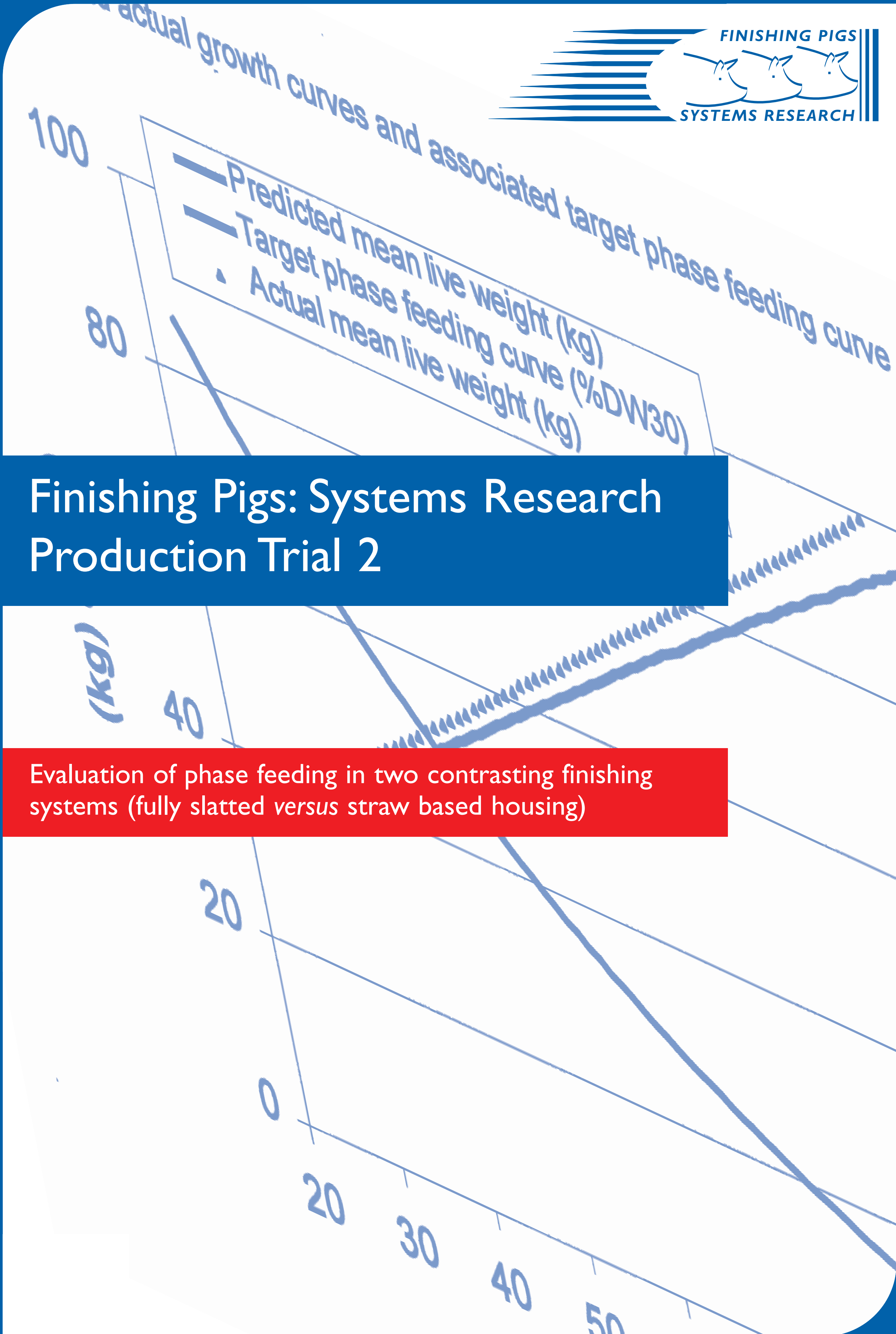
FINISHING PIGS
SYSTEMS RESEARCH

Finishing Pigs: Systems Research Production Trial 2

Evaluation of phase feeding in two contrasting finishing systems (fully slatted *versus* straw based housing)



CONTENTS

TABLES

EXECUTIVE SUMMARY

This report is based on the results from the second of four major production trials under the Finishing Systems Research Programme.

The research is evaluating two contrasting systems of housing (fully slatted v straw based) and liquid feeding technologies for pig performance, carcase quality, cost of production, pig health and welfare, microbial status, environmental impact and meat quality.

PRODUCTION TRIAL 2

The aim of this study was to evaluate liquid phase feeding (reducing daily the lysine to digestible energy (DE) ratio of the diet with increasing body weight to match requirement, ie from 0.91g/MJ DE at 35 kg live weight to 0.60g/MJ DE at 105 kg live weight). This was compared with feeding a liquid diet with a fixed ratio of lysine to DE (0.70g/MJ DE) from entry to slaughter, or equivalent to the use of a single diet under commercial production). The two feeding treatments are referred to as Phase or Single.

Two diets, DW30 and DW110, were formulated to meet the total lysine to DE requirements of pigs weighing 30 and 110 kg live weight respectively, exceeding the weight range of pigs on study. Diets DW30 and DW110 were delivered to each trough using separate pipelines. The proportionality of DW30 to DW110 delivered was changed daily to meet the target lysine to DE requirement of each pen group of pigs according mean live weight. With single diet feeding, the proportionality of DW30 to DW110 was fixed from entry to slaughter, where DW30 represented 30% of the total weight of liquid feed delivered, giving a combined lysine to DE value of 0.7g/MJ DE, the target requirement at 70 kg live weight.

The study was conducted within a fully slatted and a straw based housing system using a total of 1024 pigs housed in pen groups of 32 weighing around 35 kg at entry. Numbers per pen were reduced at week 6 to 25 in the fully slatted and 20 in the straw based system and pigs were finished to slaughter at around 102 kg.

The key findings according to the main effects of feeding, housing and systems interaction between feeding and housing are presented below.

Feeding

Production

Although phase feeding significantly changed the proportionality of DW30 and DW110 used in the growing and finishing stages, overall there were no significant differences in the daily intake of diets DW30 and DW110 between phase and single fed pigs.

Feeding a single diet significantly improved daily intake (2.06 v 1.99 kg/day) and gain (886 v 860 g/day) from entry to slaughter but there were no significant differences in the feed conversion ratio of single diet and phase fed pigs (2.36 v 2.36).

Backfat thickness (P2) was similar in single diet and phase fed pigs (11.67 v 11.53 mm) at an average dead weight of 75kg.

There were no significant differences in the variability of gain and carcase quality (P2) between single diet and phase fed pigs.

Growth performance and cost of production by feeding system are summarised below for the previous and current trial.

	Trial 1		Trial 2	
	Dry	**Liquid**[a]	**Single**[b]	**Phase**[b]
Growth rate (g/day)	754	796	886	860
Cost of production (p/kg dead weight)	99.2	94.6	85.8	86.4

[a] No liquid co-products used, major ingredients included cereals, wheatfeed, soya bean meal, rapeseed meal and fish meal.

[b] Liquid co-products used (Greenwich Gold and Lactose 16) with cereals, wheatfeed, soya bean meal and rapeseed meal as other major ingredients.

In this study phase feeding did not deliver a cost benefit over feeding a single diet. Further studies are required to provide conclusive evidence regarding the benefits of phase feeding.

The use of liquid co-products in Trial 2 improved daily gain by 77g per day and reduced cost of production by around 9p/kg dead weight compared with liquid feeding in Trial 1.

Pig health and welfare

Overall mortality was low (0.78% in single diet and 1.17% in phase fed pigs). The number of pigs failing to complete the study for health reasons averaged 7.8% for single diet and 4.5% for phase fed pigs.

Total veterinary and health treatments were similar between single diet and phase fed pigs (369 v 346 pig days), with lameness and management intervention to curtail tail biting (BITEX topical tail spray) being the major reasons for treatment. Veterinary treatment for lameness was higher in phase fed pigs. Single diet fed pigs required increased management intervention for tail biting.

Phase fed pigs had a significantly improved hygiene score (ie were cleaner) than single diet fed pigs (65% v 61% clean skin).

There were no significant effects of feeding treatment on time spent lying, sleeping, drinking and investigating, though phase feeding significantly increased time spent eating (3.6 v 4.7 %).

There were no significant effects of feeding treatment on time spent performing manipulative behaviours (eg straw, other pig, pen parts and toys).

Post-slaughter assessments revealed no major effects of feeding treatment on gastric ulceration, skin damage and lung scores, though phase feeding significantly increased sole and heel erosion scores as indicators of foot lesions.

Microbial status

Elevated viable anaerobic, lactic acid bacteria and yeast counts in the final liquid diets, compared with individual feed ingredients, indicated the presence of a naturally occurring fermentation. This was confirmed by analysis, showing the presence of end products of fermentation (0.9% lactic acid, 0.15% acetic acid and 0.15% ethanol).

Lactic acid bacteria counts, and to a lesser extent coliform counts, were significantly increased in pen faecal samples from phase fed pigs.

Salmonella could not be detected in samples of individual ingredients used in the production of liquid diets and the final liquid feed mixtures.

Only 9 out of 695 pigs tested positive for the caecal presence of Salmonella at slaughter and therefore no conclusive effects of feeding treatment on caecal carriage could be established.

Using the ELISA method, the percentage of pigs which tested positive decreased from 15% at entry to 6% at slaughter but there were no significant effects of feeding on percentage ELISA positive at slaughter.

Environmental impact

There were no significant effects of phase and single diet feeding on dust and ammonia emissions, waste composition and effluent production.

Housing

Conclusive differences between the effects of housing systems will be established following the completion of the four production studies. Interim key results from the second study are summarised below, but these should be treated with caution.

Production

There were no consistent effects of housing on pig performance and carcase quality, though growth rate was significantly higher in the straw based system (885 v 861g/day).

The cost of production was higher in the straw based system (86.6 v 85.6 p/kg dead weight).

Pig health and welfare

The number of pigs removed for health conditions was higher from the fully slatted system (40 v 23), with tail injury being the major reason for removal.

Veterinary and health treatment was higher in the straw based system (459 v 256 pig days), with management intervention to curtail tail biting being the major reason for treatment. Veterinary treatment for poor body condition was higher in the straw based system (81 v 30 pig days). Lameness was the major reason for the health treatment of pigs housed in the fully slatted system.

Pigs in the straw based system were significantly more active than those in the fully slatted system, spending less time lying down (69.5% v 73.5%) and less time 'sleeping' (53.9% v 58.2%).

Pigs in the straw based system spent a significant amount of their time investigating and manipulating straw (16.1%), whereas pigs in the slatted system spent only 1.6% of their time investigating and manipulating the hanging 'toy' that was provided for them. Pigs in the straw based system spent less time investigating pen components (4.9% v 10.5%), although a similar amount of time was spent investigating other pigs in both systems (6.9% v 7.7%).

Post-slaughter assessment of the feet found no overall difference in the amount of damage; however there were significant differences in the type of damage (on a 0-3 scale of severity). Pigs in the straw based system had significantly higher scores for toe erosions (1.45 v 0.55). Pigs in fully slatted system had more severe sole erosions (1.25 v 0.65) and heel erosions (1.30 v 0.50).

Gastric ulceration (on a 0-5 scale of severity) was significantly higher in pigs from the fully slatted system (2.75 v 1.65). There were no significant effects of housing system on rind-side damage or lung score.

Microbial status

No major differences were found between the housing systems, with the exception of a significant increase in the microbial loading (total aerobic viable and coliform counts) of dust and pen faeces sampled from the straw based system.

Salmonella could not be detected in samples of fresh straw, room dust, pen faeces and effluent.

Only 9 out of 695 pigs tested positive for the caecal presence of Salmonella at slaughter and therefore no conclusive effects of housing system on caecal carriage could be established.

Using the ELISA method, a significantly higher percentage of pigs from the straw based system tested positive for Salmonella at slaughter (9% v 3%).

Environmental impact

There were no significant effects of housing system on dust and ammonia emissions.

Feeding and housing interactions

Production

There were no consistent significant feed and housing systems interactions for growth performance. There was a significant interaction for feed conversion during the finishing stage, with phase feeding improving conversion in the straw based system and single diet feeding improving conversion in the fully slatted system.

Differences in the cost of production according to feeding and housing system were largely attributed to differences in mortality and the number of pigs removed for health conditions.

Pig health and welfare

The number of pigs removed for health conditions was higher with phase feeding in the straw based system and with single diet feeding in the fully slatted system.

Microbial status

There were no consistent or major interactions between feeding and housing systems.

Environmental impact

There were no significant feeding and housing interactions.

INTRODUCTION

The Finishing Systems Research Programme addresses Industry strategic and Government policy requirements covering several priorities through a multidisciplinary approach.

Research activity is centred at MLC's Stotfold Pig Development Unit using the purpose built Finishing Systems Research Unit. This consists of a Feed Centre, which manufactures, processes and delivers liquid feed to growing/finishing pigs in two contrasting systems of production, fully slatted v straw based housing.

The two housing systems will be evaluated over four production trials, with each trial designed to investigate liquid feeding technology.

This report is based on the results of the second production trial, which evaluated phase feeding using the liquid feeding system.

OBJECTIVES

The objective of the research programme is to investigate the effect of housing and feeding and the interaction between housing and feeding on:

Pig performance and cost of production
Pig health and welfare
Microbial status
Environmental impact
Meat quality

OUTLINE OF RESEARCH METHODOLOGY

Trial design

Phase feeding was evaluated in two contrasting systems of housing (straw-based v fully slatted) using growing and finishing pigs from 35 kg to slaughter at 102 kg live weight.

Each house consisted of four rooms, with four pens within each room. Feeding treatments were replicated within housing system and between rooms according to the following pattern.

Figure 1 Allocation of feeding treatments (single v phase) according to housing system and room[a]

Room	1	2	3	4
Straw based	Phase	Single	Phase	Single

Room	1	2	3	4
Fully slatted	Single	Phase	Single	Phase

a Allocation of feeding treatment by room was necessary for the determination of the effects of feeding treatment (single v phase) on environmental impact (see pages 12 and Trial 1 Report MLC (2004) for detail).

Diets and feeding

Two diets, DW30 and DW110, were formulated to meet the total lysine to DE requirements of pigs weighing 30 and 110 kg live weight respectively, exceeding the weight range of pigs on study. These requirements were estimated as 0.96 and 0.59 g/MJ DE at 30 and 110 kg live weight respectively, giving a targeted DE and total lysine content of 15.52 MJ/kg and 14.9 g/kg for diet DW30 and 13.10 MJ/kg and 7.7g/kg for diet DW110. The formulations were refined to meet standardised ileal digestible (SID) amino acid requirements according to the recommended ideal profile relative to SID lysine for pigs of different weight categories.

Phase feeding

Diets DW30 and DW110 were delivered to each trough using separate pipelines. The proportionality of DW30 to DW110 delivered was changed daily to meet the target lysine to DE requirement of each pen group of pigs according to the following equation:

$$Y = 3.5X^{-0.38}$$

Where Y is total lysine requirement (g/MJ DE) and X is the mean live weight (kg) of each pen group pigs.

A predicted growth curve covering the weight range from 35 to 105 kg was used to control automatically the daily delivery of diets DW30 and DW110 to meet the lysine to DE requirements for each pen group of pigs.

Pigs were weighed at two weekly intervals and where necessary to adjust their position on the growth curve and automatically change the proportionality of DW30 to DW110 delivered to meet requirement.

Single diet feeding

In pen groups on single diet feeding, the proportionality of DW30 to DW110 was fixed from entry to slaughter, where DW30 represented 30% of the total weight of liquid feed delivered, giving a combined lysine to DE value of 0.7g/MJ DE, the predicted target requirement at 70 kg live weight.

Liquid feed production and delivery

The diets were produced on site by milling cereals and mixing individual ingredients, including liquid co-products, using the liquid feeding system.

Liquid feeding was computer controlled by feed demand at the troughs using sensors, which signalled for refill on empty. Troughs were refilled with 20 kg drops. Liquid feed was available *ad libitum* except during 24:00 and 01:00 when the system was automatically paused, allowing pigs to clear troughs of any accumulated residues.

Animals and their management

Animals

A total of 1040 (Large White x Landrace) x Large White pigs weighing between 30 to 40 kg were received in 8 equal batches of 130 over 12 weeks and transferred to the housing according to the following pattern.

Figure 2 Batch entry order during stocking according to housing system and room

Room	1	2	3	4
Straw based	Batch 7	Batch 5	Batch 3	Batch 1

Room	1	2	3	4
Fully slatted	Batch 8	Batch 6	Batch 4	Batch 2

Pig identification and weighing

Two surplus pigs were randomly selected and removed to alternative accommodation. The remaining 128 pigs were ear tagged for individual identification and sorted by weight from lightest to heaviest. The batch was divided into 4 equal groups of 32 pigs in order of weight: Light Light (LL), Light Medium (LM), Medium Heavy (MH) and Heavy Heavy (HH). Each group was randomly allocated to one of four pens in the room.

On week 6 pigs were weighed and numbers were reduced from 32 to 25 and 20 pigs per pen in the fully slatted and straw based systems respectively. Pigs removed were pre-selected to represent the range (minimum and maximum) and average weight in the pen so that the overall distribution of individual weights was not potentially skewed by random selection.

Pigs were weighed 9 days prior to slaughter and those weighing more than 95 kg were selected for slaughter so that target weight at slaughter could be close to 105 kg. Pigs were re-weighed the day before slaughter.

Management

The management and care of the pigs is detailed in Appendix II and in brief covered the following elements:

Biosecurity to minimise the cross transfer of micro-organisms potentially associated with a particular feeding and housing system. Management of the environmental control system to achieve target temperature and ventilation rates. Provision of toys for the environmental enrichment of pigs in the fully slatted housing. Daily inspection to safeguard health and welfare and under veterinary supervision to take appropriate action in the care and treatment of pigs with health conditions. Daily removal of soiled bedding and provision of fresh straw in the straw based building. Daily inspection of drinkers and feeders to ensure correct operation and absence of faecal contamination. Maintaining a high level of hygiene and tidiness in the feed centre and service areas.

Research measurements

To establish the potential effects of feeding (single v phase) and housing (straw based v fully slatted) on pig performance, pig health and welfare, microbial ecology and environmental impact, the following measurements and records were taken.

Pig production	Pig weights, feed intake (automatically using the liquid feeding system), nutrient analysis of feed ingredients and complete diets, mortality and other losses, slaughter weight, commercial carcase classification measurements (weight and P2), labour use (pig husbandry and cleaning), medicine use, power consumption (liquid feed production and delivery, housing heating, lighting and ventilation and cleaning), water use (liquid feed, drinking and cleaning), straw use, effluent and manure production and cost of production.
Pig health and behaviour	All pigs: any individual health or welfare condition, pen faecal consistency, veterinary treatments, reasons for death (post mortem) or pigs removed from study. Focal pigs (6 per pen): skin lesions and cleanliness, hock bursitis, behavioural time budgets, feeding behaviour. At slaughter: skin damage, foot lesions, heart and lung scores, gastric ulceration. Blood samples at entry, mid-point and slaughter evaluated for acute phase proteins, generalised immunity and PRRS virus.
Microbial status	Salmonella: All pigs at entry and slaughter blood sampled for ELISA test, plus all pigs at slaughter tested for the presence of Salmonella in caecal samples. Individual feed ingredients, complete diets, straw, dust, pen faeces and effluent routinely tested for the presence of Salmonella. Where appropriate, microbial evaluations of systems samples also included total aerobic and anaerobic viable counts, lactic acid bacteria, Enterobacteraciae and coliform and yeast counts.
Environmental impact	In the straw and fully slatted housing by room: ammonia and dust concentrations and emissions. Effluent and farm yard manure production and composition.

KEY RESULTS

Production

Feeding and housing

Pig performance and carcase quality according to housing and feeding system are given in Table 1. Pig performance and carcase quality according to feeding system within housing system are given in Table 2.

Table 1 Pig performance and carcase quality by housing and feeding system

	Housing System		Feeding System		s.e.d.[b]	P[a]		
	Fully slatted	Straw based	Single	Phase		H	F	I
Live weight (kg)								
Entry	35.25	34.96	35.23	34.97	1.468			
Mid	66.56	64.41	66.00	64.97	2.086			
Final	100.60	103.70	102.20	102.00	0.980	**		
Liquid feed intake (kg/pig day)								
Grower								
DW30	2.85	2.68	2.18	3.35	0.087	0.059	***	
DW110	4.27	4.10	5.08	3.29	0.204		***	
Total	7.12	6.78	7.26	6.64	0.190	0.077	**	
Finisher								
DW30	1.81	2.10	2.83	1.09	0.098	**	***	0.084
DW110	7.41	7.63	6.59	8.45	0.170		***	
Total	9.22	9.73	9.41	9.54	0.201	*		
Overall								
DW30	2.36	2.44	2.46	2.35	0.063		0.098	
DW110	5.72	5.56	5.72	5.56	0.133			
Total	8.08	8.01	8.18	7.91	0.117		*	
Feed intake (kg meq/pig day)								
Grower	1.79	1.70	1.83	1.67	0.048	0.077	**	
Finisher	2.33	2.45	2.37	2.41	0.051	*		
Overall	2.03	2.02	2.06	1.99	0.091		*	
Growth (g/day)								
Grower	864	813	853	825	28.6	0.086		*
Finisher	845	921	893	873	26.9	**		*
Overall	861	885	886	860	11.5	*	*	
Feed conversion ratio								
Grower	2.08	2.10	2.15	2.04	0.053		*	0.091
Finisher	2.76	2.68	2.67	2.77	0.046	0.075	*	***
Overall	2.38	2.35	2.36	2.36	0.036			
Carcase quality								
Slaughter weight (kg)	101.3	104.0	102.9	102.4	0.832	**		
Carcase weight (kg)	74.14	76.00	75.67	74.48	0.810	*		*
Killing out %	73.01	73.14	73.38	72.76	0.475			**
Backfat P2 (mm)	11.29	11.91	11.67	11.53	0.347	0.083		

Number (n) of observations per mean = 16.

[a] In this and subsequent tables, significant probability (P) values for housing system (H), feeding system (F) and interaction (I) between housing and feeding system are given as *, ** or *** for P values <0.05, <0.01 and <0.001 respectively. P values >0.05 and <0.1 are presented numerically and P>0.1 are left blank. A P value of <0.05 (5% level) is taken as a statistically significant effect.

[b] s.e.d. is the standard error of difference.

Table 2 Pig performance and carcase quality by feeding within housing system

	Fully slatted		Straw based		s.e.d.		P	
	Single	Phase	Single	Phase		H	F	I
Live weight (kg)								
Entry	35.61	34.89	34.86	35.06	2.075			
Mid	65.57	67.55	66.43	62.39	2.950			
Final	100.10	101.00	104.20	103.10	1.386	**		
Liquid feed intake (kg/pig day)								
Grower								
DW30	2.20	3.51	2.17	3.19	0.123	0.059	***	
DW110	5.11	3.43	5.05	3.14	0.288		***	
Total	7.31	6.94	7.22	6.34	0.268	0.077	**	
Finisher								
DW30	2.77	0.86	2.88	1.32	0.139	**	***	0.084
DW110	6.46	8.35	6.71	8.54	0.241		***	
Total	9.23	9.21	9.60	9.86	0.285	*		
Overall								
DW30	2.45	2.27	2.46	2.43	0.089		0.098	
DW110	5.71	5.73	5.74	5.39	0.189			
Total	8.16	8.00	8.20	7.81	0.165		*	
Feed intake (kg meq/pig day)								
Grower	1.84	1.74	1.81	1.59	0.067	0.077	**	
Finisher	2.33	2.32	2.42	2.49	0.072	*		
Overall	2.05	2.02	2.06	1.97	0.041		*	
Growth (g/day)								
Grower	843	886	863	764	40.5	0.086		*
Finisher	888	802	898	943	38.1	**		*
Overall	879	843	893	878	16.3	*	*	
Feed conversion ratio								
Grower	2.18	1.98	2.11	2.10	0.076		*	0.091
Finisher	2.63	2.90	2.71	2.64	0.066	0.075	*	***
Overall	2.38	2.38	2.35	2.35	0.050			
Carcase quality								
Slaughter weight (kg)	101.4	101.3	104.5	103.4	1.18	**		
Carcase weight (kg)	73.76	74.53	77.58	74.43	1.146	*		*
Killing out %	72.55	73.47	74.22	72.06	0.672			**
Backfat P2 (mm)	11.16	11.41	12.18	11.64	0.491	0.083		

Number of observations per mean = 8.

Variability

There were no significant differences in the variability for intake, growth and carcase fatness according to feeding and housing system.

Feeding and housing could influence the variability in the growth rate and carcase fatness of individual pigs. For example the use of a single diet from entry to slaughter is at variance to the principles of phase feeding where nutrient supply and requirements are closely matched. Single diet feeding could therefore increase variability in growth and carcase composition when nutrient supply is either significantly above or below target requirement. Conversely if phase feeding underestimates the protein requirement for lean deposition in the finishing stage just prior to slaughter, this may also increase variability in growth rate and carcase fatness.

Variability was investigated by subjecting the within pen standard deviation (a measure of variability) for daily gain and carcase P2 to statistical analysis. No significant effects of feeding or housing system were found (see Appendix I Table 8).

Feeds

Results from the laboratory analysis of samples of liquid diets are given in Table 3.

Table 3 Nutrient analysis (%) of complete liquid diets

	Liquid diets[a]			
	DW30 (n=21)		**DW110** (n=21)	
	Mean	**SD**[d]	**Mean**	**SD**
Dry matter[b]	21.75	2.206	20.60	2.302
Crude protein	20.28	2.561	17.66	1.584
Oil (B)	9.11	0.880	5.06	0.476
NDAF	14.26	2.341	16.76	2.461
Ash	5.68	0.565	5.86	0.586
Total lysine	1.22	0.262	0.80	0.171
DE (MJ/kg)[c]	14.47	0.236	13.38	0.325

[a] In liquid diets the nutrients were adjusted to a meal equivalent (meq) of 87% dry matter.

[b] The target dry matter content of liquid diets was 22%, which was achieved according to the weight of ingredients and water used and recorded automatically by the liquid feeding system. However a representative sample of the final diet was difficult to obtain due to settling of the particulate fraction when the stirrers were switched off for sampling.

[c] Estimated by regression MAFF (1993).

[d] Standard deviation.

Major end products of natural fermentation found in the liquid diets are given in Table 4.

Table 4 Major end products of natural fermentation in liquid diets

Diet	**DW30** (n=5)		**DW110** (n=5)	
	Mean	**SD**	**Mean**	**SD**
Ethanol				
(mg/kg)	1665	1497	774	1345
(mmol/litre)	34	30	16	27
(%)	0.2	0.15	0.1	0.13
Lactic acid				
(mg/kg)	9819	4208	7681	1625
(mmol/litre)	109	47	85	18
(%)	1.0	0.42	0.8	0.16
Acetic acid				
(mg/kg)	2228	844	927	224
(mmol/litre)	36	14	15	4
(%)	0.2	0.08	0.1	0.02

Additional samples of liquid diets were taken on site and tested for dry matter content and pH and the results are presented in Table 5.

Table 5 Dry matter and pH values for liquid diets sampled and tested on site

Diet	**DW30** (n=28)		**DW110** (n=28)	
	Mean	**SD**	**Mean**	**SD**
Dry matter (%)	22.4	1.38	21.4	1.28
pH	4.6	0.49	4.5	0.26

Pig health and welfare

Losses and health conditions

Pig losses through deaths and health conditions by housing and feeding system are given in Table 6. The results are presented by feeding system within each housing system in Table 7. Veterinary treatment for health conditions by housing and feeding system are given in Table 8. The results are presented by feeding system within each housing system in Table 9.

Table 6 Pig losses by housing and feeding system

	Housing system		**Feeding system**	
	Fully slatted	**Straw based**	**Single**	**Phase**
Losses (number)				
Deaths				
Grower	2 (0.39)[a]	7 (1.37)	3 (0.59)	6 (1.17)
Finisher	1 (0.25)	0	1 (0.28)	0
Removed				
Grower	25	19	27	17
Finisher	15	4	13	6
Total	43	30	44	29
Health condition (number)				
Respiratory	0	6	1	5
Enteric	1	3	4	0
Lameness/physical damage	7	4	9	2
Tail injury	26	0	23	3
Loss of body condition[b]	2	6	2	6
Multiple[c]	3	0	2	1
Other[d]	4	11	3	12
Total	43	30	44	29

[a] Value in parenthesis is % mortality.

[b] Pigs with poor body condition (e.g. PMWS).

[c] Individual pigs with multiple conditions.

[d] Includes prolapsed, abscess, sudden death, meningitis and dermatitis.

Table 7 Pig losses by feeding within housing system

	Fully Slatted		Straw Based	
Losses (number)	**Single**	**Phase**	**Single**	**Phase**
Deaths				
Grower	2 (0.78)	0	1 (0.39)	6 (2.34)
Finisher	1 (0.50)	0	0	0
Removed				
Grower	21	4	6	13
Finisher	11	4	2	2
Total	35	8	9	21
Health condition (number)				
Respiratory	0	0	1	5
Enteric	1	0	3	0
Lameness/physical damage	6	1	3	1
Tail injury	23	3	0	0
Loss of body condition	0	2	2	4
Multiple	2	1	0	0
Other	3	1	0	11
Total	35	8	9	21

Table 8 Veterinary treatment (pig days)[a] by housing and feeding system

	Housing system		Feeding system	
Health condition	**Fully slatted**	**Straw based**	**Single**	**Phase**
Respiratory	0	12	9	3
Enteric	9	30	15	24
Lameness/physical damage	140	90	95	135
Tail biting[b]	72	234	188	118
Tail injury[c]	0	0	0	0
Loss of body condition	30	81	57	54
Multiple	0	0	0	0
Other	5	12	5	12
Total	256	459	369	346

[a] Each day a pig was treated for a given health condition, including consecutive and repeated treatments on the same pig.

[b] In pens where an outbreak of tail biting was observed tails were sprayed with BITEX (topical application containing a bitter compound, 1% bitrex) as a management intervention to curtail biting.

[c] Pigs with tail injury due to biting and at risk of infection or with signs of infection were treated with veterinary prescribed antibiotics, though in this trial this was not required.

Table 9 Veterinary treatment (pig days) by feeding within housing system

	Fully Slatted		Straw Based	
Health condition	**Single**	**Phase**	**Single**	**Phase**
Respiratory	0	0	9	3
Enteric	9	0	6	24
Lameness/physical damage	50	90	45	45
Tail biting	57	15	131	103
Tail injury	0	0	0	0
Loss of body condition	18	12	39	42
Multiple	0	0	0	0
Other	2	3	3	9
Total	136	120	233	226

Health monitoring

Weekly skin lesion and hygiene scores according to feeding within housing system are given in Table 10. Results from analysis of blood samples for Acute Phase Proteins at different stages in the trial are shown in Table 11.

Table 10 Hygiene and skin lesion scores by feeding within housing system

	Fully slatted		Straw based		P		
	Single	Phase	Single	Phase	H	F	I
Lesions/pig	9.0	8.5	8.8	8.9			
Hygiene score (% clean)	61.0	65.9	60.4	63.9		*	
Bursitis (0-5)	1.4	1.3	0.7	0.6	***		

Table 11 Acute Phase Proteins in blood by feeding within housing system

	Fully slatted		Straw based		P		
	Single	Phase	Single	Phase	H	F	I
At entry							
C-Reactive protein	174	262	187	209			
Haptoglobin	1.21	1.21	0.84	1.20			
At mid-point							
C-Reactive protein	242	230	172	267			
Haptoglobin	1.72	1.14	1.10	1.26			*
At slaughter							
C-Reactive protein	234	131	108	113			
Haptoglobin	0.76	0.60	0.64	0.52			

Behaviour

Percentage time spent performing general activities by feeding within housing system is given in Table 12. Percentage time spent performing manipulative behaviours by feeding within housing system is given in Table 13.

Table 12 Percentage time spent performing general activities by feeding within housing system

	Fully slatted		Straw based		P		
	Single	Phase	Single	Phase	H	F	I
% Time							
Lying	73	74	69	70	*		
'Sleeping'	57.1	59.3	53.7	54.1	*		
Eating	3.8	5.1	3.4	4.3		*	
Drinking	0.3	0.5	0.3	0.3			
Investigating	19.0	16.8	25.0	22.6	***		

Table 13 Percentage time spent performing manipulative behaviours by feeding within housing system

	Fully slatted		Straw based		P		
	Single	Phase	Single	Phase	H	F	I
% Time							
Straw	-	-	17.4	14.8	***		
Other pig	7.7	7.7	7.1	6.7			
Pen parts	11.3	9.7	4.6	5.1	***		
Environmental enrichment (when present)	1.8	1.3	0.4	0.4	***		

Slaughter assessments

A summary of all slaughter assessments by feeding within housing system is given in Table 14.

Table 14 Slaughter assessments by feeding within housing system

	Fully slatted		Straw based		P		
	Single	Phase	Single	Phase	H	F	I
Foot lesions (0-3 scale)							
False sand crack	0.3	0.5	0.5	0.5			
White line lesion	0.5	0.9	0.7	0.5			*
Toe erosion	0.5	0.6	1.4	1.5	***		
Sole erosion	1.1	1.4	0.5	0.8	***	*	
Heel erosion	1.2	1.4	0.3	0.7	***	*	
Gastric ulceration (0-5 scale)	2.7	2.8	1.7	1.6	***		
Rind-side damage (0-5 scale)	2.1	2.1	2.1	2.2			
Lung score (0-55 scale)	1.9	1.8	2.5	1.9			

Microbial status

Feed, water and straw

All microbial analysis results are presented as Log10 cfu per gram or per ml as appropriate. The microbial status of individual feed ingredients used in the production of the liquid diets and the resulting liquid mixture, and water and straw samples is given in Table 15.

Table 15 Microbial status of the feed, drinking water and fresh straw

Log10 cfu per gram or per ml as appropriate.	n	Salmonella	Total Aerobic Viable Count	Total Anaerobic Viable Count	Lactic acid bacteria Count	Enterobacteraciae Count	Coliform Count	Yeast Count
Liquid feed ingredients								
Wheat	7	ND	6.50	4.12	2.28	2.07		2.92
Barley	2	ND	6.39	5.67	3.87	3.21		2.13
Wheatfeed	2	ND	5.99	4.20	3.06	3.09		4.35
Soya bean meal (HP)	3	ND	5.02	4.86	3.99	0.90		1.44
Rapeseed meal	2	ND	6.57	4.87	3.35	ND		2.21
Greenwich Gold	24	ND	6.34	4.75	3.99	-0.85[a]		3.49
Lactose 16	21	ND	9.02	7.83	7.74	2.31		5.2
Minerals and vitamins (Grower)	1	ND	5.74	ND	3.97	ND		ND
Minerals and vitamins (Finisher)	1	ND	5.68	6.00	4.05	ND		6.81
Complete liquid diets								
DW30	16	ND	7.56	6.94	7.47	2.79		6.73
DW110	16	ND	6.94	6.39	6.59	2.05		5.50
Drinking water	24						ND	
Fresh straw	23	ND						

ND = not detected; [a] Log_{10} of 0.14 cfu/g.

Faeces, effluent and dust

The microbial status of faecal, effluent and dust samples according to housing and feeding system is given in Table 16. Tests for the presence of Salmonella in faecal, effluent and dust samples all proved negative.

Table 16 Microbial status of pen faeces, slurry and dust by housing and feeding system

		Housing system		Feeding system		s.e.d.	P		
	n	Fully slatted	Straw based	Single	Phase		H	F	I
Total Aerobic Viable Count									
Faeces	12	8.43	8.76	8.56	8.63	0.128	**		**
Dust	26	7.42	8.69	7.99	8.03	0.241	***		
Total Anaerobic Viable Count									
Faeces	12	9.76	9.93	9.75	9.93	0.140			
Lactic Acid Bacteria (LAB) Count									
Faeces	12	8.19	8.05	8.18	8.52	0.127	*	**	
Coliform Count									
Faeces	12	5.32	5.39	5.19	5.52	0.153		*	
Dust	24	1.51	2.13	1.76	1.85	0.193	*		
LAB : Coliform Ratio									
Faeces	12	1.57	1.61	1.61	1.56	0.048			
Enterobacteraciae Count									
Effluent	9	5.26		4.96	5.58	0.216	-	**	-

Pigs

The Salmonella status of pigs at entry and at slaughter is given in Table 17.

Table 17 Salmonella status of pigs at entry and at slaughter by housing and feeding system

		Housing system		Feeding system		s.e.d.	P		
	n	Fully slatted	Straw based	Single	Phase		H	F	I
Entry	16								
ELISA % positive		10	20	14	17	3.1	**		
Slaughter	16								
Caecal %positive		Only 9[a] pigs tested positive from a total of 695 sampled							
ELISA %positive		3	9	6	6	2.1	*		

[a] 4 straw based, 5 fully slatted; 6 single, 3 phase.

Environmental impact

Ammonia and dust

Ammonia and dust emission and dust concentration according to housing and feeding system are presented in Table 18.

Table 18 Ammonia and dust emission and dust concentration

	Fully slatted		Straw based		s.e.d.
	Single	Phase	Single	Phase	
Ammonia					
Emission (g NH_3-N per lu hour)	0.59	0.50	0.89	0.90	0.266
Dust					
Concentration (mg per m^3)	2.44	3.21	1.60	2.56	0.484
Emission (g per lu hour)	6.41	7.70	3.54	7.23	1.599

There were no significant differences between different housing and feeding systems (n=4).

Waste

The volume of effluent and weight of farm-yard manure generated and composition is presented in Table 19.

Table 19 Production and composition of waste

	Fully slatted		Straw based	
	Single	Phase	Single	Phase
Production (pig/day)				
Effluent (litres)	7.48	7.58	-	-
Farm Yard Manure (kg)	-	-	4.45	
Composition[a] (n=7)				
Dry matter (%)	9.5	8.0	19	
Ammoniacal nitrogen				
(mg NH_4-N/kg)	3350	3270	2750	
Kjeldahl nitrogen (mg N/kg)	5530	5220	7680	
Total phosphorus (mg/kg)	1250	920	1720	

[a] Composition results highly influenced by sampling error and not statistically significant.

APPENDICES

APPENDIX I OTHER RESULTS

Table 1 Inputs and waste production

	Fully slatted		Straw based	
	Single	**Phase**	**Single**	**Phase**
Feed (kg meal equivalent)				
Grower (Per pig)	65.2	64.7	66.5	57.4
Finisher (Per pig)	90.8	97.1	102.4	107.5
Labour (minutes)				
Husbandry				
Per pig day	0.21	0.21	0.39	0.39
Per pig	15.6	16.5	30.7	30.9
Cleaning				
Per pig day	0.07	0.07	0.06	0.06
Per pig	5.5	5.3	4.8	4.9
Medicines				
Per pig day (p)	0.40	1.11	0.85	0.90
Per pig (p)	29.66	87.45	66.53	71.08
Power consumption (kWh)				
Buildings				
Per pig day	0.62	0.62	0.74	0.74
Per pig	45.91	48.46	58.45	58.68
Liquid feed production and delivery				
Per pig day	0.34	0.34	0.34	0.34
Per pig	25.17	26.57	26.60	26.70
Power washing				
Per pig day	0.10	0.10	0.05	0.05
Per pig	7.54	7.96	4.20	4.21
Water used (litres)				
Drinking and liquid feed				
Per pig day	8.27	8.92	8.11	7.61
Per pig	615.75	701.01	637.26	601.30
Cleaning				
Per pig day	1.76	1.61	0.88	0.90
Per pig	130.97	126.77	69.50	70.92
Straw used (kg)				
Per pig day	-	-	0.36	0.36
Per pig	-	-	28.27	28.38
Mortality				
Growing stage				
(%)	0.78	0	0.39	2.34
Mean weight (kg)	38.75	-	42.00	43.33
Finishing stage				
(%)	0.50	0	0	0
Mean weight (kg)	49.00	-	-	-
Pigs removed				
Growing stage				
(%)	8.20	1.56	2.34	5.08
Mean weight (kg)	46.00	36.13	41.25	33.00
Finishing stage				
(%)	5.50	2.00	1.25	1.25
Mean weight (kg)	76.18	83.25	79.00	77.25
Waste production (kg)				
Farm Yard Manure				
Per pig day	-	-	4.45	4.45
Per pig	-	-	349.86	351.20
Effluent				
Per pig day	7.48	7.58	-	-
Per pig	556.73	595.55	-	-

Table 2 Input costs

	Unit	Cost per unit (£)	Notes
Variable Inputs			
Weaner	pig	32.50	Weaner costs were loaded for systems mortality. Pigs removed during the growing stage for health conditions were added to mortality losses.
Feed			Based on September 2003 costs.
Barley	t	85	
Wheatfeed	t	75	
Wheat	t	92	
Rapeseed Meal	t	108	
Soya bean meal	t	160	
Greenwich Gold	t	15	
Lactose 16	t	10	
Soya oil	t	380	
Grower mins/vits supplement	t	345	
Finisher mins/vits supplement	t	280	
Diet DW30	t	131.57	Meal equivalent costs (87% dry matter).
Diet DW110	t	78.96	Meal equivalent costs (87% dry matter).
Labour	hr	7.15	Average of basic rate plus 10hrs o/t per week, including NI etc.
Power	kWh	0.04	Assuming 50/50 normal and cheap rate tariff.
Water	m^3	0.70	
Straw	t	30	Wheat straw
Waste management			
Farm Yard Manure	t		Contractor disposal cost of £2.40 per m^3
Effluent	t		Contractor disposal cost of £1.72 per m^3
Capital Investment	Total		Capital cost of feeding equipment depreciated over 20 years at 6% interest. Capital cost of straw and fully slatted housing depreciated over 30 and 25 years at 6% interest. Repair/maintenance costs at 2% for housing and 4% for feeding equipment.
Liquid feeding			
Mill		8,500	1t/hr 3-phase hammer mill + elevator - including installation
Central processing unit		42,300	Bins and augers for 3 cereals, 2 proteins and oil, with processing tank and controls, installed in new building.
Pig house tank/ 1pipeline		13,620	Tank, pipeline and 16 feeders.
Pig house tank/ 2 pipelines		18,180	Tank, 2 pipelines and 16 feeders.
Housing			
Fully slatted	m^3	227	Average of trade quotes based on building plan.
Straw based	m^3	193	As above.

Table 3 Cost of production[a] (p/kg dead weight) by housing and feeding system

	Housing system		Feeding system	
	Fully slatted	Straw based	Single	Phase
Variable costs				
Feed	20.9	21.1	21.3	20.8
Vet and Med	0.7	1.0	0.6	1.0
Bedding	0	1.3	0.7	0.7
Total	21.7	23.4	22.6	22.6
Fixed costs				
Housing	4.8	4.2	4.4	4.6
Feed system	2.2	2.4	2.1	2.5
Labour	3.7	5.8	4.6	4.8
Energy	4.0	4.3	4.2	4.2
Water	0.7	0.4	0.5	0.6
Slurry storage and disposal	2.0	1.2	1.5	1.6
Total	17.4	18.2	17.3	18.2
Total Finishing Cost	39.0	41.5	39.9	40.7
Weaner cost	46.6	45.1	45.9	45.7
TOTAL COST	**85.6**	**86.6**	**85.8**	**86.4**

[a] Totals are correct individual costs subject to rounding to one decimal place.

Table 4 Cost of production (p/kg dead weight) by feeding within housing system

	Fully slatted		Straw based	
	Single	Phase	Single	Phase
Variable costs				
Feed	21.5	20.3	20.9	21.3
Vet and Med	0.4	1.0	0.9	1.0
Bedding	0	0	1.3	1.4
Total	21.9	21.4	23.1	23.7
Fixed costs				
Housing	4.8	4.8	4.0	4.3
Feed system	2.0	2.3	2.1	2.7
Labour	3.7	3.6	5.5	6.0
Energy	4.1	4.0	4.2	4.5
Water	0.6	0.7	0.4	0.4
Slurry storage and disposal	2.0	2.0	1.1	1.2
Total	17.3	17.4	17.3	19.0
Total Finishing Costs	39.3	38.7	40.4	42.6
Weaner cost	48.8	44.4	43.1	47.1
TOTAL COSTS	**88.1**	**83.1**	**83.5**	**89.7**

Table 5 Sensitivity analysis for cost of production (p/kg dead weight) by feeding within housing system

		Fully slatted		Straw based	
		Single	**Phase**	**Single**	**Phase**
Base line cost of production[a]		88.1	83.1	83.5	89.7
Cost of liquid feeding system					
(+/- of baseline)	+10%	88.3	83.3	83.7	89.9
	-10%	87.9	82.9	83.3	89.4
Feed costs					
(+/- of base line)	+10%	90.2	85.1	85.6	91.8
	-10%	86.0	81.0	81.4	87.6
Installation size					
Below IPPC threshold					
	1000 pig places	88.6	83.6	84.1	90.3
At IPPC threshold					
	2000 pig places	88.1	83.1	83.5	89.7
Above IPPC threshold					
	4000 pig places	87.7	82.7	83.0	89.2

[a] From Table 4.

Table 6 Formulation against actual use of raw feed ingredients in the production of liquid diets

(%)	Target	Actual		
		Mean	SD	n
Protein Mix DW30				145
Water	57.35	57.65	2.273	
Greenwich Gold	25.63	25.39	2.140	
Soyabean Meal	10.37	10.42	0.785	
Vegetable Oil	3.34	3.28	0.382	
Rapeseed Meal	1.64	1.61	0.316	
Supplement 30W	1.67	1.64	0.180	
TOTAL	100.00	100.00		
Protein Mix DW110				161
Water	44.36	44.50	2.393	
Greenwich Gold	42.50	42.44	2.448	
Wheatfeed	10.37	10.35	0.422	
Rapeseed Meal	1.96	1.91	0.376	
Supplement 110W	0.82	0.79	0.089	
TOTAL	100.00	100.00		
Cereal Mix				156
Water	68.91	68.60	1.737	
Lactose 16	6.96	7.22	1.356	
Barley	6.03	5.77	0.914	
Wheat	18.09	18.41	1.016	
TOTAL	100.00	100.00		
Liquid diet DW30				154
Protein Mix Grower	60.08	60.23	1.788	
Cereal Mix	39.92	39.77		
TOTAL	100.00	100.00		
Liquid diet DW110				157
Protein Mix Finisher	62.12	62.40	0.974	
Cereal Mix	37.88	37.60		
TOTAL	100.00	100.00		

Table 7 Nutrient analysis of ingredients used in the production of liquid diets

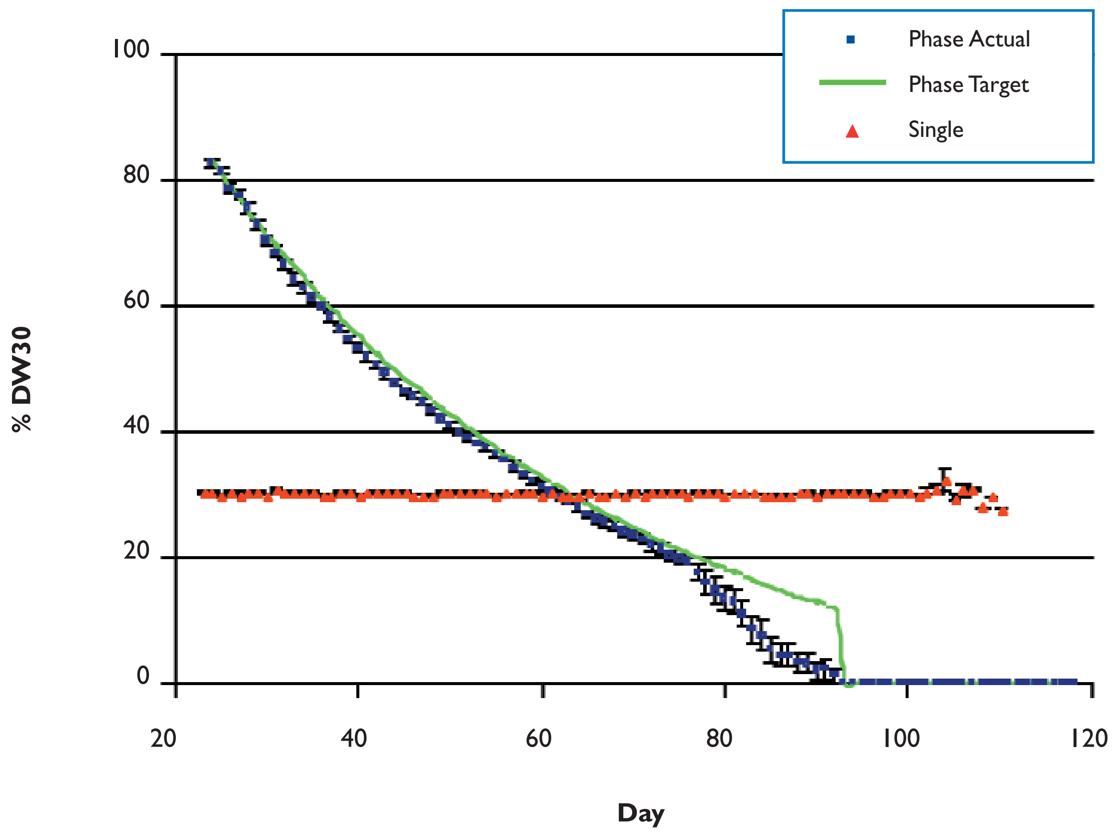
Nutrients (% dry matter)	n	DM	CP	Oil (B)	NDAF	Ash	DE (MJ/kg)[a]	Total lysine	Ca	P	Na
Feed ingredient											
Whole grain wheat	3	85.60	12.00	2.67	12.00	1.33	14.31				
Wheatfeed pellets	3	87.20	15.57	4.40	28.67	3.40	12.43				
Whole grain barley	1	87.30	13.10	3.00	18.60	2.10	13.69				
Rapeseed meal	1	89.10	34.00	4.40	33.80	6.80	12.36				
Soya bean meal (HP)	2	87.95	46.50	2.70	8.40	6.25	16.12				
Greenwich Gold	4	24.48	31.50	7.15	9.95	8.20	4.16	1.02			1.14
DW30 mineral and vitamins premix	1							6.87	20.63	7.20	4.11
DW110 mineral and vitamins premix	2							5.50	29.93	2.22	2.87

[a] Estimated by regression MAFF (1993).

Table 8 Variability (SD) in gain and carcase quality by housing and feeding system

		Housing system		Feeding system		s.e.d.	P		
	n	Fully slatted	Straw based	Single	Phase		H	F	I
Growth (g/day)									
Grower	16	185	223	192	215	18.9	0.06		**
Finisher	16	186	171	187	169	15.9			
Overall	16	118	122	118	122	8.1			*
Carcase quality									
Slaughter weight (kg)	16	5.65	6.74	6.25	6.14	0.538	*		*
Carcase weight (kg)	16	7.49	5.98	7.42	6.06	1.563			
Killing out %	16	5.60	3.36	4.93	4.04	1.756			
Backfat P2 (mm)	16	2.62	2.44	2.42	2.63	0.210			

Figure 1 Diet DW30 delivered (% of total weight; mean +/- standard error) by the liquid feeding system according to feeding treatment



APPENDIX II   DETAILED RESEARCH METHODOLOGY

Detailed research methodology can be found in the first report under the Finishing Pigs Systems Research Programme (MLC, 2004), which should be used in reference to this study. Any differences in methodology used are given below.

Production

Diet formulation

Two diets, DW30 and DW110, were formulated to meet the total lysine to DE requirements of pigs weighing 30 and 110 kg live weight respectively, exceeding the weight range of pigs on study. These requirements were estimated as 0.96 and 0.59 g/MJ DE at 30 and 110 kg live weight respectively Gill (1998), giving a targeted DE and total lysine content of 15.52 MJ/kg and 14.9 g/kg for diet DW30 and 13.10 MJ/kg and 7.7g/kg for diet DW110.

Least cost formulations were generated to meet target total lysine and DE requirements and the resulting standardised ileal digestible (SID) lysine content of the diets was estimated from SID coefficients (Degussa, 1999; AFZ *et al.*, 2000; Versteegh *et al.*, 2000). The formulations were refined to meet the SID amino acid requirements according to the recommended ideal profile relative to SID lysine for pigs of different weight categories (Degussa, 1999; Whittemore *et al.*, 2003). The estimated essential SID amino acid balance of the diets, expressed on a meal equivalent basis (87% dry matter) is given in Table 1. Formulations of the basal diet in liquid form and expressed in meal equivalents (87% dry matter) are presented in Table 2.

Table 1 Estimated SID essential amino acid balance (relative to lysine = 100) in basal diets DW30 and DW110 and the recommended balance published by BSAS 2003

	DW30	DW110	BSAS 2004	W35[a]
Lysine	100	100	100	100
Methionine	31	40	30	32
Methionine+Cystine	59	95	59	62
Threonine	65	68	65	65
Tryptophan	18	27	19	19
Isoleucine	59	79	58	61
Valine	67	107	70	71
Leucine	103	149	100	107
Pheny+Tyros	118	165	100	122
Histidine	37	57	34	38

[a] Whilst basal diet DW30 did not meet the recommended tryptophan and valine balance relative to lysine, the mean start pen weight of pigs was 35kg, requiring a delivery of proportionally 0.83 of DW30 and 0.17 of DW110 according to feed curve day 24 for phase-fed pigs. With this starting point, the SID amino acid balance met the recommended published requirements for tryptophan and valine.

Table 2 Formulations and nutrient specifications of the basal diets

	DW30		DW110	
Ingredient (%)	**Liquid**	**Meal equivalent[a]**	**Liquid**	**Meal equivalent**
Water	61.96	0.00	53.66	0.00
Greenwich Gold	15.40	17.50	26.40	30.00
Lactose 16	2.78	2.02	2.64	1.92
Wheat	7.22	28.40	6.85	26.95
Barley	2.41	9.50	2.28	9.01
Wheatfeed	0.00	0.00	6.44	25.00
Soya bean meal	6.23	25.00	0.00	0.00
Rapeseed meal	0.99	3.92	1.21	4.83
Soya oil	2.00	9.11	0.00	0.00
Limestone	0.211	0.949	0.387	1.741
Dicalcium phosphate	0.403	1.833	0.035	0.161
Salt	0.114	0.517	0.032	0.145
Lysine HCl	0.127	0.566	0.035	0.154
Methionine	0.031	0.140	0.000	0.000
Threonine	0.056	0.254	0.002	0.007
Trace elements and vitamins[b]	0.064	0.289	0.019	0.084
Nutrient Specification				
Dry matter (%)	22.0		22.0	
DE (MJ/kg)		15.52		13.10
CP (%)		22.32		16.92
Total lysine (%)		1.49		0.77
SID lysine (%)		1.34		0.63
Ca (%)		0.90		0.75
P (%)		0.75		0.60
Na (%)		0.40		0.40

[a] Meal equivalent values recalculated to a constant dry matter content of 87%.

b The trace elements and vitamins mixture was combined with limestone, dicalcium phosphate, salt, lysine HCl, methionine and threonine as a mineral and vitamin supplement added to the diet as a single mixture. Mineral and vitamin supplement provided per kg (meal equivalent) of DW30 diet: Vitamins A, D and E 12000, 2000 and 175 iu respectively, Vitamin K 2000 ug, Riboflavin 6 mg, Pyridoxine 6 mg, Cyanocobalamin 30 mg, Biotin 150 ug, Pantothenic acid 20 mg, Niacin 30 mg, Copper 175 mg, Zinc 44 mg, Manganese 49 mg, Iron 140 mg, Iodine 0.41 mg and Selenium 0.5 mg. Mineral and vitamin supplement provided per kg (meal equivalent) of DW110 diet: Vitamins A, D and E 3500, 580 and 50 iu respectively, Vitamin K 580 ug, Riboflavin 1.75 mg, Pyridoxine 1.75 mg, Cyanocobalamin 9 mg, Biotin 45 ug, Pantothenic acid 6 mg, Niacin 9 mg, Thiamine 0.5 mg, Copper 56 mg, Zinc 52 mg, Manganese 50 mg, Iron 120 mg, Iodine 0.2 mg and Selenium 0.40 mg.

Production of liquid diets

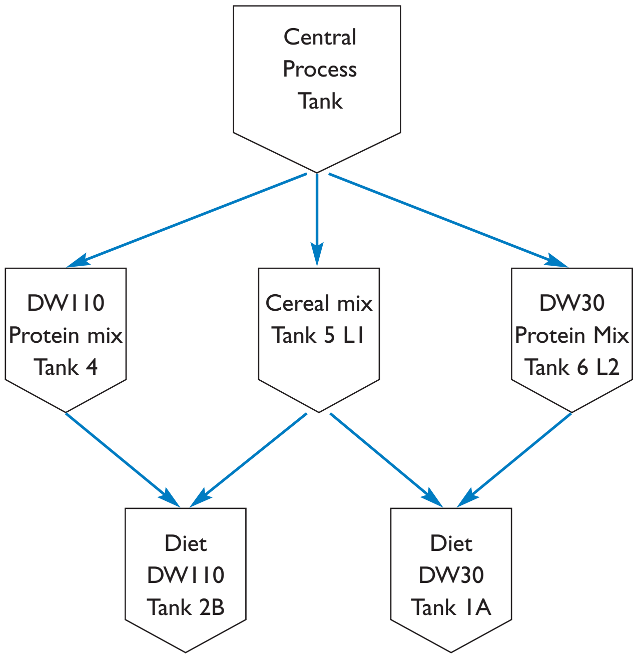
The ingredients used within the formulations for DW30 and DW110 (see Table 2), were partitioned into two fractions, either a ‘protein mix’ or a ‘cereal mix’ (see Table 3). The ingredient content of the cereal mix was common to diets DW30 and DW110. Minerals, amino acids, trace elements and vitamins were combined to produce separate supplements for DW30 and DW110 and added to the ‘protein mix’ fraction of each diet.

Table 3 Ingredient content of the protein mixtures and the cereal mix used in the production of diets DW30 and DW110

Ingredient (%)	Protein Mix DW30	Protein Mix DW110	Cereal Mix
Water	57.35	44.36	68.91
Lactose 16	-	-	6.96
Barley	-	-	6.03
Wheat	-	-	18.09
Greenwich Gold	25.63	42.50	-
Wheatfeed	-	10.37	-
Soyabean Meal	10.37	-	-
Vegetable Oil	3.34	-	-
Rapeseed Meal	1.64	1.96	-
Supplement 30W	1.67	-	-
Supplement 110W	-	0.82	-
TOTAL	100.00	100.00	100.00
Liquid diet DW30	60.08	-	39.92
Liquid diet DW110	-	62.12	37.88

The production of diets DW30 and DW110 is presented schematically in Figure 1 above. Each mixture was batch produced (300kg/batch for protein mixtures and 400kg/batch for the cereal mix) in the Central Process Tank and transferred for temporary storage at ambient temperature (DW30 Protein Mix toTank 6 L2, DW110 Protein Mix to Tank 4, Cereal Mix to Tank 5 L1). The final diets, DW30 and DW110, were generated in batches of 300 kg in the feeding tanks by transferring and blending the appropriate protein mix with the cereal mix (Diet DW30 in Tank 1A and Diet DW110 in Tank 2B).

Figure 1 Production of diets DW30 and DW110 using cereal and protein mixtures



The process was driven by feed demand at the troughs using sensors, which signalled for refill on empty. Troughs were refilled with DW30 and DW110 at a combined weight of 20 kg. The delivery of DW30 and DW110 was synchronised to maximise post valve mixing in the delivery pipe above each trough. The proportionality of DW30 and DW110 delivered was automatically controlled by Winfeed according to feeding treatment. Liquid feed was available *ad libitum* except during 24:00 and 01:00 when the system was automatically paused, allowing pigs to clear troughs of any accumulated residues.

Phase feeding

Diets DW30 and DW110 were delivered to each trough using separate pipelines. The proportionality of DW30 to DW110 delivered was changed daily to meet the target lysine to DE requirement of each pen group according to the following equation (Gill, 1998):

$$Y = 3.5X^{-0.38}$$

Where Y is total lysine requirement (g/MJ DE) and X is the mean live weight (kg) of each pen group of pigs.

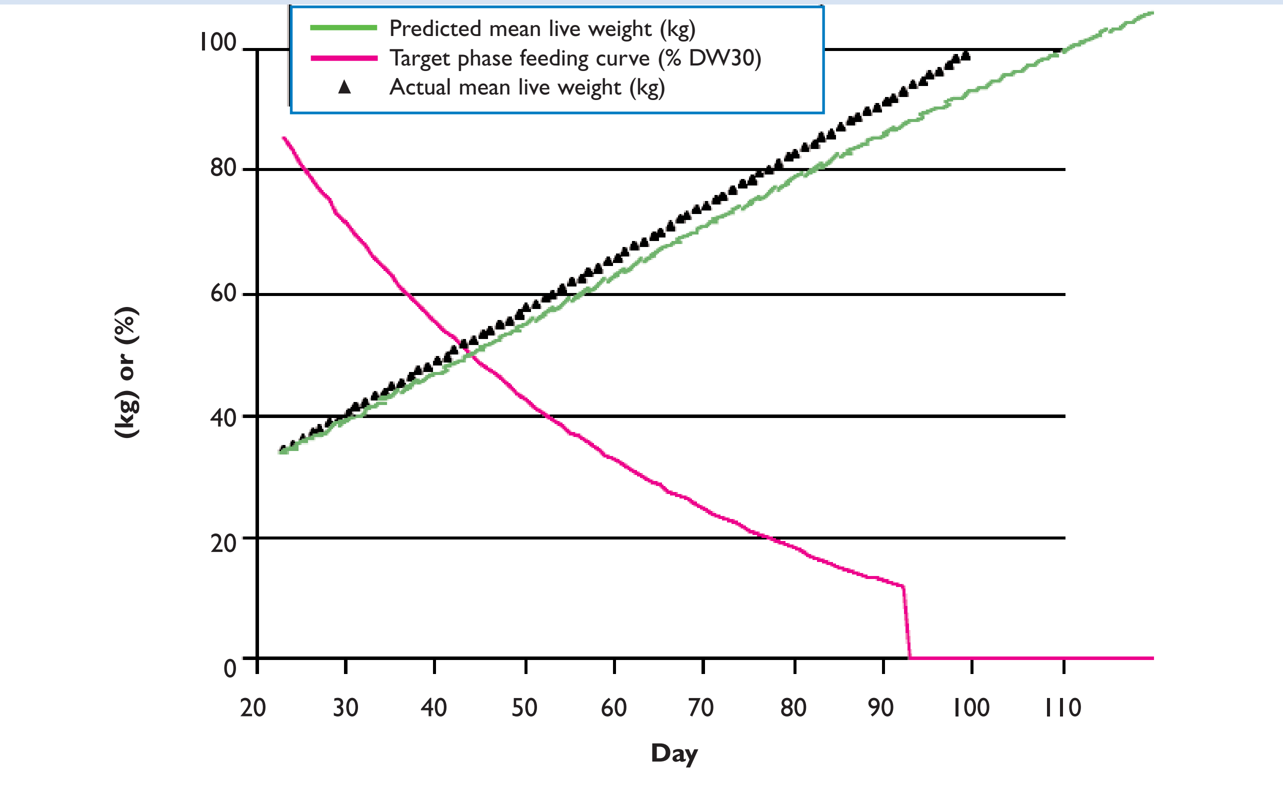
A predicted growth curve (see Figure 2) covering the weight range from 30 to 110kg was used to control automatically the daily delivery of diets DW30 and DW110 to meet the lysine to DE requirements for each pen group.

Pigs were weighed at two weekly intervals and, where necessary, their position on the feeding curve was corrected to adjust automatically the proportionality of DW30 to DW110 delivered and to meet actual requirement.

Single diet feeding

In pen groups on single diet feeding, the proportionality of DW30 to DW110 was fixed from entry to slaughter, where DW30 represented 30% of the total weight of liquid feed delivered, giving a combined lysine to DE value of 0.7g/MJ DE, the target requirement at 70kg live weight.

Figure 2 Predicted and actual growth curves and associated target phase feeding curve



Feed sampling and laboratory analysis

Each newly delivered batch of individual feed ingredient was sampled and dispatched for nutrient analysis. Weekly liquid diet samples were stored for subsequent dispatch and laboratory analysis for nutrient content . A summary of samples taken and associated laboratory analysis is given in Table 4. Liquid diets DW30 and DW110 were sampled during the course of the trial from Feed Tanks A and B for on site determination of oven dry matter content and pH.

Table 4 Feed and feed ingredients sampled and their laboratory analysis

	Dry matter (DM)	Crude protein (CP)	Oil (B)	Neutral detergent plus amylase fibre (NDAF)	Ash	Total lysine	Calcium (Ca) and phosphorous (P)	Sodium (Na)	Fatty and volatile acid profiles, ethanol and pH
Feed ingredient									
Whole grain wheat	✓	✓	✓	✓	✓				
Wheatfeed pellets	✓	✓	✓	✓	✓				
Whole grain barley	✓	✓	✓	✓	✓				
Rapeseed meal	✓	✓	✓	✓	✓				
Soya bean meal (HP)	✓	✓	✓	✓	✓				
Greenwich Gold	✓	✓	✓	✓	✓	✓		✓	
DW30 mineral and vitamins premix						✓	✓ ✓	✓	
DW110 mineral and vitamins premix						✓	✓ ✓	✓	
Complete liquid diets	✓	✓	✓	✓	✓	✓			✓

Animals

A total of 1040 (Large White x Landrace) x Large White pigs weighing between 30 to 40 kg were received in 8 equal batches of 130 over 12 weeks commencing 29 November 2002 and transferred to the housing according to the pattern given below.

Room	1		2		3		4	
	Batch 7		Batch 5		Batch 3		Batch 1	
Straw based	Pen 2	Pen 4	Pen 6	Pen 8	Pen 10	Pen 12	Pen 14	Pen 16
	Pen 1	Pen 3	Pen 5	Pen 7	Pen 9	Pen 11	Pen 13	Pen 15

Room	1		2		3		4	
	Batch 8		Batch 6		Batch 4		Batch 2	
Fully Slatted	Pen 31	Pen 29	Pen 27	Pen 25	Pen 23	Pen 21	Pen 19	Pen 17
	Pen 32	Pen 30	Pen 28	Pen 26	Pen 24	Pen 22	Pen 20	Pen 18

Pig identification and weighing

Two surplus pigs were randomly selected and removed to alternative accommodation. The remaining 128 pigs were ear tagged for individual identification and sorted by weight from lightest to heaviest.

All subsequent procedures relating to the management of animals and research methodology covering production, pig health and welfare, microbial status, environmental impact, data processing and statistical analysis have been previously reported (MLC, 2004). Any differences are given below.

Pig health and welfare

Slaughter assessments

In this study no measurements for osteochondrosis were taken on leg joints of focal pigs at slaughter.

Microbial status

Sampling

There was no baseline assessment of gut microbial status of pigs entering the study. Focal pigs were not sampled for gut (ileum and colon) microbial status at slaughter. However as previous (MLC, 2004), caecal contents were sampled from all pigs at slaughter.

Microbial evaluations

There were no determinations for the presence of Lawsonia and Brachyspira in the gut (colon) of focal pigs at slaughter.

Meat quality

There were no measurements for quality on fresh and cooked samples of meat.

APPENDIX III SYSTEMS TECHNICAL SPECIFICATIONS

The technical specification of the Finishing Systems Research Unit (FSRU) can be found in the first report under the Finishing Pigs Systems Research Programme (MLC, 2004).

GLOSSARY

A glossary can be found in the first report under the Finishing Pigs Systems Research Programme (MLC, 2004), which should be used as a reference to this report.

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