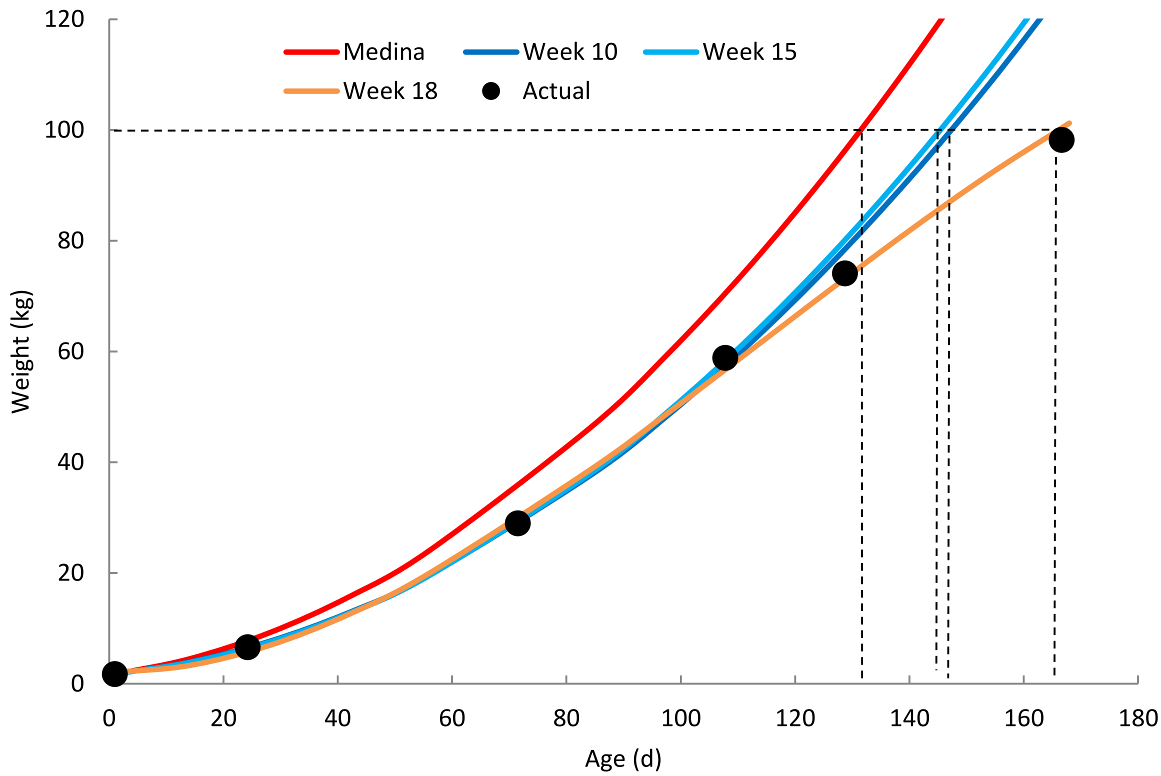

Figure 1: Comparison of weight change over time between Medina and a commercial piggery with a similar genetic base (van Barneveld, unpub).

To validate the results from the experiment at Medina for the commercial industry, the Pork CRC and Australian Pork Limited arranged for the three largest piggeries in Australia to conduct an experiment at the same time of year using diets of a similar composition. Medina Research Station was included to provide a standard. In contrast to the experiment conducted by Moore *et al.* (2012a):

- the experiment will stop at a standard age and not LW

- there will be an increased number of treatments in the available lysine range tested which will allow the requirement to be determined using break point analysis
- the experiment will be conducted over a standard feeding period (equating to the weight range 60 to 100 kg LW) compared to 50 to 100 kg LW.

The hypotheses tested were:

i) That finisher pigs will respond to increasing levels of Av Lys/MJ DE by having an increased growth rate and reduced feed conversion ratio, until a plateau is reached corresponding to their genetic potential.

ii) That the lysine requirement will be higher than that currently used by industry for both males and females.

4. Experiment 1 Research Methodology

The experiment was conducted at the Department of Agriculture and Food Western Australia's (DAFWA) Medina Research Centre. The experimental protocols used were approved by the DAFWA Animal Research Committee and by the Animal Ethics Committee. The animals were handled according to the Australian code of practice for the care and use of animals for scientific purposes (NHMRC, 2004).

4.1 Animals and experimental design

A total of three hundred and ninety two Large White x Landrace x Duroc entire male and female pigs were used in this experiment. The experiment was a 2 x 7 factorial with the main treatments being:
i) sex (entire males and females) and;
ii) available lysine to MJ digestible energy (Av Lys/MJ DE) ratio (0.40, 0.46, 0.52, 0.58, 0.64, 0.70 and 0.76 g Av Lys/MJ DE).

4.2 Allocation and housing

Pigs were sourced at approximately 50 kgs liveweight from a high health status commercial herd whose bloodlines were sourced from the Pig Improvement Company. On arrival the pigs were stratified by liveweight and randomly allocated to treatment. The pigs were housed in groups of 7 in a naturally ventilated grower-finisher facility. The experiment was conducted in July 2012. All pigs had *ad libitum* access to feed and water for the entire period of the experiment.

4.3 Diets

The experimental diets were fed for five weeks from 63.7 (±0.44 SEM) until slaughter at 100.4 (±0.55 SEM) kg LW. The composition of the diets and the ratios used to attain the blended diets using the Feedlogic system are given in Tables 1 and 3, respectively. The diets were submitted for quantitative amino acid analysis (Animal Health Laboratories, Department of Agriculture and Food Western Australia) and the results are given in Table 2.

Table 1: The composition of the diets for the two extreme lysine levels.

Diet	Diet 1 (Low)	Diet 2 (High)
Ingredients (g/kg)		
Barley	200	200
Wheat	683	487
Soyabean meal	65.0	270
Tallow	19.5	10.0
Salt	2.00	2.00
Limestone	15.0	14.5
Dical Phosphorus	11.0	9.5
Lysine-HCl	2.00	2.05
D, L-Methionine	0	1.25
Threonine	0.45	1.20
Minerals and Vitamins[a]	2.00	2.00
Nutrient composition[b]		
DE (MJ/kg)	14.0	14.0
Crude protein (%)	12.7	20.5

Available lysine:DE (MJ/kg)	0.40	0.76

[a] Each kilogram of vitamin and mineral premix contains 7 MIU Vitamin A, 1.4 MIU Vitamin D_3, 20 g Vitamin E, 1 g Vitamin K, 1 g Vitamin B_1, 3 g Vitamin B_2, 1.5 g Vitamin B_6, 15 mg Vitamin B_{12} 12 g niacin, 10 mg pantothentic acid, 0.19 g folic acid, 30 mg biotin, 10.6 g Calcium pantothenatic, 60 g iron, 100 g zinc, 40 g manganese, 10 g copper, 0.2 g cobalt, 0.5 g iodine, 0.3 g selenium, and 20 g antioxidant.

[b] Calculated composition.

Table 2: Quantitative amino acid analysis of the two basal diets.

Amino acid (g/100 g)	**Low**	**High**
Cysteine-x	0.51	0.41
Histidine	0.30	0.48
Serine	0.68	1.03
Arginine	0.71	1.18
Glycine	0.54	0.81
Aspartic acid	0.93	1.73
Glutamic acid	3.26	4.13
Threonine	0.51	0.80
Alanine	0.50	0.79
Proline	1.26	1.49
Lysine	0.61	1.04
Tyrosine	0.41	0.63
Methionine	0.26	0.43
Valine	0.55	0.82
Isoleucine	0.48	0.76
Leucine	0.92	1.41
Phenylalanine	0.64	0.95

Table 3: The blend ratios of the two basal diets to produce the five dietary treatments.

Treatment	**Diet 1**	**Diet 2**	**MJ DE/kg**	**Av. Lys/MJ DE**
1	100	0	14.0	0.40
2	83	17	14.0	0.46
3	66	34	14.0	0.52
4	50	50	14.0	0.58
5	33	67	14.0	0.64
6	16	84	14.0	0.70
7	0	100	14.0	0.76

4.4 Measurements

Individual pig weight was recorded on the same day and at approximately the same time each week, and feed disappearance was recorded daily using the Feedlogic system. The feed to gain ratio was calculated on a per pen basis by dividing the total weight of feed eaten by the LW gain in the same period.

After 35 days on the experimental diet the pigs were individually tattooed, removed from feed overnight and transported to a commercial abattoir (approx. 90 minute transport time). The pigs were stunned using a carbon dioxide, dip-lift stunner set at 85% CO_2 for 1.8 minutes (Butina, Denmark). Exsanguination, scalding, dehairing and evisceration were performed using standard commercial procedures. Hot carcass weight (AUSMEAT Trim 13; head off, fore trotters off, hind trotters on; AUS-MEAT Ltd, South Brisbane, Qld, Australia) and P2 backfat depth, 65 mm from the dorsal midline at the point of the last rib (PorkScan) were measured approximately 35 minutes after exsanguination, prior to chiller entry (2°C, airspeed 4 m/second).

4.5 Statistical analysis

Two-way analysis of variance (ANOVA) was performed with the Genstat 15 program (VSN International Ltd, Hemel Hempstead, UK) to analyse the main and interactive effects of sex and diet. Position within the shed was used as a block in the analysis. A level of probability of less than 0.05 was used to determine statistical difference between treatments.

A quadratic curve was fitted to the treatment means to predict the optimum dietary lysine concentration for maximum daily gain and minimum feed to gain. The quadratic curves were fitted using $y = ax^2 + bx + c$, where y = either daily gain or feed to gain, x = g SID lysine/MJ DE and a, b, and c are representative components of the equation (O'Connell *et al.* 2006). The data was also analysed using the linear plateau and quadratic plateau models fitted to the treatment means (Nutrient Response Models Version 1.1, University of Georgia, Excel).

5. Experiment 1 Results

Nine percent of the pigs in this experiment were treated for meningitis with all responding to treatment. The cases were spread across sex and lysine treatment. Subsequently, 3 pens were removed from the analysis as one pig in each of these pens was very slow in responding to treatment and lost a significant amount of body weight. Results and predicted lysine levels are also provided for the entire period only due to the meningitis outbreak. The data was examined for the LW ranges 63 to 77 kg and 77 kg to slaughter, however because of the meningitis outbreak in the middle the authors do not believe that these are an appropriate reflection of requirements in these weight ranges. Overall, all bar 3 pigs responded well to treatment and therefore the results and the predicted lysine levels are analysed for the entire period only.

Pigs were an average of 63.6 kg LW at the start of the experiment with no difference between entire males and females. Entire males were significantly heavier than the females (P=0.001) when the experiment ceased (Table 4).

The males had a higher average daily gain (P=<0.001), improved feed to gain (P=<0.001), and a heavier carcass weight (P=0.013) compared to the females (Table 4, Figure 1 and 2). There was no difference in feed intake (P=0.513), dressing percentage (P=0.200) or P2 (P=0.969) between entire males and females.

There was no significant difference in start LW between lysine levels however, those on the higher levels of lysine were significantly heavier than those on the lower levels at the end of the experiment (P=0.803 and P=0.015, respectively). Pigs that received the lowest levels of lysine grew slower (P=0.009) and had a worse feed to gain (P=0.006) compared to pigs that received the higher levels of lysine. There was no difference between lysine levels for feed intake (P=0.623), carcase weight (P=0.091) and P2 (P=0.196).

The optimum SID lysine requirement for males and females between 63 and 103 kg LW was assessed using linear plateau, quadratic plateau and quadratic models (Figure 2 and 3, Tables 5, 6 and 7). For females the SID lysine level to optimise daily gain was 0.64 and 0.62 g/MJ DE, and feed:gain was 0.65 and 0.54 g/MJ DE using the quadratic model and mean for the linear plateau and quadratic plateau model, respectively. For males the SID lysine level for daily gain was 0.72 and 0.64 g/MJ DE, and feed:gain was 0.67 and 0.58 g/MJ DE using the quadratic model and mean for the linear plateau and quadratic plateau model, respectively. When the models were combined, the estimated SID lysine level for females and males from 63 to 103 kg LW was 0.61 and 0.64 g/MJ DE, respectively.

Table 4: Growth performance and carcase characteristics for male and female pigs fed varying levels of Av Lys/MJ DE from 63.6 to 100.5 kgs (n=4).

	Lysine level (g Av Lys/MJ DE)							SED[a]	P-value		
	0.40	0.46	0.52	0.58	0.64	0.70	0.76		Lysine	Sex	LxS
Initial LW (kg)											
Male	64.5	62.0	64.6	65.9	63.0	63.9	63.7	0.774	0.803	0.131	0.018
Female	63.3	63.7	62.4	62.1	63.9	63.7	64.0				
Final LW (kg)											
Male	98.9	102	102	105	103	105	104	1.20	0.015	<0.001	0.199
Female	96.7	96.9	98.7	97.0	99.7	100	98.1				
Daily gain (kg)											
Male	1.01	1.09	1.06	1.16	1.13	1.15	1.15	0.030	0.009	<0.001	0.086
Female	0.97	0.95	1.03	0.99	1.02	1.06	0.98				
Feed Intake (kg/d)											
Male	2.66	2.59	2.55	2.72	2.63	2.59	2.67	0.071	0.623	0.513	0.500
Female	2.71	2.54	2.60	2.58	2.63	2.66	2.50				
Feed to gain											
Male	2.65	2.39	2.42	2.35	2.33	2.27	2.32	0.079	0.006	<0.001	0.868
Female	2.80	2.69	2.53	2.59	2.59	2.52	2.59				
Carcase weight (kg)											
Male	68.4	67.9	69.0	71.6	69.7	70.4	71.1	0.978	0.091	0.013	0.580
Female	68.4	67.6	67.0	68.1	69.1	69.4	69.0				
Dressing percentage (%)											
Male	69.2	69.6	68.2	70.2	68.7	68.3	68.4	0.495	0.020	0.200	0.634
Female	69.1	69.6	68.1	70.2	68.7	68.3	68.4				
P2 (mm) [b]											
Male	9.74	10.3	9.61	10.1	9.83	8.69	9.11	0.433	0.196	0.969	0.554
Female	10.0	9.79	9.91	9.94	9.49	9.79	8.99				

[a] SED for level × sex

[b] Carcase weight used as a covariate for P2.

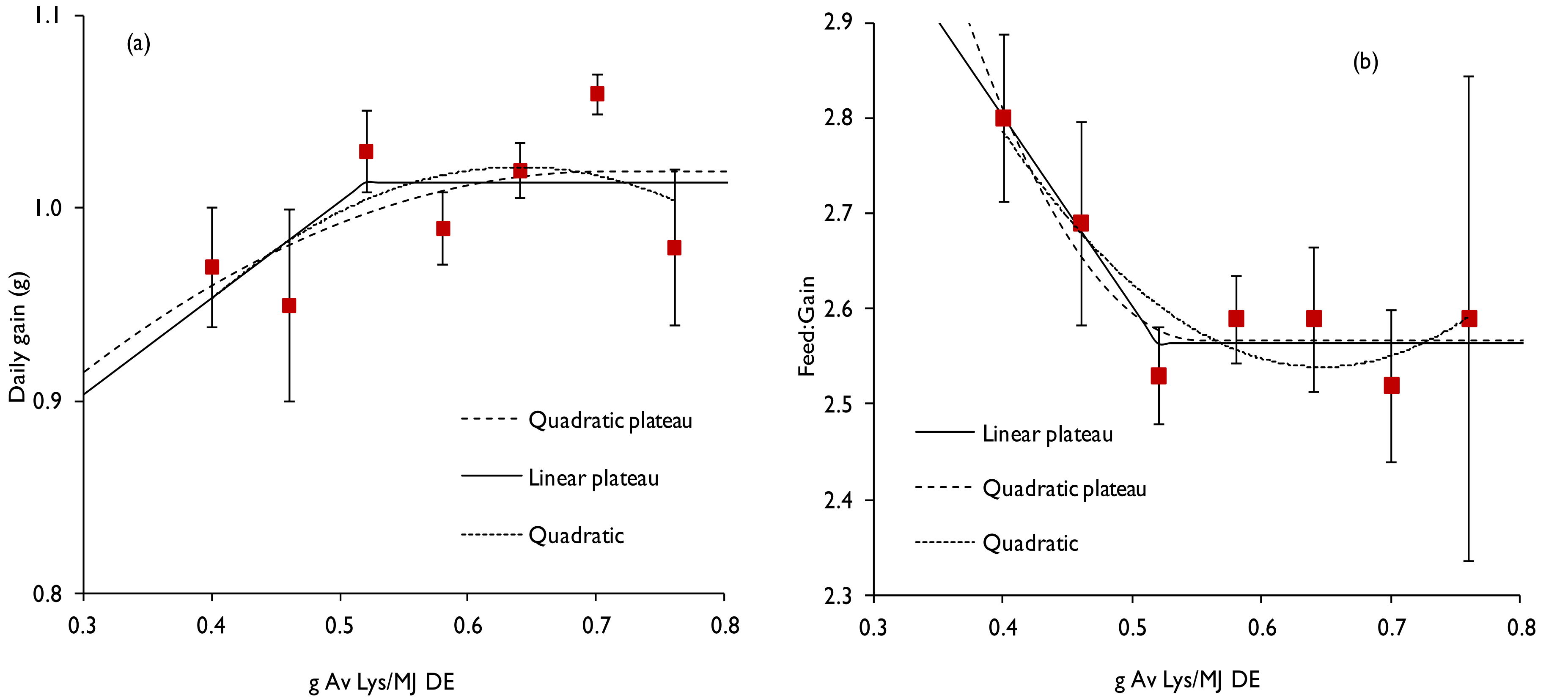

Figure 2: Effect of available lysine on daily gain (a) and feed to gain (b) for females (± SEM) 63.3 to 98.2 kg LW.

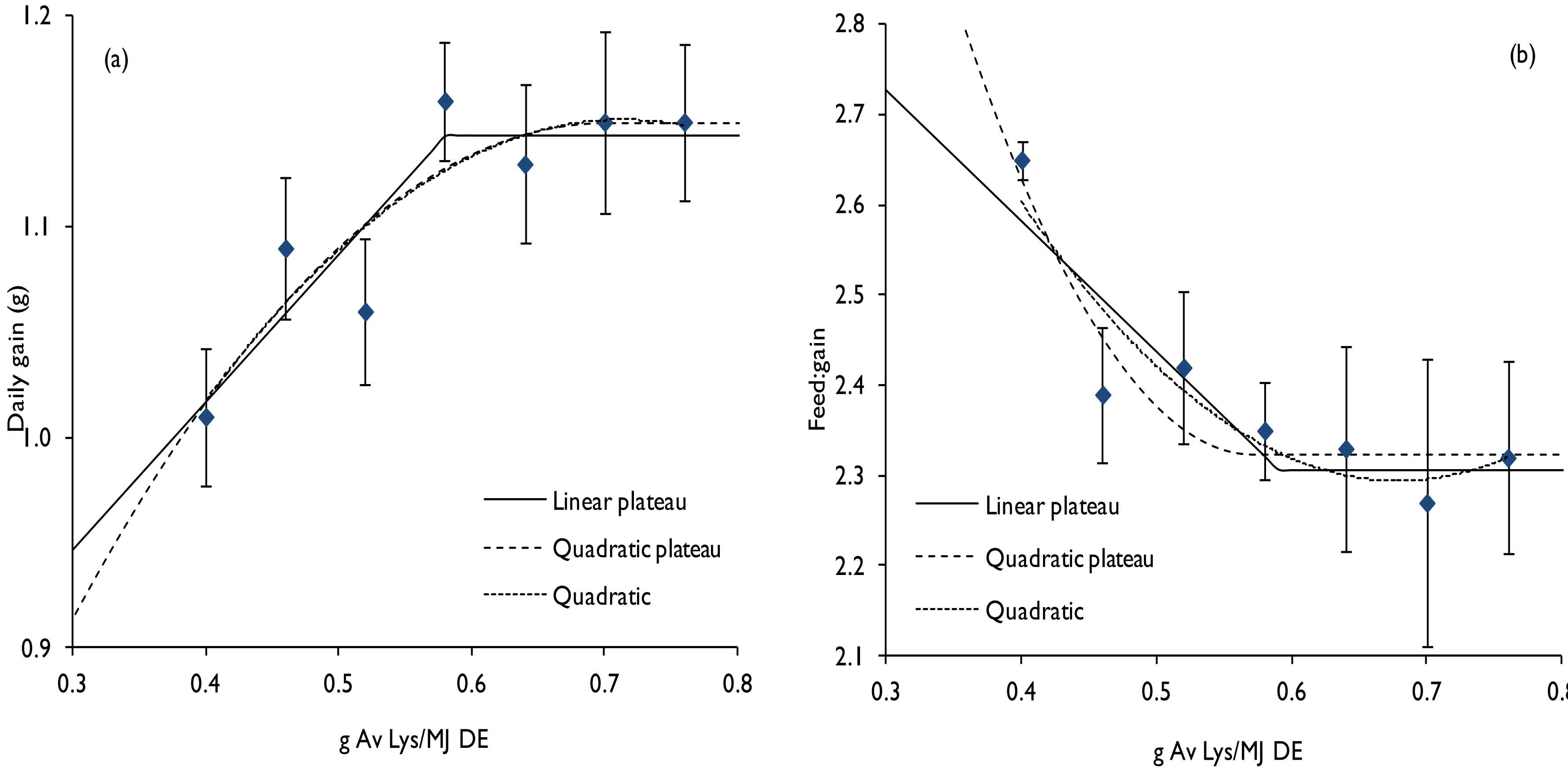

Figure 3: Effect of available lysine on daily gain (a) and feed to gain (b) for entire males (± SEM) 63.9 to 102.8 kg LW.

Table 5: Quadratic response equations[A] used to predict the optimum SID lysine level (g/MJ DE) for female and male pigs for maximum daily gain or minimum feed:gain ratio from 63 to 103 kg LW.

	Quadratic equation	R^2	Optimum lysine level
Females			
Daily gain	$y= -1.295x^2 + 1.594x + 0.516$	0.42	0.64
Feed to gain	$y= 3.915x^2 – 5.091x + 4.195$	0.82	0.65
Males			
Daily gain	$y= -1.368x^2 + 1.973x + 0.440$	0.80	0.72
Feed to gain	$y= 4.061x^2 – 5.438x + 4.138$	0.84	0.67

[A]Where y=either daily gain or F:G, x= g SID lysine/ MJ DE.

Table 6: Fitted lysine requirement using a linear-plateau (LP) or a quadratic-plateau (QP) model for female and male pigs from 63 to 103 kg LW.

	Model	Break point	Lysine requirement	SE	R^2	P=	Mean lysine requirement[1]
Females							
Daily gain	LP	1.01	0.52	0.077	0.37	0.003	0.62
	QP	1.02	0.71	0.366	0.35	0.126	
Feed to gain	LP	2.56	0.52	0.041	0.91	<0.001	0.54
	QP	2.57	0.55	0.054	0.87	<0.001	
Males							
Daily gain	LP	1.14	0.58	0.041	0.83	<0.001	0.64
	QP	1.15	0.70	0.126	0.81	0.005	
Feed to gain	LP	2.31	0.59	0.05	0.80	<0.001	0.58
	QP	2.32	0.57	0.06	0.86	<0.001	

[1]Mean lysine requirement: (LP+QP)/2

Table 7: Summary of predicted lysine requirements for female and male pigs from 63 to 103 kg LW using the different statistical models.

	Mean linear and quadratic plateau	Quadratic polynomial	Estimated lysine requirement
Females			
Daily gain	0.62	0.64	0.61
Feed to gain	0.54	0.65	
Males			
Daily gain	0.64	0.72	0.64
Feed to gain	0.58	0.67	

6. Experiment 1 Discussion

The objective of this experiment was to confirm the optimal Av Lys/MJ DE ratio for the Pig Improvement Company (PIC) genotype from 60 to 100 kg LW. In the present experiment pigs again showed a response to increased levels of lysine between 60 and 100 kg LW. The suggested SID lysine levels to optimise daily gain and minimise feed to gain in the LW range 60 to 100 kg were 0.62 g and 0.65 g/MJ DE for female and entire male pigs, respectively. This confirmed the results of Moore *et al.* (2012a) who found that for female pigs from 50 to 100 kg LW the mean SID lysine levels to optimise daily gain and feed to gain were 0.67 g and 0.60 g/MJ DE, respectively. In comparison, for entire male pigs the optimum SID lysine levels to optimise daily gain and feed to gain were 0.63 g and 0.70 g/MJ DE, respectively. These lysine levels were approximately 10% higher than those being used by the Australian industry (0.55 g SID lys/MJ DE). As reported by Moore *et al.* (2012a) the results in this experiment are also in agreement with recent studies where the estimated requirements were 0.50 g SID Lys/MJ DE (O'Connell *et al.* 2006) and 0.77 g SID Lys/MJ DE (Miller *et al.* 2008). In contrast, with Moore *et al.* (2012a) there was little difference in the optimum lysine to maximise daily gain and minimise feed to gain between entire males and females.

Moore *et al.* (2012a) reviewed the response of pigs to increasing dietary lysine in 2009 as it was likely that the latest pig genotypes had a greater potential to deposit more protein and therefore would respond to high levels of dietary protein (Campbell *et al.* 1985; Schneider *et al.* 2010). The higher lysine requirement for a genotype selected for high lean meat deposition is likely due to an increased rate of body protein deposition in modern genotypes (Campbell *et al.* 1988). For example, the mean P2 back fat of the pigs used by Campbell *et al.* (1988) was 20 mm, which is ~10 mm greater than the P2 back fat thickness in the present experiment. Campbell *et al.* (1988) suggested that the increased back fat thickness in pigs fed the high lysine diets in their study was likely due to the limited genetic capacity for lean deposition.

It was not possible in this experiment to calculate the lysine requirements for various LWs between 60 and 100 kg LW due to the meningitis outbreak. However, based on the overall requirement from 60 to 100 kg LW it is reasonable to assume that the optimum lysine levels at the liveweight ranges 65 to 80 kg and 80 to 95 kgs are similar to that suggested by Moore et al. (2012a), with the exception of the optimum feed to gain requirement from 80-95 kg LW for females. The increased response to lysine at higher liveweights is supported by Shelton *et al.* (2011) who found that for female pigs fed from 85 to 110 kg, growth performance was maximised at the highest level of lysine (1.07% total lysine) included. They also examined the response to lysine in female pigs from 55 to 80 kg LW. An increase in the response to lysine above current US recommendations was not observed in this experiment, however, they suggest that this was due to the positive PRRSv status of the pigs which meant they had a decreased potential for protein deposition and so would not have responded to higher lysine levels (Shelton *et al.* 2011).

In comparison with Moore *et al.* (2012a) the response to lysine in this experiment was estimated by the linear-plateau, quadratic plateau and a quadratic model. The choice of model to analyse the data can give different results (Baker, 1986; Dunshea *et al.* 2000). Baker (1986) states that the linear-plateau (broken-line) response describes the requirements of the average animal in a population. In contrast the curvilinear or quadratic method provides the requirements for a maximum response from all the animals in the population. Therefore, the quadratic method can overestimate the results while the linear-plateau can underestimate the requirements depending on the data set (Williams *et al.* 1984;

Robbins *et al.* 2006). In the current experiment the linear-plateau model also appeared to underestimate the requirements while in most instances both quadratic approaches appeared to overestimate the requirements. Williams *et al.* (1984) used an average of the linear-plateau model and the quadratic model which is similar to the approach in this experiment where an average of the linear-plateau, quadratic plateau and quadratic model was used to determine the optimum lysine requirement to maximise growth performance and minimise feed to gain.

7. Analysis of all sites

Similar experiments to that undertaken at DAFWA were also completed at CHM (APL Project 2012/009), Rivalea (APL Project 2011/1034.428) and APFG (APL Project 2011/1034.437). Despite the original intention of the experiment being the same at each site each experiment was of a slightly different design or methodology and a summary of each is given below. The results below are given for females only as this was the common sex across all of the sites. Only growth performance was compared as carcass data was not available for all sites. Further information on each experiment can be obtained by referring to the relevant APL report.

7.1 Methods

7.1.1 DAFWA

A total of one hundred and ninety six Large White x Landrace x Duroc female pigs were used in this experiment. The main treatment was available lysine to MJ digestible energy (Av Lys/MJ DE) ratio (0.40, 0.46, 0.52, 0.58, 0.64, 0.70 and 0.76 g Av Lys/MJ DE).

Pigs were sourced at approximately 50 kg LW from a high health status commercial herd whose bloodlines were sourced from the Pig Improvement Company. On arrival the pigs were stratified by liveweight and randomly allocated to treatment. The pigs were housed in groups of 7 in a naturally ventilated grower-finisher facility.

The experimental diets were fed for five weeks from 63.3 kg LW until slaughter at 98.2 kg LW.

7.1.2 APFG

A total of 1120 female pigs were used in this experiment. The main treatment was available lysine to MJ digestible energy (Av Lys/MJ DE) ratio (0.40, 0.46, 0.52, 0.58, 0.64, 0.70 and 0.76 g Av Lys/MJ DE).

Pigs were sourced at approximately 30 kg LW from a weekly production batch of commercial PIC pigs. The pigs were graded at placement into 4 weight categories (Heavy, Medium 1, Medium 2, Small) with each category commencing on experiment as they reached 60 kg LW. The pigs were housed in 56 pens with 20 pigs per pen.

The experimental diets were fed for six weeks from 60 kg LW until slaughter at 105 kg LW.

7.1.3 CHM

A total of one hundred and twenty female pigs from the PIC blood lines were used in this experiment. The main treatment was available lysine to MJ digestible energy (Av Lys/MJ DE) ratio (0.58, 0.64, 0.70 and 0.76 g Av Lys/MJ DE).

The pigs were housed in twelve pens with ten pigs per pen. The experiment was conducted in two time blocks.

The experimental diets were fed for 4 weeks from 61.0 kg LW until slaughter at 86.5 kg LW.

7.1.4 *Rivalea*

A total of 1584 female pigs (Large White × Landrace) with PrimeGro™ Genetics were used in this experiment. The main treatment was available lysine to MJ digestible energy (Av Lys/MJ DE) ratio (0.40, 0.46, 0.52, 0.58, 0.64, 0.70 and 0.76 g Av Lys/MJ DE).

The pigs were housed in groups of approximately 37 in a commercial finisher facility. Pigs commenced the experimental period over four replicates with the heaviest pens starting one week earlier than the lightest pens.

The experimental diets were fed for five weeks from 59.0 kg LW until slaughter at 85.3 kg LW.

7.1.5 *Statistics*

For each site a quadratic curve was fitted to the treatment means to predict the optimum dietary lysine concentration for maximum daily gain and minimum feed to gain ratio (F:G). The quadratic curves were fitted using $y = ax^2 + bx + c$, where y = either daily gain or F:G, x = g SID lysine/MJ DE and a, b, and c are representative components of the equation (O'Connell *et al.* 2006). The data was also analysed using the linear plateau and quadratic plateau models fitted to the treatment means (Nutrient Response Models Version 1.1, University of Georgia, Excel).

Two-way analysis of variance (ANOVA) was performed with the Genstat 15 program (VSN International Ltd, Hemel Hempstead, UK) to analyse the main effects of lysine level and site. Initial LW and final LW were used as covariates due to significant differences in these between the sites. The data from CHM was not included in the overall analysis as only 4 out of the 7 lysine levels were included in this experiment. For the overall result a quadratic curve and the linear plateau and quadratic plateau models were fitted to the treatment means to predict the optimum dietary lysine concentration for maximum daily gain and minimum F:G as described above.

7.2 Results

7.2.1 Individual sites

Each site was analysed using the linear plateau, quadratic plateau and quadratic models (Figure 4, 5, 6 and 7, Tables 9, 10 and 11) to determine the optimum lysine level to maximise daily gain and minimise feed to gain. For DAFWA the SID lysine level for daily gain was 0.62 and 0.64 g/MJ DE, and feed to gain was 0.54 and 0.65 g/MJ DE using the quadratic model and the mean for linear plateau and quadratic plateau model, respectively. For APFG the SID lysine level for daily gain was 0.68 and 0.73 g/MJ DE, and feed to gain was 0.63 and 0.71 g/MJ DE using the quadratic model and the mean for linear plateau and quadratic plateau model, respectively. For CHM the SID lysine level for daily gain was 0.735 and 0.76 g/MJ DE, and feed to gain was 0.64 and 0.74 g/MJ DE using the quadratic model and the mean for linear plateau and quadratic plateau model, respectively. For Rivalea the SID lysine level for daily gain was 0.54 g/MJ DE and for feed to gain was 0.48 g/MJ DE using the mean for the linear plateau and quadratic plateau models. The solution for the quadratic model was outside of the range of lysine levels tested.

7.2.2 Overall

Pigs were an average of 60.5 kg LW at the start of the experiment with those from Rivalea lighter by approximately 3 kgs than those from APFG and DAFWA ($P<0.001$, Table 8). Pigs from Rivalea ended the experiment more than 12 kgs lighter than those from DAFWA and 14 kgs lighter than those from APFG ($P<0.001$). Daily gain was higher for pigs from DAFWA and Rivalea compared to APFG, however there was no difference in feed to gain between sites ($P<0.001$ and $P=0.170$, respectively).

There was no difference in commencing LW between lysine levels however there was a trend for pigs on the lowest levels of lysine to be lighter than those on the higher levels at the end of the experiment ($P=0.813$ and $P=0.067$, respectively). Pigs that received the lowest levels of lysine grew slower ($P<0.001$) and had a worse feed to gain ($P<0.001$) compared to pigs that received the highest levels of lysine.

The optimum SID lysine requirement for females between 60 and 93 kg LW was assessed using linear plateau, quadratic plateau and quadratic models (Figure 8, Tables 9, 10 and 11). The SID lysine level for daily gain was 0.70 and 0.61 g/MJ DE, and feed to gain was 0.75 and 0.63 g/MJ DE using the quadratic model and the mean for linear plateau and quadratic plateau model, respectively.

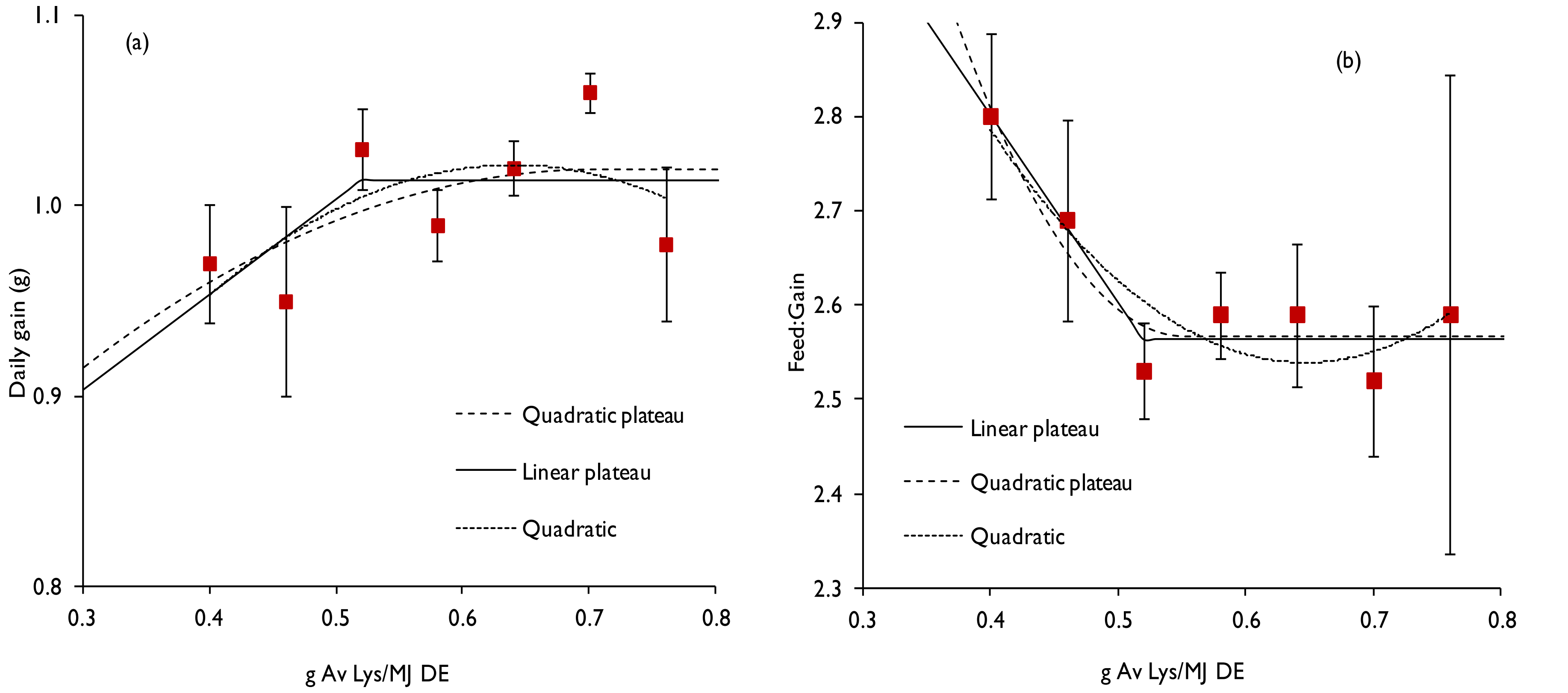

Figure 4: Effect of available lysine on daily gain (a) and feed to gain (b) for DAFWA females (± SEM) 63.3 to 98.2 kg LW.

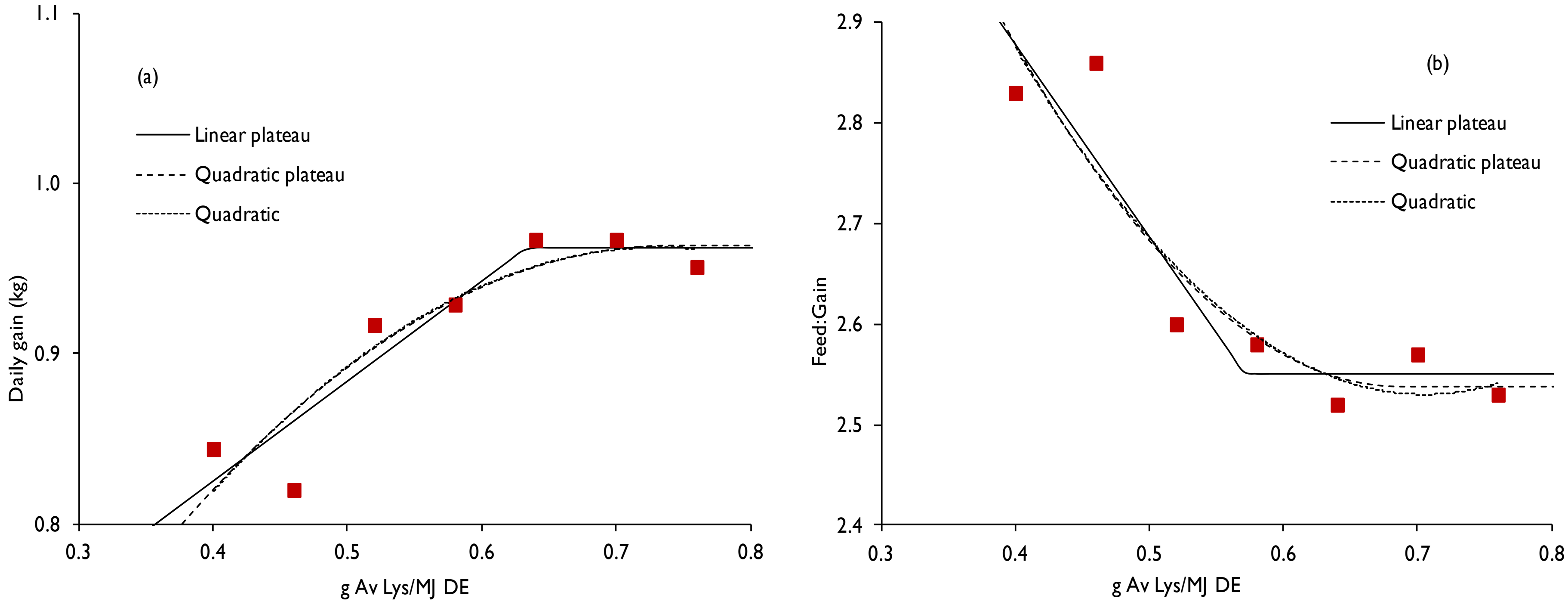

Figure 5: Effect of available lysine on daily gain (a) and feed to gain (b) for APFG females from 60 to 105 kg LW.

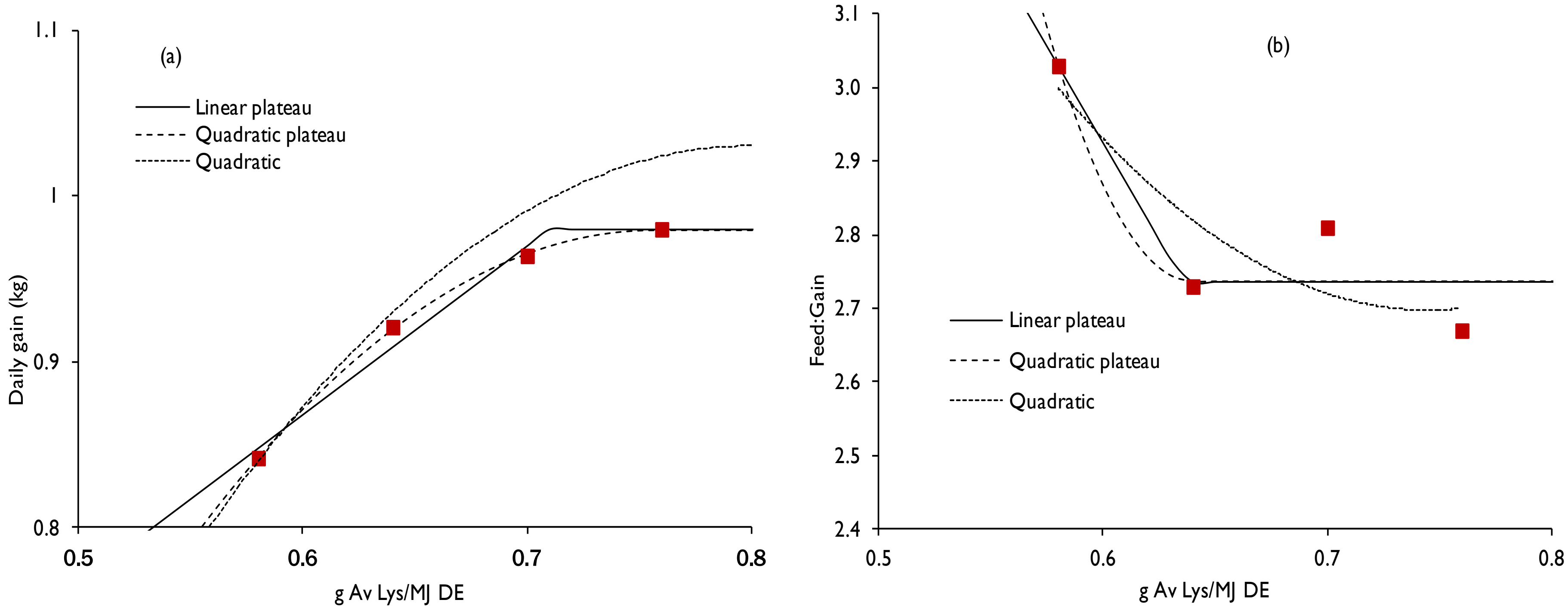

Figure 6: Effect of available lysine on daily gain (a) and feed to gain (b) for CHM females from 61 to 86.5 kg LW.

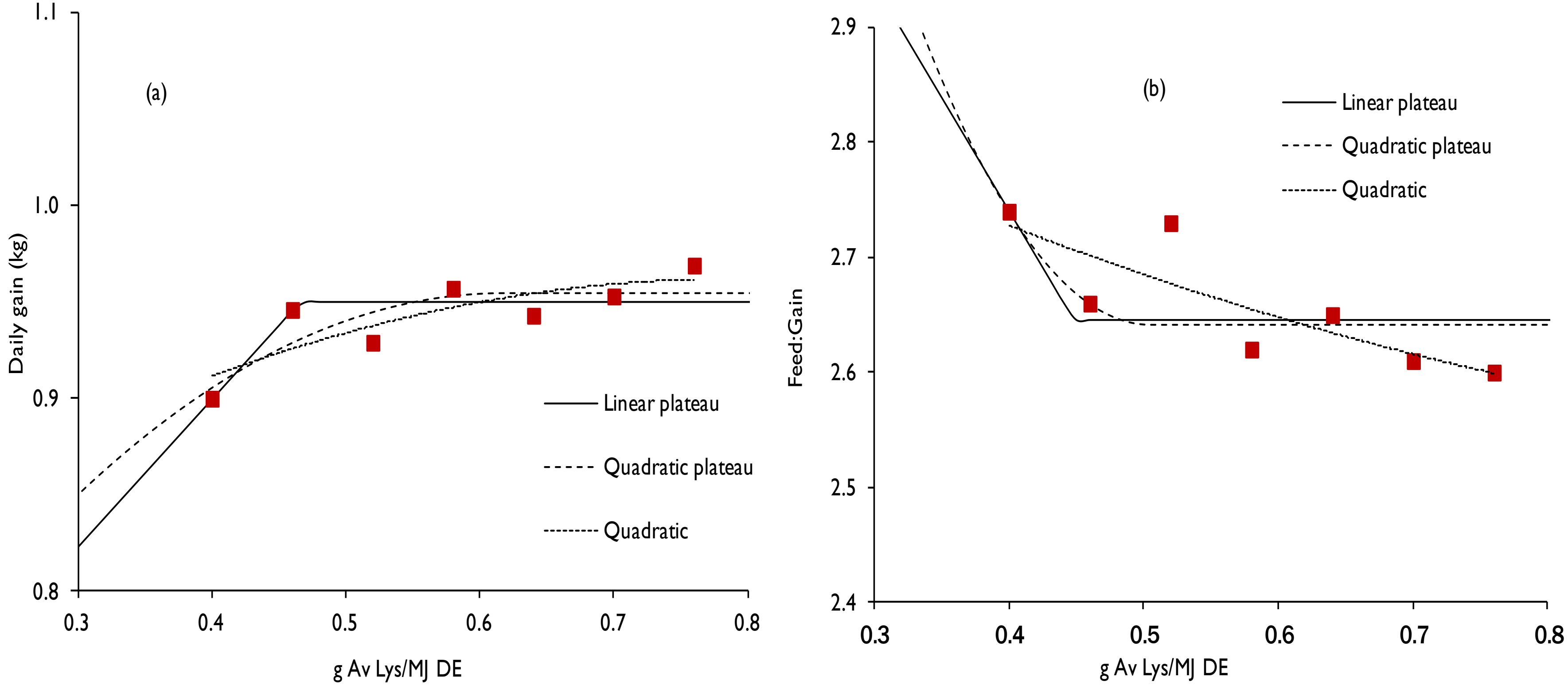

Figure 7: Effect of available lysine on daily gain (a) and feed to gain for Rivalea females from 58.4 to 85.3 kg LW.

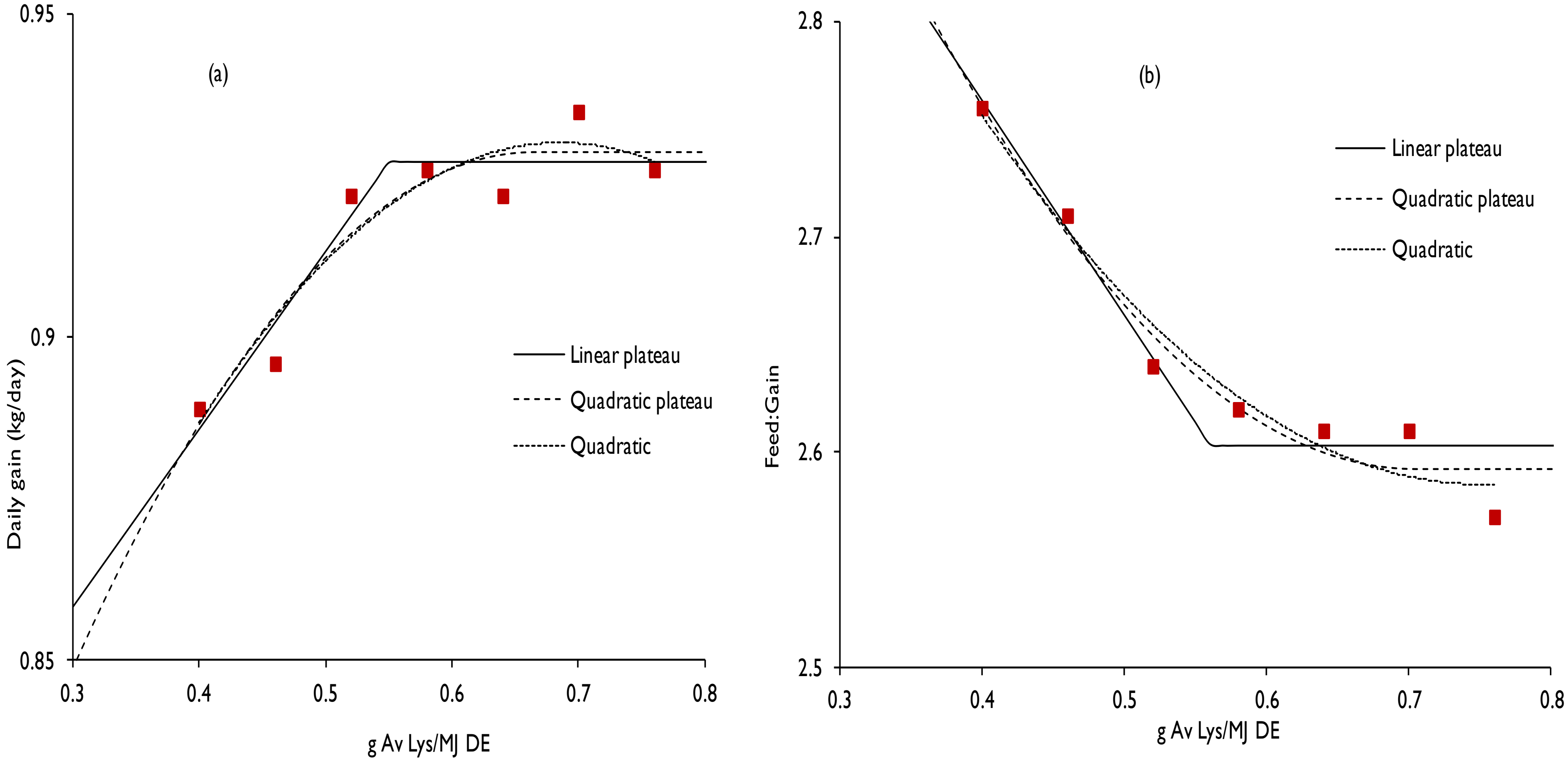

Figure 8: Effect of available lysine on daily gain (a) and feed to gain (b) for the combined data from 60.5 to 93.0 kg LW.

Table 8: Growth performance and carcase characteristics for female pigs fed varying levels of Av Lys/MJ DE from 60.5 to 93.0 kgs (n=4-6).

	Lysine level (g Av Lys/MJ DE)							SED[a]	P-value		
	0.40	0.46	0.52	0.58	0.64	0.70	0.76		Lysine	Site	LxS
Initial LW (kg)											
DAFWA	63.3	63.7	62.5	59.5	63.9	63.7	64.0				
APFG	61.1	61.7	61.3	60.3	61.0	61.3	61.6	2.39	0.813	<0.001	0.998
Rivalea	58.5	58.1	58.4	57.8	58.3	58.7	58.9				
Final LW (kg)											
DAFWA	96.7	96.9	98.7	95.0	99.6	100	98.1				
APFG	96.5	95.8	99.8	99.3	102	102	101	2.33	0.067	<0.001	0.782
Rivalea	83.9	84.5	85.1	85.8	85.5	85.3	86.8				
Daily gain (kg)[b]											
DAFWA	0.938	0.919	0.965	0.981	0.953	0.980	0.924				
APFG	0.800	0.790	0.830	0.841	0.848	0.853	0.844	0.027	<0.001	<0.001	0.322
Rivalea	0.916	0.951	0.954	0.944	0.950	0.961	0.983				
Feed to gain[b]											
DAFWA	2.80	2.69	2.53	2.48	2.59	2.52	2.62				
APFG	2.83	2.86	2.60	2.58	2.52	2.57	2.53	0.095	<0.001	0.170	0.384
Rivalea	2.76	2.70	2.72	2.66	2.65	2.66	2.57				

[a] SED for level × site

[b] Final LW and initial LW used as a covariate.

Table 9: Quadratic response equations[A] used to predict the optimum SID lysine level (g/MJ DE) for female finisher pigs for maximum daily gain or minimum feed:gain ratio.

	Quadratic equation	R^2	Optimum lysine level
DAFWA			
Daily gain	$y= -1.295x^2 + 1.594x + 0.516$	0.42	0.64
Feed to gain	$y= 3.915x^2 – 5.091x + 4.195$	0.82	0.65
APFG			
Daily gain	$y= -1.299x^2 + 1.903x + 0.265$	0.84	0.73
Feed to gain	$y= 4.061x^2 – 5.438x + 4.138$	0.84	0.71
CHM			
Daily gain	$y= -3.949x^2 + 6.316x – 1.495$	0.99	0.76
Feed to gain	$y= 11.11x^2 – 16.56x + 8.86$	0.76	0.74
Rivalea			
Daily gain	$y= -0.327x^2 + 0.52x + 0.756$	0.69	Outside range
Feed to gain	$y= -0.265x^2 – 0.664x + 2.951$	0.68	Outside range
Combined			
Daily gain	$y= -0.532x^2 + 0.731x + 0.678$	0.90	0.70
Feed to gain	$y= -1.389x^2 – 2.087x + 3.369$	0.95	0.75

[A]Where y=either daily gain or F:G, x= g SID lysine/ MJ DE.

Table 10: Fitted lysine requirement using a linear-plateau (LP) or a quadratic-plateau (QP) model for female finisher pigs.

		Model	Break point	Lys requirement	SE	R^2	P=	**Mean lysine requirement[1]**
Daily gain	DAFWA	LP	1013	0.52	0.078	0.37	0.003	**0.62**
		QP	1019	0.71	0.366	0.35	0.126	
	APFG	LP	962	0.63	0.057	0.88	<0.001	**0.68**
		QP	963	0.74	0.139	0.84	0.006	
	CHM	LP	980	0.71	0.02	0.98	0.018	**0.735**
		QP	979	0.76	0.006	1.00	0.005	
	Rivalea	LP	950	0.47	0.023	0.69	0.000	**0.54**
		QP	955	0.62	0.127	0.69	0.008	
	Combined	LP	927	0.55	0.029	0.91	<0.001	**0.61**
		QP	929	0.67	0.080	0.89	0.001	
Feed to gain	DAFWA	LP	2.56	0.52	0.041	0.91	0.001	**0.54**
		QP	2.57	0.55	0.054	0.87	0.001	
	APFG	LP	2.55	0.57	0.471	0.86	<0.001	**0.63**
		QP	2.54	0.69	0.107	0.84	0.003	
	CHM	LP	2.74	0.64	-	-	-	**0.64**
		QP	2.74	0.64	-	-	-	
	Rivalea	LP	2.64	0.45	-	-	-	**0.48**
		QP	2.64	0.51	0.124	0.42	0.015	
	Combined	LP	2.60	0.56	0.028	0.94	<0.001	**0.63**
		QP	2.59	0.70	0.058	0.95	<0.001	

[1]Mean lysine requirement: (LP+QP)/2

- Unable to solve with this approach

Table 11: Summary of predicted lysine requirements for female and male pigs from approx 60 to 100 kg LW using the different statistical models.

	Mean linear and quadratic plateau	Quadratic polynomial	Estimated lysine requirement
DAFWA			
Daily gain	0.62	0.64	0.61
Feed to gain	0.54	0.65	
APFG			
Daily gain	0.68	0.73	0.65
Feed to gain	0.63	0.71	
CHM			
Daily gain	0.735	0.76	0.71
Feed to gain	0.64	0.74	
Rivalea			
Daily gain	0.54	Out of range	0.51
Feed to gain	0.48	Out of range	
Combined			
Daily gain	0.61	0.70	0.64
Feed to gain	0.63	0.75	

7.3 Discussion

These experiments aimed to obtain an optimal Av Lys/MJ DE ratio for a modern genotype from 60 to 100 kg LW that was likely to be accepted by industry. Although different genotypes and slightly different designs were used it was possible with statistical analysis to determine both an individual requirement for each site and an overall requirement. An estimate of the optimal lysine requirement for the Australian pork industry to maximise growth performance for female pigs is 0.64 g Av Lys/MJ DE. This is approximately 10% higher than the level than was previously used by industry.

Unfortunately due to individual circumstances in each experiment it was not possible to obtain optimal lysine requirements for LW ranges within the overall range of 60-100 kg LW. However, given the overall similarity in results between Edwards (2013) and Moore *et al.* (2012a) (Figure 9) it may be reasonable to estimate the lysine requirements for the various LW ranges as given in Table 12.

Table 12: Estimate of the optimal lysine requirements for various LW ranges in the finisher period.

LW (kg) Edwards (2013) (Moore *et al.* 2012a)	Edwards (2013)	Moore *et al.* (2012a) Daily gain, Feed to gain	Recommended level
60-75 (50-65)	0.64	0.67, 0.64	0.65
75-90 (65-80)	0.58	0.63, 0.66	0.62
90-105 (80-95)	0.52	0.58, 0.40	0.55

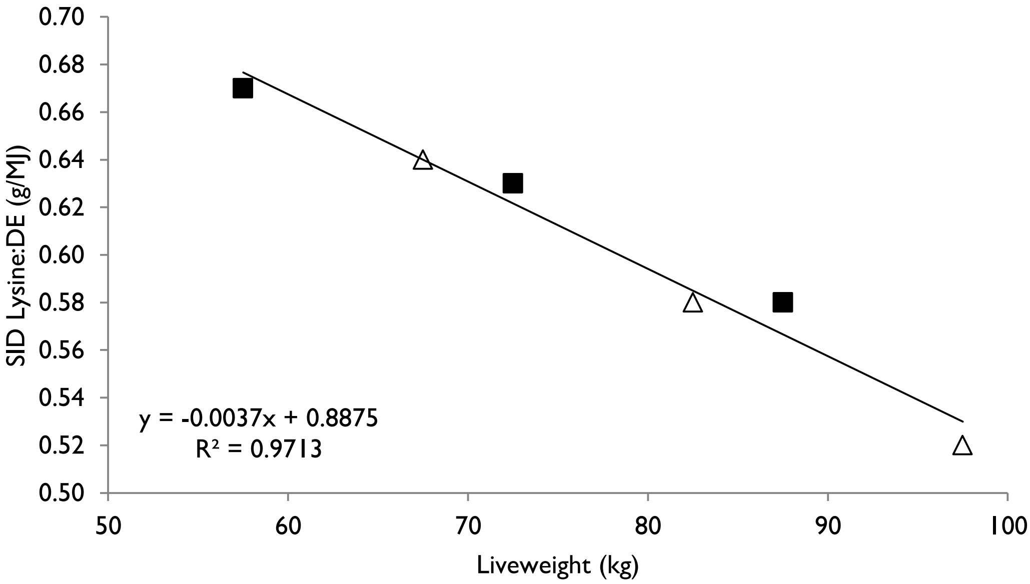

Figure 9: Regression of combined estimates of lysine requirements to maximise daily gain for Moore et al. (2012a) (■) and Edwards (2013) (∆) from 50 to 100 kg LW (Graph courtesy of Tony Edwards, ACE Livestock Consulting).

8. Experiment 2 Introductory Technical Information

The conventional practice among the majority of pork producers in Australia is for pigs to be fed three or four diets during the grower-finisher (20 -100 kg LW) period. However, since the requirements of pigs are constantly changing, the diet is frequently supplying excess nutrients as the requirement for protein relative to energy decreases as weight increases (MLC Technical Division 1998). An alternative is blend-feeding in which two diets are mixed together in varying ratios, allowing the diet to be changed on a weekly basis. This has the potential to reduce feed costs and minimise nitrogen output as the diet more accurately matches the requirements of the growing pig (Mullan *et al.* 1997). The opportunity to blend-feed is now more commercially viable with the development of dry and liquid feeding systems which have the ability to deliver any number of blends of feed in different pens. On the opposite spectrum to blend-feeding is feeding the same diet throughout the grower-finisher period. While the diet is deficient in nutrients initially, during the later stages there is an excess supply of energy and amino acids and the compensatory growth phenomenon should occur (Fabian *et al.* 2002). The single diet has the advantage of simplifying the feeding of pigs and could possibly offer a means to improve the decrease in feed efficiency found in the late finishing stage (Edwards, 2011).

Moore *et al.* (2012b) found that blend feeding and feeding a single diet reduced diet costs by approximately $3/pig compared to the conventional three-phase feeding regime with no impact on growth performance or conventional measures of carcass quality (P2 backfat thickness and dressing percentage). Feeding a single diet and blend feeding were then subsequently explored in a commercial environment by Edwards (2011). Similarly, they found little difference in growth performance between the single diet and the conventional three-phase feeding program when fed from 25 kg LW (Edwards, 2011). However, in this study the compensatory growth effect observed by Moore *et al.* (2012b) was not observed. There was some concern that the lysine requirement in the diet was not sufficient and as a result the true effect of feeding the single diet was not realised (Edwards, 2011). As a result there has not been any uptake of this finding by the Australian pork industry.

Since the experiments of Edwards (2011) and Moore *et al.* (2012b) were conducted, the current lysine requirements of grower-finisher pigs have been determined in a number of herds. Moore *et al*. (2012a) found that the current requirement for lysine of pigs from 50 to 100 kg LW was approximately 10% higher than that being used by industry. This result was confirmed in Experiment 1. Three other experiments were also conducted by Australian Pork Limited in Queensland (CHM Farms), New South Wales (Rivalea) and South Australia (Australian Pork Farms,). While some of these experiments were compromised by disease outbreaks, the results are similar to that determined by Moore *et al*. (2012a). Therefore it is proposed to further investigate the use of blend feeding and feeding a single diet throughout the grower and finisher phase using the ideal lysine requirements that have been determined. Using the lysine requirements of the modern genotype should allow the maximum growth response and feed efficiency to be realised.

The proposed experiment also incorporated measures of whole body protein/fat deposition rate using Dual-energy X-ray Absorptiometry (DXA), meat quality and intramuscular fat, which was not included in the first experiment (Moore *et al*, 2012b), as there is the potential that feeding the single diet may alter mobilisation/distribution of body fat and will increase intramuscular fat due to the lysine restriction in the early growing period (De Greef *et al.* 1992). Increasing the level of intramuscular fat has positive benefits on sensory pork quality (Font-i-Furnols *et al*., 2012). Therefore, this experiment examined effects of three different feeding strategies (conventional three-phase feeding, blend feeding and single diet feeding) on growth performance, carcass composition, economic analysis and meat quality.

The hypotheses were:

1. Blend feeding or feeding a single diet will reduce the cost of feeding pigs compared to the conventional system by minimising the excess of nutrients in the diets without adversely affecting pig growth performance, whole body protein and fat deposition rate, carcass quality and meat quality.
2. There will be no difference in growth performance of blend feeding compared to feeding pigs a single diet.
3. Pigs fed a single diet will have more intramuscular fat than those that receive the conventional or blend feeding diet.

9. Experiment 2 Research Methodology

The experiment was conducted at the Department of Agriculture and Food Western Australia's (DAFWA) Medina Research Centre. The experimental protocols used were approved by the DAFWA Animal Research Committee and by the Animal Ethics Committee. The animals were handled according to the Australian code of practice for the care and use of animals for scientific purposes (NHMRC, 2013).

9.1 Animals and experimental design

A total of 147 female pigs (Large White × Landrace × Duroc) were allocated to the following treatments: (1) phase-feeding: diets change when the average liveweight (LW) of pigs in the pen reaches 30, 50 or 80 kg; (2); blend: diets change weekly to meet the requirements of the average LW of pigs in the pen and; (3) single: the same diet is fed throughout (formulated to meet the requirements of the pig at 60 kg LW). The protocol used in the experiment conformed to all regulations of the Western Australian Department of Agriculture and Food Animal Ethics Committee (AEC Activity No. 2-14-08) concerning the health and care of experimental animals.

9.2 Allocation and housing

Pigs were sourced at approximately 21 kg LW from a high health status commercial herd whose bloodlines were sourced from the Pig Improvement Company. On arrival the pigs were stratified by LW and randomly allocated to treatment. The pigs were housed in groups of 7 in a naturally ventilated grower-finisher facility. All pigs had *ad libitum* access to feed and water for the entire period of the experiment.

9.3 Diets

The experimental diets were fed for ten weeks from 30.1 (±0.33 SEM) kg LW until slaughter at 97.3 (±1.4 SEM) kgs LW. The level of standardised ileal digestible (SID) lysine required for pigs from 30 to 100 kg LW was determined from the results of Moore et al (2012a) and from Experiment 1 and is given in Table 13. These values were then used to set the nutrient specifications and formed the basis for formulating the base diets (Table 14). The energy contents of the high and low lysine diets were set according to standard industry practice (14.5 and 13.5 MJ digestible energy (DE)/kg, respectively). All diets were created by blending the high and low lysine diets in the appropriate ratios for the lysine requirement relative to weight. The diet for the single treatment comprised 45% of the high lysine diet and 55% of the low lysine diet and was 13.9 MJ DE/kg and 0.65 g SID lysine/MJ DE. The energy and SID lysine contents of the blend diets were gradually decreased on a weekly basis from 14.5 MJ/kg and 0.84 g SID lysine/MJ DE to 13.5 MJ/kg and 0.49 g SID/MJ DE. The diets were submitted for quantitative amino acid analysis (Animal Health Laboratories, Department of Agriculture and Food Western Australia) and the results are given in Table 15.

Table 13: The predicted lysine requirement (g SID lysine/MJ DE) for pigs of different LW and the blending ratios of the low and high lysine diets for the blend treatment.

	Treatment			Blending ratio	
LW (kg)	**Predicted and blend requirement**	**Conventional**	**Single**	**Low (%)**	**High (%)**
30	0.84	0.84	0.65	0	100
35	0.81	0.84	0.65	10	90
40	0.77	0.84	0.65	20	80
45	0.73	0.84	0.65	30	70
50	0.67	0.67	0.65	45	55
55	0.66	0.67	0.65	50	50
60	0.65	0.67	0.65	55	45
65	0.63	0.67	0.65	60	40
70	0.60	0.67	0.65	70	30
75	0.57	0.67	0.65	75	25
80	0.55	0.55	0.65	80	20
85	0.53	0.55	0.65	85	15
90	0.52	0.55	0.65	90	10
95	0.50	0.55	0.65	95	5
100	0.49	0.55	0.65	100	0

Table 14: The composition of the diets for the two lysine levels.

Diet	**Low**	**High**
Ingredients (g/kg)		
Wheat	388	349
Barley	401	196
Canola meal	127	150
Soyabean meal	20	205
Meat and bone meal	40.0	40.0
Tallow press	-	30.0
Tallow mixer	8.00	9.00
Salt	3.00	3.00
Limestone	10.0	10.0
Dical Phosphorus	1.00	-
Lysine-HCl	1.20	3.50
Alimet	-	1.60
Threonine	-	1.64
Phytase	0.05	0.05
Minerals and Vitamins[a]	1.00	1.00
Nutrient composition[b]		
DE (MJ/kg)	13.5	14.5
Crude protein (%)	15	22.4
SID lysine	6.34	12.4

[a] Each kilogram of vitamin and mineral premix contains 11 MIU Vitamin A, 2.1 MIU Vitamin D_3, 100 g Vitamin E, 3 g Vitamin K, 3 g Vitamin B_1, 7 g Vitamin B_2, 4 g Vitamin B_6, 29 mg Vitamin B_{12} 36 g niacin, 36 mg pantothentic acid, 1 g folic acid, 143 mg biotin, 1 g Calcium pantothenatic, 80 g iron, 143 g zinc, 57 g manganese, 29 g copper, 1 g cobalt, 1 g iodine, and 100 g antioxidant.

[b] Calculated composition.

Phytase from Phyzyme, Danisco Australia Pty Ltd.

Table 15: Quantitative amino acid analysis of the two basal diets.

Amino acid (g/100 g)	Low	High
Cysteine-x	0.36	0.46
Histidine	0.35	0.51
Serine	0.66	1.06
Arginine	0.86	1.36
Glycine	0.73	1.10
Aspartic acid	1.01	1.65
Glutamic acid	3.10	4.19
Threonine	0.56	0.94
Alanine	0.63	0.93
Proline	1.27	1.50
Lysine	0.72	1.28
Tyrosine	0.48	0.75
Methionine	0.25	0.32
Valine	0.62	0.90
Isoleucine	0.46	0.98
Leucine	1.05	1.54
Phenylalanine	0.63	0.96

9.4 Measurements

Individual pig weight was recorded on the same day and at approximately the same time each week, and feed disappearance was recorded daily using the Feedlogic system. The feed to gain ratio was calculated on a per pen basis by dividing the total weight of feed eaten by the LW gain in the same period.

Three pigs in each pen were randomly selected for carcass composition assessment using dual-energy x-ray absorptiometry (DXA). The pigs were scanned immediately prior to the commencement of the experiment (Day -1, where Day 0 is the commencement of the experiment) and one week prior to the end of the experiment (Day 63). The pigs were removed from feed and fasted for approximately 16 hours before scanning. Immediately prior to scanning the pigs were weighed and then transferred to the DXA facility. They were injected intramuscularly with Stresnil® (azaperone 40 mg/mL, Stresnil Neuroleptic Injection for Pigs, Ausrichter Pty Ltd, NSW) at 2 mL/10 kg LW. When sufficiently sedated the pigs were transferred to the DXA machine (Norland XR46 Densitometer Machine). The pigs were scanned in ventral-recumbency, with hind legs extended. Whole body mode was used to scan and the scan was subsequently analysed using whole body analysis. Measurements made by DXA included total tissue mass, lean tissue mass, fat tissue mass and bone mineral content. After scanning the pigs were placed in a recovery room until they were able to stand and were then returned to their pens. The pigs were given their respective diets on return to their individual pens.

After 70 days on the experimental diet the pigs were individually tattooed, removed from feed overnight and transported to a commercial abattoir (approx. 90 minute transport time). The pigs were stunned using a carbon dioxide, dip-lift stunner set at 85% CO_2 for 1.8 minutes (Butina, Denmark). Exsanguination, scalding, dehairing and evisceration were performed using standard commercial procedures. Hot carcass weight (AUSMEAT Trim 13; head off, fore trotters off, hind trotters on; AUS-MEAT Ltd, South Brisbane, Qld, Australia) and P2 backfat depth, 65 mm from the dorsal midline at the point of the last rib (PorkScan Pty Ltd, Canberra) were measured approximately 35 minutes after exsanguination, prior to chiller entry (2°C, airspeed 4 m/second).

Objective meat quality assessment was undertaken on the pigs that had been scanned and on one additional pig randomly selected from each pen (n=28). At 24h post-slaughter a section of the *Longissimus thoracis* (LT) muscle was removed from the left hand side of the carcass between the 12^{th} and 13^{th} rib. For determination of pH, temperature and drip loss a 2 cm steak was cut from the appropriate sample. The muscle pH was measured using a portable pH/temperature meter (Cyberscan pH 300, Eutech Instruments,Singapore) fitted with a polypropylene spear-type gel electrode (Ionode IJ44, Ionode Pty Ltd, Brisbane, QLD) and a temperature probe. Drip loss was measured in duplicate using a modification of the method described by Rasmussen and Andersson (1996). The muscle was cut to a 40 g cube then wrapped in netting and suspended in a sealed plastic container. The samples were stored for 24h at 4°C. The sample was then removed and gently patted dry to remove excess moisture before being re-weighed. Colour (relative lightness - L*, relative redness - a* and relative yellowness - b*) was measured with a Minolta Chromameter CR-400 (Minolta, Osaka, Japan), using D65 illumination, a 2° standard observer, and an 8-mm aperture in the measuring head, standardised to a white tile after a bloom time of 10 min. An 80±5 g sample was cut from the loin samples to measure cooking loss and shear force (Bouton, Harris, & Shorthose, 1971). The samples were then frozen in individual bags. The bagged frozen samples were then suspended from a metal rack and placed in a water bath which had been pre-heated to 70°C. The samples were then cooked at 70°C until an internal temperature of 70°C was reached (approximately 30 minutes). After removal from the water bath, the samples were allowed to cool in iced water for 30 min, patted dry to remove excess moisture, and re-weighed before being refrigerated at 4°C overnight. Cooking loss percentage for each sample was determined by dividing the difference in the raw and cooked weights by the weight of the raw pork sample. The cooked sample was then cut into five cross-section samples (1 cm^2) parallel to the muscle fibres. Warner Bratzler shear force was measured using a Warner Bratzler shear blade fitted to a Lloyd Texture Analyser (TA-2, United Kingdom). A 40 g sample of LT muscle, trimmed of visible fat and skin, was used to determine the percentage of intramuscular fat via the Ankom method (extraction of crude fat using petroleum ether) (Silliker Australia, Perth, Australia).

9.5 Statistical analysis

One-way analysis of variance (ANOVA) was performed with the Genstat 15 program (VSN International Ltd, Hemel Hempstead, UK) to analyse the main effect of feeding strategy. Pen was used as the experimental unit for the growth performance data. Pig was used as the experimental unit for the carcass, DXA and meat quality data. A level of probability of less than 0.05 was used to determine statistical difference between treatments.

10. Experiment 2 Results

The growth performance and carcass evaluation results are present in Table 16. The results have been analysed over three periods, the first corresponding to the period the diets were introduced until 60 kg LW when the single diet was considered to be deficient (Day 0-35), and the second from this point to slaughter (Day 35-70), and then overall (Day 0-70). There was no difference in LW, daily gain, feed intake or feed to gain for any time period (P>0.05). There was a trend for the DE intake per kg LW gain to be lower for the blend and single diet compared to the phase diet from Day 0-35 (P=0.073). From Day 35-70 the DE intake per kg LW gain was lower for pigs on the blend diet compared to those on the phase or single diet feeding strategy (P<0.001). Overall the DE intake per kg LW gain was lower for pigs on the blend diet compared to phase feeding strategy (P<0.007). There was no difference in the DE intake per kg LW gain between the blend and single feeding strategy or the single and phase feeding strategy (P>0.05). Carcass weight and P2 backfat were not affected by feeding regime (P>0.05). Pigs fed the single diet had a lower dressing % compared to pigs fed the phase diet (P=0.05). There was no difference in dressing % between the single and blend feeding strategy or the blend and phase feeding strategy. There was no significant difference in diet costs per pig between feeding strategies (P>0.05).

The coefficient of variation for daily gain, feed intake and feed to gain is given in Table 17. There appears to be little difference in the coefficient of variation between feeding strategies for daily gain. However, feed intake and feed to gain appear to be increased for the single diet and blend feeding for Day 35-70 and overall compared to phase feeding.

Pigs on the blend or single feeding strategy deposited 38 g/day more fat than phase fed pigs (P=0.026). There was no difference in the amount of lean or ash deposited per day between feeding strategies (P=0.336 and P=0.368, respectively; Table 18).

There was no difference between feeding strategies for any measure of meat quality (P>0.05, Table 19). Pigs receiving the blend feeding strategy had nearly twice as much intramuscular fat compared to phase feeding or the single feeding strategy (P=0.029).

Table 16: Liveweight (LW), average daily gain (ADG), feed intake (FI) and feed conversion ratio (FCR) for female pigs fed one of three different feeding strategies.

	Feeding strategy			SEM	P-value
	Phase	Blend	Single		
		LW (kg)			
Day 0 (start)	30.1	30.0	30.2	0.333	0.734
Day 35	62.2	62.1	62.3	0.939	0.963
Day 70 (end)	97.4	96.2	98.4	1.40	0.335
		Daily gain (g/day)			
Day 0-35	917	917	917	0.021	1.00
Day 35-70	1007	975	1030	0.027	0.178
Day 0-70	962	946	973	0.018	0.343
		Feed intake (g/day)			

Day 0-35	1957	1946	1947	0.063	0.979
Day 35-70	2506	2487	2503	0.087	0.974
Day 0-70	2231	2216	2225	0.066	0.974
		Feed to gain (g feed/g LW gain)			
Day 0-35	2.14	2.12	2.12	0.038	0.869
Day 35-70	2.49	2.55	2.43	0.066	0.227
Day 0-70	2.32	2.34	2.28	0.048	0.501
		DE intake (MJ DE/kg LW gain)			
Day 0-35	33.8	31.4	29.0	1.85	0.073
Day 35-70	44.3^{b}	40.3^{a}	46.3^{b}	1.15	<0.001
Day 0-70	39.3^{b}	36.0^{a}	38.1^{ab}	0.856	0.007
		Carcass evaluation			
CW (kg)	68.7	67.1	68.6	1.02	0.204
Dressing %	70.6^{a}	70.0^{ab}	69.8^{b}	0.328	0.050
P2 (mm)	9.43	9.61	9.39	0.395	0.837
		Diet costs/pig			
	$67.75	$65.89	$65.82	1.83	0.509

Table 17: Coefficient of variation (%) for growth performance for female pigs fed one of three different feeding strategies from 30 to 97 kg LW.

	Feeding strategy		
	Phase	Blend	Single
		Daily gain	
Day 0-35	7.91	4.78	6.78
Day 35-70	4.48	6.43	4.51
Day 0-70	5.50	4.05	4.61
		Feed intake	
Day 0-35	6.12	5.07	10.2
Day 35-70	4.23	7.25	8.02
Day 0-70	4.74	5.73	8.32
		Feed to gain	
Day 0-35	3.51	2.81	5.55
Day 35-70	1.97	5.37	6.61
Day 0-70	1.52	3.56	5.44

Table 18: Change in carcass composition using DXA for female pigs fed one of three different feeding strategies from 30 to 87 kg LW (n=21).

	Feeding strategy			SEM	P-value
	Phase	Blend	Single		
Lean (g/day)	778	753	752	20.0	0.336
Fat (g/day)	140^{a}	178^{b}	178^{b}	15.7	0.026
Ash (g/day)	18.5	17.6	18.3	0.667	0.368

Table 19: Objective meat quality for female pigs fed one of three different feeding strategies from 30 to 97 kg LW (n=28).

	Feeding strategy			SEM	P-value
	Phase	Blend	Single		
pH 24hr	5.46	5.46	5.47	0.029	0.959
Temperature	11.4	11.6	11.4	0.260	0.660
Drip loss (%)	6.92	6.42	5.92	0.859	0.507
L*	54.5	54.2	52.9	0.905	0.162
a*	6.27	7.08	6.90	0.377	0.089
b*	3.83	3.83	3.83	0.360	1.00
Cook loss (%)	19.8	20.2	19.4	0.708	0.536
Shear force (N)	39.9	41.9	44.1	2.62	0.296
IM fat (%)	0.40[a]	0.77[b]	0.45[a]	0.106	0.029

11. Experiment 2 Discussion

The hypothesis that blend feeding or feeding a single diet will reduce the cost of feeding pigs compared to the conventional system by minimising the excess of nutrients in the diets without adversely affect pig growth performance, whole body protein and fat deposition rate, carcass quality and meat quality was not supported. There was no difference in the cost of feeding pigs between the feeding strategies. This is in contrast to Moore *et al.* (2012b) who found that feeding a single diet and blend feeding from 20 to 100 kgs LW reduced feed costs by 3.51% and 3.74%, respectively, compared with the phase-fed diet. BPEX (2004) also fund no difference in feeding costs between blend and single diets, however, a phase-feeding strategy was not included in that experiment. In contrast, MLC Technical Division (1998) found that it was cheaper to phase-feed, than feed either a single or two diets from 30 kg to slaughter (at either 88 kg or 107 kg). The differences in costs between experiments may be due to the lysine levels targeted or the raw ingredient costs at the time of diet formulation and may need to be assessed on a case-by-case basis.

The hypothesis that there will be no difference in growth performance of blend feeding compared to feeding pigs a single diet was supported. Daily gain, feed intake and feed to gain were the same for each feeding strategy. This is in agreement with Moore *et al.* (2012b) and Edwards (2011) who also found no difference in overall growth performance between phase-feeding, blend and single feeding strategies. Mullan *et al.* (1997) also found no difference in growth performance between phase-feeding and blend feeding strategies. In contrast when using a similar SID lysine content to this experiment in pigs from 30 to 110 kg LW BPEX (2004) found that feeding a single diet significantly improved daily intake and gain. MLC Technical Division (1998) also found that that feeding a single diet to pigs from 30 to 88 kg LW improved the growth rate compared to phase-feeding.

There was also no evidence of compensatory growth when pigs were fed a single diet in this experiment as there was no difference in growth performance or feed intake in either the first period to 60 kg LW or the second period from 60 kg LW to slaughter. It was thought that while the diet is deficient in nutrients initially, during the later stages there is an excess supply of energy and amino acids and the compensatory growth phenomenon should occur (Fabian *et al.* 2002). Edwards (2011) also found no compensatory growth when feeding a single diet from 25 to 103 kg LW. In contrast, Moore *et al.* (2012b) found that from 98 days of age (approximately 54 kg LW) pigs on the single diet feeding strategy had a significantly better feed to gain that those in the phase-feeding or blend feeding strategy.

The differences between Moore *et al.* (2012b) and the present experiment in both diet costs and lack of any compensatory growth may be because of the initial commencing LW and that these pigs were sold on time and not by LW. Commencing at 20 kg LW as was the case in Moore *et al.* (2012b) may help to improve the cost benefit of the single diet as more of the cheaper diet is fed. The initial LW of 30 kg was chosen in the present experiment to be more representative of commercial practice in terms of for example, shifting of pigs into different accommodation.

None of the feeding strategies appeared to have an effect on the coefficient of variation for daily gain, however the coefficient of variation for feed intake and feed to gain was increased for Day 35-70 and for the overall period. BPEX (2004) also found no difference in the variability of gain between pigs fed either a phase or single diet when variance was determined by looking at the within pen standard deviation, however they did not look at variation for intake or feed to gain.

The hypothesis that pigs fed single diet will have more intramuscular fat than those that receive the phase feeding or blend feeding diet was not supported. Pigs fed the blend feeding strategy had nearly twice as much intramuscular fat as those receiving the phase feeding or single diet feeding strategy. In addition, carcass fatness was increased in both the blend and single feeding strategy, however, this was not reflected in an increase in backfat or in intramuscular fat in the single diet. It was thought that feeding a single diet may alter the mobilisation of body fat and increase the level of intramuscular fat due to protein restriction in the early growing period. For example, in protein restricted pigs from 25 to 65 kg LW, de Greef *et al.* (1992) found twice as much whole body lipid compared to the controls. From 65 to 105 kg LW a nutrient adequate diet was fed and a compensatory growth response was observed. The protein deposition increased by 13% in the pigs which had been previously restricted while the ratio of lipid to protein deposition decreased from 1.69 to 1.23 (de Greef *et al.* 1992). An intermediate DXA scan was not performed at 60 kg LW in this experiment so it is unknown how the fat and lean deposition changed before and after the diet met the nutrient requirements of the pigs. It is possible that part of the increase in carcass fatness was due to the lysine restriction, however this may not be the whole story as the expected compensatory growth response was not observed nor was there any difference in growth performance in the period from 30 to 60 kg LW between those on the phase fed or single diet. The increase in both intramuscular fat and carcass fatness in pigs that were blend-fed was unexpected as the pigs were fed a diet that reflected their nutrient requirements at all stages and although the diet was changed regularly the changes in composition were minimal. It may be possible that the predicted lysine requirements at the highest LWs were slightly understated.

Although nitrogen excretion rate was not measured in this experiment, as in Moore *et al.* (2012b) it is worth noting the extra benefit the blend-feeding strategy might offer for sustainability of the pork industry. The blend-feeding diet matches the nitrogen requirements of the pig more accurately than a conventional phase-feeding strategy. For example, a computer-simulation study predicted that daily tailored blend-feeding can reduce nitrogen excretion by 38% compared with a conventional three phase-feeding system (Pomar *et al*. 2009). Pomar *et al.* (2007) observed a 12% reduction in N excretion due to a 7% reduction in N intake during the grow-finish period. This has benefits in terms of reducing costs and also in terms of reducing the impact of pig production on the environment by reducing nutrient excretion (Portejoie *et al.* 2004).

12. Implications & Recommendations

Lysine level

An estimate of the optimal lysine requirement for female pigs from 60-100 kg LW for the Australian pork industry to maximise growth performance is 0.64 g Av Lys/MJ DE. This is approximately 10% higher than the level than was previously used by industry.

Unfortunately due to individual circumstances it was not possible to obtain optimal lysine requirements for LW ranges within the overall range of 60-100 kg LW. However, given the overall similarity in results between Edwards (2013) and Moore *et al.* (2012a) it may be reasonable to estimate the lysine requirements for the various LW ranges as given in Table 12.

Table 12: Estimate of the optimal lysine requirements for various LW ranges in the finisher period.

LW (kg) Edwards (2013) (Moore *et al.* 2012a)	Edwards (2013)	Moore *et al.* (2012a) Daily gain, Feed to gain	Recommended level
60-75 (50-65)	0.64	0.67, 0.64	0.65
75-90 (65-80)	0.58	0.63, 0.66	0.62
90-105 (80-95)	0.52	0.58, 0.40	0.55

Single diet

Although there was no cost benefit to a single diet in this experiment using a single diet is a very practical alternative to phase feeding and has several advantages for feed manufacture, storage and delivery. As cautioned by Moore *et al.* (2012b) its success will depend on the diet specifications that are chosen, which will vary depending on the genetic potential of the herd and the weight range over which the pigs are to be fed. Although blend feeding requires significant initial infrastructure, it has the ease of only 2 diets on hand at any time and may also be a practical alternative to phase feeding.

13. Intellectual Property

There was no intellectual property arising from this experiment.

14. Technical Summary

No additional technical information on methodologies, equipment design etc. was developed as part of these experiments.

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16. Publications Arising

There are no publications arising at this point. It is envisaged that there may be papers produced for the upcoming Australasian Pig Science Meeting in November 2015.