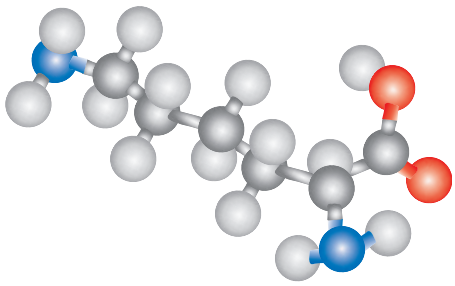
Finishing Pigs Systems Research Production Trial 4



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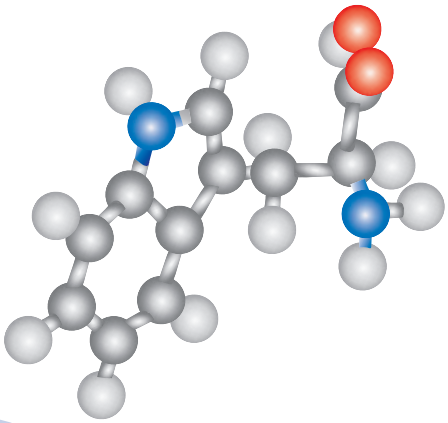
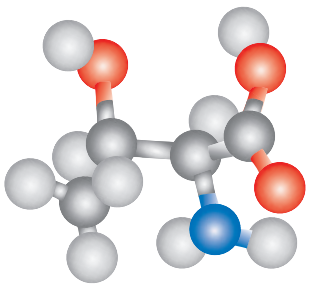


TRYPTOPHAN

Reducing the protein content of liquid diets fed to pigs in two contrasting finishing systems

(fully slatted *versus* straw based housing)



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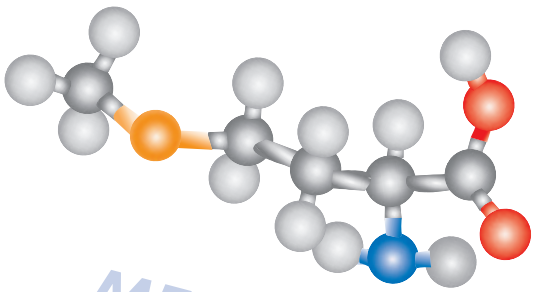


METHIONINE

FINISHING PIGS SYSTEMS RESEARCH

CONTENTS

TABLES

EXECUTIVE SUMMARY

This report is based on the results from the fourth and final major production trial under the Finishing Systems Research Programme.

The research evaluated 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 4

The aim of this study was to evaluate the effects of feeding a liquid diet in which the crude protein content was reduced from circa 20% to 15% (on a meal equivalent basis at 87% dry matter) by the use of synthetic amino acids, namely lysine HCl, threonine, methionine and tryptophan.

The study was conducted within a fully slatted and a straw based housing system using a total of 1280 pigs housed in pen groups of 32 weighing around 34kg 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 101kg.

The key findings according to the main effects of feeding (control - liquid v low protein - liquid), housing and systems interaction between feeding and housing are presented below.

Feeding

Production

Intake was significantly increased overall by feeding the low protein liquid diet (2.11 v 2.03kg/day). This did not result in improved daily gain but significantly reduced overall daily gain from entry to slaughter (821 v 851 g/day), particularly during the finishing stage (878 v 924 g/day). As a result feed conversion ratio was significantly poorer on the low protein diet in the growing (2.43 v 2.26) and finishing stage (2.92 v 2.71) and overall (2.68 v 2.49).

Backfat thickness (P2) was significantly increased by feeding the low protein diet (12.77 v 12.22mm) at an average carcase weight of 77.5kg.

Growth performance and cost of production (CoP) by feeding system (average of straw based and fully slatted systems) are summarised below for all trials.

	Trial 1		Trial 2		Trial 3		Trial 4	
	Dry	Liquid[a]	Single[b]	Phase[b]	Control[c]	Fermented[c]	Control[d]	Low Protein[d]
Growth rate (g/day)	754	796	886	860	844	818	851	821
Cost of production (p/kg dead weight)	99.2	94.6	85.8	86.4	93.6	113.8	87.3	90.1

[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.

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

[d] Liquid co-product used (Greenwich Gold) with cereals, soya bean meal and rapeseed meal as other major ingredients.

Natural fermentation was present in both control and low protein liquid diets as shown by elevated microbial counts and the presence of end products of fermentation (e.g. lactic and acetic acid and ethanol).

There was no microbial degradation of free amino acids in the low protein diet with complete recovery of supplemented lysine, methionine and threonine under laboratory analysis. Analysis of complete diets for total amino acids (methionine plus cystine, threonine, tryptophan, isoleucine, valine, leucine, phenylalanine plus tyrosine, histidine and arginine) showed that levels met formulation targets for the control and low protein diets.

Feeding a liquid diet supplemented with synthetic amino acids to reduce crude protein content from circ 20% to 15% (on a meal equivalent basis) did not deliver a cost benefit.

Pig health and welfare

Overall mortality was low (0.53% control v 0.89% low protein). The number of pigs failing to complete the study for health reasons averaged 4.08% on the control and 5.01% on the low protein feeding treatments.

Total veterinary and health treatments were higher for pigs fed the low protein diet (302 v 131 pig days), with lameness, enteric problems, management intervention to curtail tail biting (BITEX topical tail spray), and loss of body condition being the major reasons for treatment.

Pigs fed the low protein diets showed significantly higher hygiene scores (80.6 v 72.0 % clean) and reduced skin lesion scores (6.9 v 7.9). There were no significant effects of feeding treatment on bursitis scores.

There were no significant effects of feeding treatment on time spent lying, sleeping, eating, drinking and investigating.

There were no significant effects of feeding treatment on the amount of time pigs spent manipulating and investigating straw, performing manipulative behaviours towards other pigs, pen parts and environmental enrichment.

Post-slaughter assessment of foot damage revealed that low protein fed pigs had significantly lower scores for toe erosion but there were no significant feeding treatment effects on other foot lesion scores (e.g. false sand crack, white line lesions and sole and heel erosion).

There were no significant feeding treatment effects on gastric ulceration, rind-side damage, and lung and osteochondrosis scores.

Microbial status

Elevated viable aerobic and anaerobic, lactic acid bacteria and yeast counts in the final liquid diets (control and low protein), compared with individual dry feed ingredients used in the production of liquid diets, indicated the presence of active natural fermentation. This was confirmed by analysis, with end products of fermentation (lactic acid, acetic acid and ethanol) present in final diets. The final diets (control v low protein) had similar levels of lactic acid (1.38% v 1.25%), acetic acid (0.28% v 0.24%) and ethanol (0.27% v 0.28%). There were no significant differences in the microbial status of the control and low protein liquid diets.

Low protein diet reduced pen faecal sample counts for aerobic, anaerobic and lactic acid bacteria. The reduction in lactic acid bacteria (LAB) count significantly reduced the LAB to coliform ratio in pen faecal samples from pigs fed the low protein diet as the coliform count was not significantly affected by feeding treatment.

Salmonella could not be detected in samples of fresh straw and individual ingredients used in the production of liquid diets.

Only 22 out of 610 pigs tested positive for the caecal presence of Salmonella at slaughter, with pigs fed the low protein diet showing a statistically significant reduction in the percentage of pigs found positive for caecal presence at slaughter (1.7% v 5.6%).

Using the ELISA method, around 13% of pigs tested positive for Salmonella at entry and at slaughter this averaged 28.6% on control and 19.6% on low protein feeding treatments, with the difference between treatments approaching statistical significance (P=0.087).

Environmental impact

Reducing the protein content of the liquid diet significantly reduced the ammoniacal nitrogen content of pig effluent and ammonia emission from the straw and fully slatted housing.

There were no significant effects of feeding treatment on aerial concentration and emission of dust.

Meat quality

There were no significant effects of feeding treatment on the quality of fresh and cooked meat samples.

Housing

The effects of housing system on pig performance, health and welfare, microbial status, environmental impact and carcase and meat quality based on all four production trials are presented in Appendix IV. Key results from this study are summarised below.

Production

Feed intake was significantly higher in the fully slatted building but this did not translate into increased daily gain resulting in a significantly poorer feed conversion ratio.

There were no significant housing effects on carcase fatness though straw based pigs had a significantly reduced killing out percentage and lighter carcases.

The cost of production was about 4p/kg dead weight higher in the straw based system.

Pig health and welfare

Numbers of pigs removed for health conditions were higher from the straw based system (64 v 47). Loss of body condition being one of the major reasons for removal from the straw based system and tail injury from the fully slatted system.

Veterinary and health treatments were higher in the fully slatted system (256 v 177 pig days), with lameness and physical damage and management intervention to curtail tail biting being the major reasons for treatment. Treatment for enteric problems and loss of body condition were higher for pigs housed in the straw based system.

Pigs in the straw based system spent significantly less time sleeping and drinking.

There were no significant effects of housing system on skin lesions, but pigs housed in the straw based system had a significantly reduced hygine score (76.8 v 85.3% clean). Fully slatted housing significantly increased bursitis score (0.7 v 0.6) on a severity scale of 0 to 5.

Pigs in the straw based system spent only 0.3% of their time investigating and manipulating the environmental enrichment (toy) that was provided for them. This increased to 1.2% in the fully slatted system resulting in a significant difference between housing system.

Pigs in the straw based system spent significantly less time investigating pen components (3.3% v 11.9%) and other pigs (5.0% v 6.5%) and spent 21.1% of their time manipulating straw bedding.

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 to 3 severity scale). Pigs in the straw based system had significantly higher scores for toe erosions (1.2 v 0.4). Pigs in the fully slatted system had more severe sole erosions (1.6 v 0.5) and heel erosions (1.7 v 0.3).

Gastric ulceration (on a 0 to 5 scale of severity) was significantly higher in pigs from the fully slatted system (1.7 v 0.9). There were no significant effects of housing system on rind-side damage, lung scores or osteochondrosis scores.

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 counts) of dust sampled from the straw based system. The dust-borne coliform count did not differ between the two housing systems, suggesting that in this study most of the extra dust-borne contamination in the straw housing system came from the straw itself, rather than of faecal origin.

Salmonella was detected in five separate occasions in pen faecal samples removed from the straw based (2) and fully slatted (3) housing and on three occasions in samples of effluent from the fully slatted housing. Salmonella appeared only once in dust samples, and no count was obtained, suggesting that the level of contamination was extremely low (less than 10 cells per gram).

Only 22 out of 610 pigs tested positive for the caecal presence of Salmonella at slaughter with no conclusive effects of housing system established.

Whilst a significantly higher percentage of pigs tested positive for Salmonella (ELISA) on entry to the fully slatted system (18.8% v 7.2%), by slaughter levels had increased but the difference between housing system was not significant (28.0% fully slatted v 20.1% straw).

Environmental impact

There were no significant differences between housing systems in ammonia and dust emissions.

Meat quality

Fresh meat from pigs housed in the fully slatted system had significantly improved colour saturation values at carcase butchery and during eight days of simulated retail display.

Pork odour scores for cooked fat were higher (i.e. more favourable) in samples from pigs housed on straw; conversely skatole odour scores were higher (i.e. less desirable) in samples from pigs housed on fully slatted flooring.

Feeding and housing interactions

Production

The negative effects from feeding the low protein diet on daily gain tended to be greater in the straw based system.

Pig health and welfare

The 10 pigs removed during the trial for tail injury were restricted to the low protein diet fed in the fully slatted system, with 8 of these animals removed from the same pen. There were no significant interactions between feeding and housing system in respect of other behavioural or post mortem health assessments.

Microbial status

There were no consistent interactions between feeding and housing systems.

Environmental impact

There were no significant feeding and housing interactions.

Meat quality

There were no consistent 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 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 were evaluated over four production trials, with each trial designed to investigate different aspects of liquid feeding technology.

This report is based on the results of the fourth and final production trial, which evaluated the potential for reducing the nitrogen (crude protein) content of liquid diets by supplementation with synthetic amino acids (lysine, methionine, threonine and tryptophan).

OBJECTIVES

The objective of the research programme was 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

Feeding treatments

Two feeding treatments were evaluated as follows.

Control

A single diet fed in liquid form (22% dry matter) formulated to provide 9.65 MJ of net energy (NE) per kg of meal equivalent (MEq) at 87% dry matter with a dietary ideal protein content based on 8.5g standardised ileal digestible (SID) lysine/kg MEq without the use of synthetic amino acids giving a nitrogen content of 32g/kg MEq or about 20% crude protein.

Low Protein

A single diet fed in liquid form (22% dry matter) formulated to provide 9.65 MJ NE/kg MEq with a dietary ideal protein content based on 8.5g SID lysine/kg MEq using synthetic amino acids (lysine hydrochloride, methionine, threonine and tryptophan) to reduce nitrogen content to 24g/kg MEq or about 15% crude protein.

Feeding treatments were evaluated in two contrasting systems of housing (straw- based v fully slatted) using growing and finishing pigs from around 34kg to slaughter at 101kg 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 (control v low protein) according to housing system and room[a]

Room	1	2	3	4
Straw based	Control	Low Protein	Control	Low Protein

Room	1	2	3	4
Fully slatted	Low Protein	Control	Low Protein	Control

[a] Allocation of feeding treatment by room was necessary for the determination of the effects of feeding treatment (control v low protein) on environmental impact (see MLC (2004) for detail).

Diets and feeding

Formulation

Diets were formulated for pigs growing over the weight range from 30kg to 110kg. The formulations were targeted to meet standardised ileal digestible (SID) amino acid requirements resulting in a net energy content of 9.65 MJ and SID lysine content of 8.5g per kg of meal equivalent (87% dry matter).

Liquid feed production and delivery

The diets were produced on site from individual raw materials using the milling, mixing and liquid feeding system equipment available.

The diets were batch produced in the Central Process Tank and transferred to reservoir tanks (Tanks 4 and 5) with on demand delivery to feeding tanks (A and B).

The process was driven by feed demand at the troughs using sensors, which signalled for refill on empty. Feeding troughs were refilled with 20kg drops of liquid feed. 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 1280 (Large White x Landrace) x Large White pigs weighing between 30 to 40kg were received in 10 equal batches of 128 over 19 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 & 9

Room	1	2	3	4
Fully slatted	Batch 8	Batch 6	Batch 4	Batch 2 & 10

Pig identification and weighing

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 skewed by random selection.

Pigs were weighed 9 days prior to slaughter and those weighing more than 95kg were selected for slaughter so that the target weight at slaughter could be close to 105kg. 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 (control v low) and housing (straw based v fully slatted) on pig performance, pig health and welfare, microbial ecology, environmental impact and meat quality the following measurements and records were taken.

Pig production	Pig weights, feed intake (automatically for liquid), 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, behavioural time budgets, feeding behaviour. At slaughter: skin damage, foot lesions, osteochondrosis, 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, coliform and yeast counts and Lawsonia and Brachyspira.
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.
Meat Quality	Fat firmness, subcutaneous fat skatole and indole contents, and fatty acid profile, drip loss, muscle colour, simulated retail display, oxidative rancidity (TBARS) and sensory evaluation of cooked loins.

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	Control	Low Protein		H	F	I
n	20	20	20	20				
Live weight (kg)								
Entry	34.64	34.07	34.26	34.45	1.223			
Mid	62.17	58.04	60.56	59.64	1.784	*		
Final	100.48	101.78	101.34	100.93	0.914			*
Liquid feed intake (kg/pig day)								
Grower	7.23	6.13	6.57	6.79	0.225	***		
Finisher	9.96	10.02	9.86	10.11	0.194			*
Overall	8.54	7.84	8.03	8.35	0.129	***	*	0.053
Feed intake (kg MEq/pig day)								
Grower	1.83	1.55	1.66	1.72	0.057	***		
Finisher	2.52	2.53	2.49	2.56	0.049			*
Overall	2.16	1.98	2.03	2.11	0.033	***	*	0.053
Growth (g/day)								
Grower	758	684	734	708	24.2	**		
Finisher	865	938	924	878	12.3	***	***	*
Overall	831	840	851	821	11.5		*	0.052
Feed conversion ratio								
Grower	2.43	2.27	2.26	2.43	0.056	**	**	
Finisher	2.92	2.71	2.71	2.92	0.058	***	***	
Overall	2.67	2.50	2.49	2.68	0.039	***	***	
Carcase quality								
Slaughter weight (kg)	102.2	102.7	102.4	102.6	0.57			
Carcase weight (kg)	78.07	76.60	76.72	77.95	0.400	***	**	0.071
Killing out %	76.31	74.33	74.96	75.69	0.214	***	**	
Backfat P2 (mm)	12.46	12.52	12.22	12.77	0.229		*	0.067

[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		e.m.s.[a]	P		
	Control	Low Protein	Control	Low Protein		H	F	I
n	12	8	8	12				
Live weight (kg)								
Entry	35.33	33.94	33.18	34.96				
Mid	62.63	61.71	58.50	57.58		*		
Final	101.91	99.05	100.76	102.81	8.36			*
Liquid feed intake (kg/pig day)								
Grower	6.95	7.51	6.19	6.07		***		
Finisher	9.62	10.30	10.10	9.93	0.378			*
Overall	8.25	8.83	7.81	7.86		***	*	0.053
Feed intake (kg MEq/pig day)								
Grower	1.76	1.90	1.57	1.53		***		
Finisher	2.43	2.61	2.56	2.51	0.024			*
Overall	2.09	2.23	1.97	1.99		***	*	0.053
Growth (g/day)								
Grower	759	758	709	658		**		
Finisher	870	859	978	898	1510	***	***	**
Overall	835	828	868	813			*	0.052
Feed conversion ratio								
Grower	2.32	2.54	2.21	2.33		**	**	
Finisher	2.80	3.04	2.62	2.80		***	***	
Overall	2.57	2.77	2.41	2.58		***	***	
Carcase quality								
Slaughter weight (kg)	102.6	101.9	102.1	103.4				
Carcase weight (kg)	77.84	78.30	75.61	77.59		***	**	0.071
Killing out %	75.87	76.76	74.05	74.62		***	**	
Backfat P2 (mm)	11.97	12.96	12.47	12.58			*	0.067

[a] Error mean square (e.m.s.). Where there are significant ($P<0.05$) interactions, the standard error of difference (s.e.d.) between any two means based on n_1 and n_2 observations can be calculated using the following formula s.e.d. = $\sqrt{}$ e.m.s.*$((1/n_1)+(1/n_2))$

Variability

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

Variability was investigated by subjecting the within pen standard deviation (a measure of variability) for daily gain and carcase P2 to analysis of variance (ANOVA). No significant effects of feeding or housing system were found (see Appendix I Table 10).

Feeds

The results from the laboratory analysis of samples of liquid diets are given in Tables 3 and 4.

Table 3 Nutrient analysis (%) of complete liquid diets

	Liquid diets[a]			
	Control (n=44)		Low Protein (n=43)	
	Mean	SEM[c]	Mean	SEM
Oil (B)	4.60	0.471	3.42	0.206
NDAF	11.92	0.686	9.59	0.394
Ash	5.90	0.187	5.78	0.191
Calcium	0.87	0.042	0.82	0.034
Phosphorus	0.68	0.020	0.67	0.016
Copper (ppm)	26.62	0.938	25.75	1.321
Sodium	0.58	0.140	0.62	0.097
DE (MJ/kg)b	13.99		13.80	

[a] Nutrients adjusted to a meal equivalent of 87% dry matter.

[b] Estimated by regression (MAFF, 1993) using crude protein values given in Table 4.

[c] Standard error of the mean.

Table 4 Dry matter, protein and amino acid analysis[a,b] of complete liquid diets

	Control		Low Protein		s.e.d.	P
n	43		43			
Dry matter%[c]						
Oven	20.1		17.3		0.73	***
Freeze dried	21.8		19.1		0.73	***
Nitrogen (%)	3.40		2.66		0.050	***
Crude protein (%)	21.3		16.6		0.73	***
n	11		9			
Total amino acids (%)	**Actual**	**Expected**	**Actual**	**Expected**		
Lysine	1.011	0.990	0.930	0.960		
Methionine	0.288	0.320	0.272	0.300		
Threonine	0.760	0.730	0.657	0.650		
Tryptophan	0.271	0.260	0.219	0.210		
Free amino acids (%)						
Lysine	0.024	0	0.351	0.356		
Methionine	0.017	0	0.061	0.050		
Threonine	0.020	0	0.151	0.144		

[a] Adjusted to a meal equivalent of 87% dry matter

[b] Lysine, methionine and threonine analysed according to (EC, 1998), tryptophan according to AFNOR (1998).

[c] 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.

Additional samples of liquid diets were taken on site and tested for oven 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	Control (n=33)	Low Protein (n=33)	s.e.d.	P
Dry matter (%)	23.2	22.3	0.51	0.075
pH	5.24	5.00	0.093	*

Major end products of natural fermentation in the control and low protein liquid diets are presented in Table 6.

Table 6 Major end products of natural fermentation in liquid diets (fresh basis)

	Control (n=20)		Low Protein (n=21)	
	Mean	SEM	Mean	SEM
(mg/kg)				
Ethanol	2655	248.4	2760	193.8
Lactic Acid	13782	1231.4	12470	1730.4
Acetic Acid	2807	256.7	2353	202.2
(mmol/litre)				
Ethanol	53	5.0	55	3.9
Lactic Acid	144	12.8	130	18.0
Acetic Acid	44	4.0	37	3.2
(%)				
Ethanol	0.27	0.025	0.28	0.019
Lactic Acid	1.38	0.123	1.25	0.173
Acetic Acid	0.28	0.026	0.24	0.020

Pig health and welfare

Losses and health conditions

Pig losses through deaths and health conditions by housing and feeding system are given in Table 7. The results are presented by feeding system within each housing system in Table 8. Veterinary treatment for health conditions by housing and feeding system are given in Table 9. The results are presented by feeding system within each housing system in Table 10.

Table 7 Pig losses by housing and feeding system

	Housing system		Feeding system	
	Fully slatted	**Straw based**	**Control**	**Low Protein**
Losses (number)				
Deaths				
Grower	3 (0.47)[a]	8 (1.25)	4 (0.63)	7 (1.09)
Finisher	2 (0.40)	3 (0.75)	2 (0.43)	3 (0.68)
Removed				
Grower	14	42	24	32
Finisher	28	11	17	22
Total	47	64	47	64
Health condition (number)				
Respiratory	2	6	7	1
Enteric	1	3	1	3
Lameness/physical damage	13	12	13	12
Tail injury	10	0	0	10
Loss of body condition[b]	7	21	15	13
Multiple[c]	6	11	8	9
Other[d]	8	11	3	16
Total	47	64	47	64

[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, dermatitis and low body weight.

Table 8 Pig losses by feeding within housing system

	Fully Slatted		Straw Based	
Losses (number)	**Control**	**Low Protein**	**Control**	**Low Protein**
Deaths				
Grower	2 (0.52)	1 (0.39)	2 (0.78)	6 (1.56)
Finisher	1 (0.33)	1 (0.50)	1 (0.63)	2 (0.83)
Removed				
Grower	6	8	18	24
Finisher	10	18	7	4
Total	19	28	28	36
Health condition (number)				
Respiratory	1	1	6	0
Enteric	1	0	0	3
Lameness/physical damage	6	7	7	5
Tail injury	0	10	0	0
Loss of body condition	4	3	11	10
Multiple	5	1	3	8
Other	2	6	1	10
Total	19	28	28	36

Table 9 Veterinary treatment (pig days)[a] by housing and feeding system

	Housing system		Feeding system	
Health condition	**Fully slatted**	**Straw based**	**Control**	**Low Protein**
Respiratory	0	3	3	0
Enteric	36	99	45	90
Lameness/physical damage	111	36	36	111
Tail biting[b]	88	1	20	69
Tail injury[c]	0	0	0	0
Loss of body condition	6	30	12	24
Multiple	0	0	0	0
Other	15	8	15	8
Total	256	177	131	302

[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.

Table 10 Veterinary treatment (pig days) by feeding within housing system

	Fully Slatted		Straw Based	
Health condition	**Control**	**Low Protein**	**Control**	**Low Protein**
Respiratory	0	0	3	0
Enteric	6	30	39	60
Lameness/physical damage	24	87	12	24
Tail biting	20	68	0	1
Tail injury	0	0	0	0
Loss of body condition	0	6	12	18
Multiple	0	0	0	0
Other	9	6	6	2
Total	59	197	72	105

Health monitoring

Weekly skin lesion and hygiene scores according to feeding within housing system are given in Table 11. Results from analysis of blood samples for Acute Phase Proteins at different stages in the trial are shown in Table 12.

Table 11 Hygiene and skin lesion scores by feeding within housing system

	Fully slatted		Straw based		P		
	Control	**Low Protein**	**Control**	**Low Protein**	**H**	**F**	**I**
Lesions/pig	8.1	7.7	7.9	6.9		*	
Hygiene score (% clean)	84.3	86.3	72.9	80.6	**	*	
Bursitis (0-5 scale)	0.8	0.6	0.6	0.6	*		

Table 12 Acute Phase Proteins in blood by feeding within housing system

	Fully slatted		Straw based		P		
	Control	Low Protein	Control	Low Protein	H	F	I
At entry							
C-Reactive protein (Ug/ml)	373	379	348	334			
Haptoglobin (mg/ml)	0.93	1.02	0.90	1.05			
At mid-point							
C-Reactive protein (Ug/ml)	266	167	327	242		*	
Haptoglobin (mg/ml)	1.38	0.87	1.34	1.28			
At slaughter							
C-Reactive protein (Ug/ml)	209	143	153	166			
Haptoglobin (mg/ml)	0.55	0.57	0.34	0.47	*		

Behaviour

Percentage time spent performing general activities by feeding within housing system is given in Table 13. Percentage time spent performing manipulative behaviours by feeding within housing system is given in Table 14.

Table 13 Percentage time spent performing general activities by feeding within housing system

	Fully slatted		Straw based		P		
	Control	Low Protein	Control	Low Protein	H	F	I
% Time							
Lying	69.3	71.5	70.2	68.0			
'Sleeping'	55.8	56.3	52.0	50.6	*		
Eating	5.4	4.3	4.6	4.4			
Drinking	0.3	0.2	0.1	0.1	*		
Investigating	19.4	18.0	26.8	30.0	***		

Table includes both postures and behaviours within posture categories and will therefore not add to 100%.

Table 14 Percentage time spent performing manipulative behaviours by feeding within housing system

	Fully slatted		Straw based		P		
	Control	Low Protein	Control	Low Protein	H	F	I
% Time							
Straw	-	-	19.6	22.5			
Other pig	6.5	6.4	5.5	4.5	*		
Pen parts	12.7	11.1	2.8	3.7	***		
Environmental enrichment	1.0	1.3	0.3	0.3	**		
(when present)							

Slaughter assessments

A summary of all slaughter assessments by feeding within housing system is given in Table 15.

Table 15 Slaughter assessments by feeding within housing system

	Fully slatted		Straw based		P		
	Control	Low Protein	Control	Low Protein	H	F	I
Foot lesions (0-3 scale)							
False sand crack	0.8	0.5	0.1	0.3	**		
White line lesion	0.7	0.7	0.6	0.6			
Toe erosion	0.4	0.3	1.4	1.0	***	**	
Sole erosion	1.3	1.8	0.5	0.5	***		
Heel erosion	1.7	1.6	0.3	0.3	***		
Osteochondrosis (0-4 scale)							
Front score	2.2	2.2	2.2	2.4			
Rear score	1.3	1.4	1.3	1.4			
Gastric ulceration (0-5 scale)	1.6	1.7	0.9	0.8	**		
Rind-side damage (0-5 scale)	2.0	2.0	2.0	2.0			
Lung score (0-55 scale)	2.8	3.4	3.5	3.1			

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, water and straw samples is given in Table 16.

Table 16 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	5	ND	4.47	3.67	0.72	1.36		2.49
Barley	3	ND	6.12	2.79	0.90	2.30		2.49
Soya bean meal (HP)	1	ND	2.69	ND	ND	ND		ND
Rapeseed meal	1	ND	3.69	2.72	ND	ND		2.72
Greenwich Gold	24	ND	4.53	2.42	4.69	ND		3.65
Minerals and vitamins (Control)	2	ND	2.42	ND	ND	ND		ND
Minerals and vitamins (Low Protein)	2	ND	2.42	ND	2.00	ND		ND
Complete liquid diets								
Control	16	ND	8.42	8.04	8.69	3.68		5.65
Low Protein	16	ND	8.32	7.96	8.04	3.18		5.86
Drinking water	23						ND	
Fresh straw	21	ND						

ND = not detected.

Faeces, effluent and dust

Details relating to the number of pen faecal, effluent and room dust samples found positive for the presence of Salmonella are summarised in Table 17. The microbial status of pen faecal, effluent and room dust samples according to housing and feeding system is given in Table 18.

Table 17 Detection of Salmonella in faecal, effluent and room dust samples by housing and feeding system and room and pen

	n	Housing system	Feeding system	Date	Room	Pen	Log 10 cfu/100 ml
Faeces	96						
		Straw	Low Protein	17/7/04	4	16	
		Slatted	Control	2/8/04	4	17	See note
							(a) below
		Slatted	Control	2/8/04	4	18	
		Straw	Control	23/8/04	3	9	
		Slatted	Low Protein	27/9/04	1	32	
Effluent	25						
		Slatted	Low Protein	27/9/04	1		1.70
		Slatted	Low Protein	4/10/04	1		<1
		Slatted	Control	4/10/04	2		<1
Dust	75						
		Straw	Control	23/8/04	3		No count
							obtained

[a] Faecal Salmonella samples were recorded as presence or absence only.

Table 18 Microbial status of pen faeces, effluent and room dust by housing and feeding system

		Housing system		Feeding system		s.e.d.	P		
	n	Fully slatted	Straw based	Control	Low Protein		H	F	I
Total Aerobic Viable Count									
Faeces	12	8.86	8.94	9.04	8.77	0.241		0.057	
Dust	36	7.71	8.53	8.32	7.92	0.264	**		
Total Anaerobic Viable Count									
Faeces	12	9.59	9.85	9.84	9.60	0.199	*	*	
Lactic Acid Bacteria (LAB) Count									
Faeces	12	9.03	9.03	9.21	8.86	0.208		**	
Coliform Count									
Faeces	12	5.98	5.81	5.81	5.98	0.393			*
Dust	36	2.52	2.32	2.23	2.62	0.354			
LAB : Coliform Ratio									
Faeces	12	1.55	1.61	1.64	1.52	0.098		*	0.062
Enterobacteraciae Count									
Effluent	12	4.62		4.46	4.76	0.339			

Pigs

The Salmonella status of pigs at entry and at slaughter is given in Table 19.

Table 19 Salmonella status of pigs at entry and at slaughter by housing and feeding system

	Housing system		Feeding system		s.e.d.	P		
	Fully slatted	Straw based	Control	Low Protein		H	F	I
n	16	16	16	16				
Entry								
ELISA % positive	18.8	7.2	13.9	12.2	2.33	***		
Slaughter								
Caecal positive [a]	10	12	18	4				
(number of pigs)								
Caecal %positive	3.1	4.2	5.6	1.7	1.69		*	
ELISA %positive	28.0	20.1	28.6	19.6	5.03		0.087	

[a] Of the 610 pigs finished and sampled, 22 were found positive for caecal Salmonella presence.

Environmental impact

Ammonia and dust

Ammonia and dust emission and dust concentration according to housing and feeding system are presented in Table 20.

Table 20 Ammonia and dust emission and dust concentration

		Housing system		Feeding system		P		
		Fully slatted	Straw based	Control	Low Protein	H	F	I
Ammonia	n	4	4	4	4			
Emission (g NH_3-N per lu hour)		1.18	0.66	1.11	0.73		***	
Dust								
Concentration (mg per m^3)		0.79	0.63	0.71	0.71			
Emission (g per lu hour)		0.22	0.22	0.24	0.20			

Waste

The volume of effluent and weight of farmyard manure generated and composition is presented in Table 21.

Table 21 Production and composition of waste

	Fully slatted		Straw based
	Control	Low Protein	
Production (pig/day)			
Effluent (litres)	6.98	7.68	-
Farm Yard Manure (kg)	-	-	4.46
Composition[a] (n=7)			
Dry matter (%)	7.3	8.3	17.3
Ammoniacal nitrogen (mg NH_4-N/kg)	4150	3530[a]	2788
Kjeldahl nitrogen (mg N/kg)	5690	5210[a]	6487
Total phosphorus (mg/kg)	1673	1584	2218

[a] Nitrogen content significantly lower (P<0.05) with low protein diet

Meat quality

Fresh meat, chemical composition and sensory quality

The results from the evaluation of fresh meat samples for quality and chemical composition and sensory panel scoring of cooked samples are presented in Table 22.

The subcutaneous fat characteristics and sample fatty acid profiles by housing and feed system are presented in Appendix I Table 12.

Table 22 Meat quality by housing and feeding system

	Housing system		Feeding system		s.e.d.	P		
	Fully slatted	Straw based	Control	Low Protein		H	F	I
n	64	64	64	64				
Fresh								
Drip loss (%)	4.27	3.82	3.94	4.16	0.215	*		
Colour Saturation								
At carcase butchery	7.54	6.71	6.97	7.28	0.204	***		
Retail display								
Day 1	10.43	9.32	9.77	9.99	0.204	***		
Day 2	10.08	9.17	9.55	9.70	0.200	***		
Day 5	9.30	8.71	9.01	9.00	0.168	***		
Day 6	9.11	8.48	8.83	8.77	0.173	***		
Day 7	8.89	8.29	8.58	8.60	0.172	***		
Day 8	8.55	8.01	8.19	8.36	0.193	**		
TBARS								
Display day 1	0.050	0.046	0.044	0.052	0.010			
Display day 7	0.078	0.086	0.078	0.086	0.014			
Taints (ppm)								
Indole	0.027	0.033	0.028	0.031	0.009			
Skatole	0.030	0.047	0.034	0.043	0.011			
Eating								
Lean								
Juiciness	38.29	37.48	38.02	37.76	1.025			*
Tenderness	42.73	40.70	41.12	42.32	1.606			
Pork flavour	34.08	34.75	34.90	33.93	0.889			
Abnormal flavour	4.04	3.30	3.26	4.07	0.643			
Boar flavour	7.27	6.38	6.84	6.81	1.381			
Fat								
Pork odour	20.03	21.95	21.44	20.54	0.924	*		**
Abnormal odour	2.24	3.01	2.78	2.48	0.750			
Androstenone odour	8.11	6.31	6.30	8.13	1.702			
Skatole odour	2.85	1.38	2.24	2.00	0.573	*		

APPENDICES

APPENDIX I OTHER RESULTS

Table 1 Inputs and waste production

	Fully slatted		Straw based	
	Control	Low Protein	Control	Low Protein
Feed (kg meal equivalent)				
Grower (Per pig)	63.3	70.5	56.0	52.7
Finisher (Per pig)	110.0	113.5	110.7	126.6
Labour (minutes)				
Husbandry				
Per pig day	0.08	0.08	0.28	0.28
Per pig	6.2	6.1	21.9	23.5
Cleaning				
Per pig day	0.04	0.07	0.06	0.04
Per pig	3.6	5.4	4.9	3.3
Medicine cost (p)				
Per pig day	0.15	0.63	0.29	0.26
Per pig	12.34	50.21	22.75	21.85
Power consumption (kWh)				
Buildings				
Per pig day	0.25	0.25	0.35	0.35
Per pig	20.56	20.31	27.50	29.53
Liquid feed production and delivery				
Per pig day	0.22	0.22	0.22	0.22
Per pig	17.66	17.44	17.18	18.45
Power washing				
Per pig day	0.08	0.08	0.08	0.08
Per pig	6.35	6.27	6.18	6.63
Water used (litres)				
Drinking and liquid feed				
Per pig day	7.95	8.40	7.44	7.48
Per pig	644.76	672.95	587.32	633.95
Cleaning				
Per pig day	1.95	1.95	0.60	0.60
Per pig	158.22	156.25	46.99	50.46
Straw used (kg)				
Per pig day	-	-	0.38	0.38
Per pig	-	-	30.23	32.46
Mortality				
Growing stage				
(%)	0.52	0.39	0.78	1.56
Mean weight (kg)	45.25	46.00	30.75	34.83
Finishing stage				
(%)	0.33	0.50	0.63	0.83
Mean weight (kg)	48.00	52.50	57.50	73.00
Pigs removed				
Growing stage				
(%)	1.56	3.13	7.03	6.25
Mean weight (kg)	33.25	41.31	39.94	34.92
Finishing stage				
(%)	3.33	9.00	4.38	1.67
Mean weight (kg)	68.90	70.72	58.93	73.13
Waste production (kg)				
Farm Yard Manure				
Per pig day	-	-	4.46	4.46
Per pig	-	-	352.20	378.18
Effluent				
Per pig day	6.98	7.68	-	-
Per pig	566.20	615.21	-	-

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	
Wheat	t	92	
Rapeseed Meal	t	108	
Soya bean meal	t	160	
Greenwich Gold	t	15	
Soya oil	t	380	
Mineral & Vitamin Supplement			
Control	t	235	
Low Protein	t	470	
Complete diet			
Control diet	t	107.91	Meal equivalent costs (87% dry matter).
Low Protein diet	t	104.97	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.
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 diets (£/t) at meal equivalent 87% dry matter

	-10%	Base line	+10%
Control[a]	97.12	107.91	118.70
Low Protein[b]	94.47	104.97	115.47
Low Protein[c]	103.92	104.97	105.99

[a,b] Base line +/- 10% shift in diet cost

[c] Base line +/- 10% shift in the cost of amino acids in the diet

Table 4 Cost of production[a] (p/kg dead weight) by housing and feeding system

	Housing System		Feeding System	
	Fully slatted	Straw based	Control	Low Protein
Variable costs				
Feed	27.1	26.3	26.1	27.4
Vet and Med	0.5	0.3	0.2	0.5
Bedding	0	1.4	0.7	0.7
Total	27.6	28.0	27.0	28.6
Fixed costs				
Housing	5.2	4.6	4.8	5.0
Feed system	2.1	2.4	2.2	2.3
Labour	1.8	4.7	3.2	3.4
Energy	2.3	2.8	2.5	2.6
Water	0.8	0.5	0.7	0.6
Waste storage and disposal	2.1	1.2	1.6	1.7
Total	14.3	16.2	15.0	15.6
Total Finishing Costs	41.9	44.2	42.0	44.2
Weaner cost	44.6	46.6	45.3	45.9
TOTAL COSTS	**86.4**	**90.8**	**87.3**	**90.1**

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

Table 5 Cost of production (p/kg dead weight) by feeding within housing system

	Fully slatted		Straw based	
	Control	Low Protein	Control	Low Protein
Variable costs				
Feed	26.4	27.8	25.7	26.9
Vet and Med	0.2	0.7	0.3	0.3
Bedding	0	0	1.3	1.4
Total	26.6	28.5	27.3	28.6
Fixed costs				
Housing	5.1	5.2	4.4	4.8
Feed system	2.1	2.1	2.3	2.5
Labour	1.7	2.0	4.7	4.7
Energy	2.3	2.3	2.6	2.9
Water	0.8	0.8	0.6	0.4
Waste storage and disposal	2.0	2.2	1.2	1.3
Total	14.0	14.6	15.9	16.6
Total Finishing Costs	40.6	43.1	43.2	45.2
Weaner cost	43.6	45.6	47.0	46.1
TOTAL COSTS	**84.1**	**88.7**	**90.2**	**91.4**

Table 6 Sensitivity analysis for cost of production (p/kg dead weight) by feeding within housing system

		Fully slatted		Straw based	
		Control	Low Protein	Control	Low Protein
Base line cost of production[a]		84.1	88.7	90.2	91.4
Feed costs					
(+/- of baseline)	+10%	86.8	91.5	92.8	94.1
	-10%	81.5	85.9	87.6	88.7
Amino acid costs					
(+/- of base line)	+10%	n/a	89.0	n/a	91.6
	-10%	n/a	88.4	n/a	91.1
Installation size					
Below IPPC threshold					
	1000 pig places	84.7	89.3	90.8	92.1
At IPPC threshold					
	2000 pig places	84.1	88.7	90.2	91.4
Above IPPC threshold					
	4000 pig places	83.7	88.2	89.7	90.8

[a] From Table 4.

Table 7 Formulation against actual use of raw feed ingredients in the production of liquid diets

(kg)	Target	Actual		
		Mean	SD[a]	n
Control diet				
Water	685.90	688.38	9.824	195
Greenwich Gold	88.00	88.11	4.554	
Wheat	114.83	114.18	6.326	
Barley	38.28	36.28	3.369	
Soya bean meal	50.68	50.75	1.902	
Rapeseed meal	12.59	12.73	0.883	
Soya oil	2.41	2.48	0.663	
Mineral and vitamin supplement	7.31	7.08	0.649	
Low protein diet				
Water	685.08	687.39	11.651	188
Greenwich Gold	88.00	88.62	5.621	
Wheat	144.19	144.22	7.204	
Barley	48.06	45.40	3.844	
Soya bean meal	12.62	12.84	1.506	
Rapeseed meal	12.59	12.90	1.005	
Mineral and vitamin supplement	9.46	8.64	1.400	

[a] Standard deviation.

Table 8 Analysis of mineral and vitamin supplements for free amino acid[a] content

(g/kg)	Expected	Actual	
		Batch 1	Batch 2
Control diet			
Lysine	0	0	0.27
Methionine	0	0	0.00
Threonine	0	0	0.54
Low protein diet			
Lysine	95.2	96.6	80.3[b]
Methionine	13.6	14.5	13.0
Threonine	38.5	37.7	36.4

[a] Adjusted for purity coefficients of 0.788, 1.0 and 1.0 for lysine hydrochloride, methionine and threonine in the supplemented mineral and vitamin mixture for the Low Protein dietary treatment.

[b] 14.9 g below expected, equivalent to a shortfall of 0.064% in lysine content of the final diet at 87% dry matter.

Table 9 Nutrient analysis of ingredients used in the production of liquid diets

Nutrients (% dry matter)	n	DM	CP	Oil (B)	NDAF	Ash	DE (MJ/kg fresh)[a]	Ca	P	Na
Feed ingredient										
Whole grain wheat	2	87.25	13.20	2.55	10.50	1.75	14.72			
Whole grain barley	1	87.30	12.70	2.50	16.00	2.50	13.79			
Rapeseed meal	1	88.30	31.40	6.60	30.60	6.40	12.88			
Soya bean meal (HP)	1	87.80	47.90	2.00	8.70	6.40	16.01			
Greenwich Gold	7	22.03	26.65	6.68	7.72	8.43	3.81			
Mineral and vitamins premix										
(Control)	1							23.80	6.89	9.15
Mineral and vitamins premix										
(Low Protein)	1							18.69	6.43	7.24

[a] Estimated by regression (MAFF, 1993).

Table 10 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	Control	Low Protein		H	F	I
Growth (g/day)									
Grower	20	177	211	185	202	16.0	*		*
Finisher	20	197	176	185	187	22.9			*
Overall	20	109	114	113	110	8.8			
Carcase quality									
Slaughter weight (kg)	20	4.24	5.75	5.07	4.92	0.479	**		0.073
Carcase weight (kg)	20	3.66	4.49	4.13	4.02	0.381	*		0.058
Killing out %	20	1.96	1.89	1.96	1.89	0.173			
Backfat P2 (mm)	20	2.47	2.34	2.46	2.34	0.159			

Table 11 Detail of individual pigs found caecal positive for Salmonella at slaughter

Housing	Feeding	Slaughter date	Room	Pen	Serotype[a]
Slatted	Control	06/10/2004	4	18	Group B
Slatted	Control	06/10/2004	4	18	Group B
Slatted	Control	06/10/2004	4	19	Group B
Slatted	Control	06/10/2004	4	19	Group B
Slatted	Control	20/10/2004	4	17	Group B
Straw	Control	03/11/2004	3	10	Group B
Straw	Control	03/11/2004	3	10	Group B
Straw	Control	03/11/2004	3	10	Group B
Straw	Control	03/11/2004	3	12	Group B
Straw	Control	03/11/2004	3	12	Group B
Straw	Control	03/11/2004	3	12	Group B
Slatted	Low Protein	03/11/2004	3	23	Group B
Slatted	Low protein	03/11/2004	3	24	Group B
Straw	Control	10/11/2004	3	9	No ID
Straw	Control	10/11/2004	3	9	No ID
Straw	Low Protein	17/11/2004	2	8	No ID
Slatted	Control	24/11/2004	2	28	Group B
Straw	Control	01/12/2004	1	1	Group B
Straw	Control	01/12/2004	1	4	Group B
Slatted	Control	01/12/2004	2	28	Group B
Slatted	Low Protein	01/12/2004	1	31	Group B
Straw	Control	08/12/2004	1	1	Group D

[a] Group B isolates were *Salmonella typhimurium*. The group D isolate was *Salmonella enteriditis*.

Table 12 Subcutaneous fat characteristics and fatty acid profile of the lean

		Housing system		Feeding system		s.e.d.	P		
	n	Fully slatted	Straw based	Control	Low Protein		H	F	I
Fat characteristics									
Backfat P2 (mm)	618	12.40	12.58	12.20	12.78	0.202		**	*
Fat Firmness (shoulder)	128	4.80	5.13	4.55	5.38	0.116	**	***	**
Fat Firmness (back)	128	4.25	4.55	3.92	4.88	0.113	**	***	
Mean penetrometer score	128	802.6	794.9	774.2	823.3	12.43		***	*
g fatty acids/100g lean	20	1.32	1.36	1.30	1.38	0.120			
g/100g fatty acids									
Saturated	20	32.29	32.89	32.43	32.74	0.577			
Monounsaturated	20	39.64	40.19	38.02	41.80	1.381		**	
Polyunsaturated	20	21.37	20.59	23.02	18.93	1.219		**	
Aldehydes	20	2.02	1.92	1.91	2.04	0.173			

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

The diets were formulated to supply equivalent levels of net energy (NE) and standardised ileal digestible (SID) lysine as the first limiting amino acid. Formulations were targeted to meet or exceed the amino acid requirements according to the recommended ideal profile relative to SID lysine for growing pigs (BSAS, 2003). Formulations of the diets in liquid form and expressed in meal equivalent (87% dry matter) are presented in Table 1.

Table 1 Formulations and nutrient specifications of the liquid diets

	Control		Low Protein	
Ingredient (%)	**Liquid**	**Meal equivalent[a]**	**Liquid**	**Meal equivalent**
Water	68.590		68.508	
Greenwich Gold	8.800	10.000	8.800	10.000
Wheat	11.483	45.150	14.419	56.693
Barley	3.828	15.102	4.806	18.963
Soya bean meal	5.068	20.342	1.262	5.064
Rapeseed meal	1.259	5.000	1.259	5.000
Soya oil	0.241	1.098	0.000	0.000
Limestone	0.237	1.068	0.218	0.983
Dicalcium phosphate	0.280	1.274	0.343	1.560
Salt	0.181	0.821	0.183	0.830
Lysine HCl	0.000	0.000	0.114	0.509
Methionine	0.000	0.000	0.013	0.059
Threonine	0.000	0.000	0.036	0.165
Tryptophan	0.000	0.000	0.006	0.029
Trace elements and vitamins[b]	0.032	0.145	0.032	0.145
Nutrient Specification				
Dry matter (%)	22.0		22.0	
DE (MJ/kg)		13.77		13.38
NE (MJ/kg)		9.65		9.65
CP (%)		20.29		15.25
Total lysine (%)		0.99		0.96
SID lysine (%)		0.85		0.85
SID methionine (%)		0.29		0.28
SID threonine (%)		0.61		0.55
SID tryptophan (%)		0.23		0.19
Ca (%)		0.80		0.80
P (%)		0.65		0.65
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 and synthetic amino acids as a mineral and vitamin supplement added to the diet as a single mixture. Mineral and vitamin supplement provided per kg (meal equivalent) of diet: Vitamins A, D and E 6000, 1000 and 100 iu respectively, Vitamin K 1000 ug, Riboflavin 3 mg, Pyridoxine 3 mg, Cyanocobalamin 15 mg, Biotin 75 ug, Pantothenic acid 10 mg, Niacin 15 mg, Copper 17 mg, Zinc 40 mg, Manganese 40 mg, Iron 100 mg, Iodine 0.25 mg and Selenium 0.2 mg.

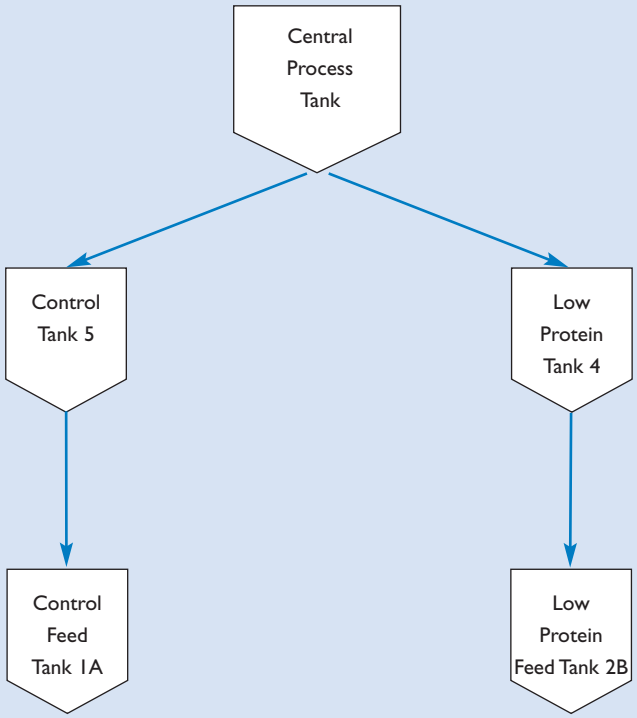
Production of liquid diets

The production of liquid diets is presented schematically in Figure 1.

The diets were batch produced in the Central Process Tank and transferred to reservoir tanks (Tanks 4 and 5) with on demand delivery to feeding tanks (A and B).

The process was driven by feed demand at the troughs using sensors, which signalled for refill on empty. Feeding troughs were refilled with 20kg drops of liquid feed. 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.

Figure 1 Production of liquid diets



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. Liquid diets 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.

Animals

A total of 1280 (Large White x Landrace) x Large White pigs weighing between 30 to 40kg were received in 10 equal batches of 128 over 19 weeks commencing 9th July 2004 and transferred to the housing according to the following pattern.

Room	1		2		3		4	
	Batch 7		Batch 5		Batch 3		Batch 1 & 9	
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 & 10	
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

All subsequent procedures relating to the management of animals and research methodology have been previously reported (MLC, 2004).

APPENDIX III SYSTEMS TECHNICAL SPECIFICATIONS

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

APPENDIX IV HOUSING SYSTEMS COMPARED OVER FOUR TRIALS

Summary

Production

Over the four trials, cost of production was an average of 3p/kg dead weight higher for the straw based system.

Whilst feed intake and daily gain were higher in the fully slatted system during the growing stage and conversely higher in the straw based system during the finishing stage, overall there were no significant effects of housing on performance and carcase quality over the four trials. Variability in daily gain was higher during the growing stage in the straw based system and higher during the finishing stage in the fully slatted housing with no overall difference from entry to slaughter. Backfat thickness variability was significantly higher in the fully slatted system.

Pig health and welfare

Mortality levels remained low over the four trials, with the straw based system giving the highest level (1.19%) during the growing stage.

The total number of pigs removed were similar for the two housing systems, though the distribution of losses within housing system varied according to health condition. Loss of body condition (PMWS like conditions) and enteric and respiratory problems were the major reasons for the removal of pigs from the straw based system. Lameness/physical damage and tail injury were the major reasons for the removal of pigs from the fully slatted system.

Veterinary treatment for respiratory and enteric problems and loss of body condition and management interventions for controlling tail biting were higher in the straw based system, whereas veterinary treatment for lameness/physical damage and tail injury were greater in the fully slatted system.

Acute phase protein titres at slaughter were higher in pigs from the fully-slatted system.

Skin lesion score did not differ between systems; however bursitis was more severe in pigs in the fully slatted system.

Pigs in the straw-based system had poorer hygiene scores, but the magnitude of this difference varied between studies depending on season.

Pigs with straw were more active, spending a large proportion of time manipulating straw. In the absence of straw, pigs spent more time in behaviour directed at other pigs and the pen components and, when present, manipulating enrichment objects placed in the pen environment (e.g. toys).

Post-slaughter assessment showed no housing systems differences in lung lesions or osteochondrosis. Gastric lesion scores were higher in the fully-slatted system.

Pigs with straw had more severe toe erosions on the foot, whilst pigs without straw had more severe sole and heel erosions.

Microbial status

There were no major housing systems effects on microbial status over the four trials, with the exception that room dust sampled from the straw based system carried a higher burden of aerobic viable bacteria.

The percentage of pigs found positive for the caecal presence of Salmonella at slaughter were higher in the straw based housing, but the difference was not statistically significant.

The ratio of lactic acid bacteria (LAB) to coliforms in ileal samples was higher at slaughter from pigs finished in the straw based system. This was due to a non-significant increase in LAB and a reduction in coliform counts.

Environmental impact

There were no significant effects of housing system on the concentration of aerial dust within the internal environment of the buildings and on the emission of dust and ammonia.

Meat quality

There were no significant effects of housing system on key meat quality measurements.

Table 1 Pig performance and carcase quality

	Fully slatted	Straw based	s.e.d.	P
n	4	4		
Live weight (kg)				
Entry	34.81	33.78	0.616	
Mid	63.79	60.27	0.707	*
Final	101.20	102.80	0.534	0.06
Feed intake				
(kg MEq/pig day)				
Grower	1.66	1.51	0.045	*
Finisher	2.36	2.44	0.041	
Overall	1.98	1.91	0.037	
Growth (g/day)				
Grower	757	705	7.7	**
Finisher	864	918	13.0	*
Overall	825	833	7.7	
Feed conversion ratio				
Grower	2.21	2.16	0.038	
Finisher	2.74	2.68	0.078	
Overall	2.46	2.40	0.040	
Carcase quality				
Slaughter weight (kg)	102.4	103.7	0.61	
Carcase weight (kg)	76.22	76.34	0.688	
Killing out %	74.37	73.59	0.471	
Backfat P_2 (mm)	11.73	11.74	0.264	

Table 2 Variability (SD) in gain and carcase quality

	Fully slatted	Straw based	s.e.d.	P
n	4	4		
Growth (g/day)				
Grower	184	215	6.5	*
Finisher	178	165	5.0	0.09
Overall	105	111	5.4	
Carcase quality				
Slaughter weight (kg)	4.87	5.94	0.184	**
Carcase weight (kg)	4.97	4.86	0.498	
Killing out %	3.31	2.44	0.488	
Backfat P_2 (mm)	2.35	2.17	0.033	*

Table 3 Pig losses

	Fully slatted		Straw based		P[a]
	Mean	Median	Mean	Median	
n	4	4	4	4	
Deaths (number)					
Grower	3.0	3.0	6.5	6.5	*
Finisher	1.5	1.5	1.3	1.0	
Mortality (%)					
Grower	0.56		1.19		*[b]
Finisher	0.35		0.34		
Removed (number)					
Grower	22.5	23.0	24.8	23.0	
Finisher	17.5	14.5	7.8	7.5	0.08
Health condition (number)					
Respiratory	1.5	1.0	4.5	5.5	
Enteric	3.8	1.0	5.5	3.0	
Lameness/physical damage	11.0	12.0	5.8	4.0	
Tail injury	15.3	12.5	2.0	0.5	*
Loss of body condition[b]	3.7	2.0	14.0	15.0	
Multiple[c]	3.3	3.0	4.0	2.5	
Other[d]	7.0	7.0	8.0	8.0	
Total	44.5	45.0	40.3	39.0	

[a] Data analysed using Mann-Whitney non-parametric statistical test (Mann and Whitney, 1947).

[b] Mortality data analysed by ANOVA using a general linear model.

Table 4 Veterinary treatment (pig days)

	Fully slatted		Straw based		P[a]
	Mean	Median	Mean	Median	
n	4	4	4	4	
Health condition					
Respiratory	7.3	1.5	72.3	18.0	
Enteric	12.0	6.0	49.8	39.5	
Lameness/physical damage	112.5	119.5	50.3	40.5	0.06
Tail biting	69.8	77.5	136.8	117.5	
Tail injury	7.8	1.5	0	0	
Loss of body condition	20.0	24.0	59.0	66.0	
Multiple	0	0	1.8	0	
Other	7.8	6.5	10.0	10.0	
Total	232	236	365	409	

[a] Data analysed using Mann-Whitney non-parametric statistical test.

Table 5 Health and welfare

	Fully slatted	Straw based	P
n	4	4	
Hygiene and skin lesions			
Skin lesions/pig	9.2	9.5	
Hygiene score (% clean)	79.8	72.1	***
Bursitis (0-5 scale)	1.0	0.7	***
Acute Phase Proteins			
At entry			
C-Reactive protein (µg/ml)	245.9	239.1	
Haptoglobin (mg/ml)	0.99	0.91	
At mid-point			
C-Reactive protein (µg/ml)	198.1	197.6	
Haptoglobin (mg/ml)	1.28	1.10	0.054
At slaughter			
C-Reactive protein (µg/ml)	162.3	128.4	0.053
Haptoglobin (mg/ml)	0.66	0.47	***
General activities (%Time)[a]			
Lying	70.9	68.7	*
'Sleeping'	56.7	52.2	***
Eating	4.7	4.3	
Drinking	0.4	0.4	
Investigating	19.9	28.0	***
Manipulative behaviours (%Time)			
Straw	-	17.6	
Other pig	7.8	6.2	***
Pen parts	11.3	4.6	***
Enrichment (when present)	1.4	0.7	*
Post-slaughter measurements			
Foot lesions (0-3 scale)			
White line lesion	0.7	0.7	
Toe erosion	0.4	1.3	***
Sole erosion	1.1	0.6	***
Heel erosion	1.3	0.3	***
Other			
Gastric ulceration (0-5 scale)	2.1	1.3	***
Rind-side damage (0-5 scale)	2.1	2.1	
Lung score (0-55 scale)	2.3	2.3	
Osteochondrosis (0-4 scale)			
Front score	2.4	2.4	
Rear score	1.5	1.6	

[a] Includes both postures and behaviours within posture categories and will therefore not add to 100%.

Table 6 Microbial status of pen faeces, effluent and room dust

	Fully slatted	Straw based	s.e.d.	P
n	4	4		
Total Aerobic Viable Count				
Faeces	8.69	8.79	0.084	
Dust	7.25	8.30	0.093	**
Total Anaerobic Viable Count				
Faeces	9.42	9.54	0.058	
Lactic Acid Bacteria (LAB) Count				
Faeces	8.48	8.46	0.053	
Coliform Count				
Faeces	5.92	5.90	0.080	
Dust	1.90	2.32	0.309	
LAB : Coliform Ratio				
Faeces	1.47	1.48	0.039	

Table 7 Salmonella status of pigs at entry and at slaughter

	Fully slatted	Straw based	s.e.d.	P
n				
Entry				
Caecal positive (number of pigs)[a] 2				
ELISA % positive 4	10.5	8.8	4.65	
Slaughter				
Caecal positive (number of pigs) 4	31	32	0.7	
Caecal %positive 4	8.3	10.5	1.32	
ELISA %positive 4	14.3	15.8	3.43	

[a] One pig was found to be positive at the start of trial 1 (allocated to the straw housing). No positives were found at the start of trial 3. No measurements were taken for trials 2 and 4.

Table 8 Salmonella positives in faecal and dust samples

	Fully slatted	Straw based	s.e.d.	P
n	4	4		
Faecal (number of pens positive)	2	3.75	1.80	
Dust (number of rooms positive)	1	1	0.41	

Table 9 Microbial status of pigs at slaughter

	Fully slatted	Straw based	s.e.d.	P
n[a]	8	8		
Total Aerobic Viable Count				
Ileal	7.74	7.81	0.276	
Caecal	8.19	8.28	0.243	
Colon	8.25	8.46	0.239	
Total Anaerobic Viable Count				
Ileal	8.15	8.25	0.276	
Caecal	9.36	9.33	0.218	
Colon	9.30	9.39	0.200	
Lactic Acid Bacteria (LAB) Count				
Ileal	7.46	7.71	0.224	
Caecal	8.30	8.27	0.216	
Colon	8.25	8.50	0.236	
Coliform Count				
Ileal	7.18	6.87	0.288	
Caecal	6.14	6.17	0.265	
Colon	5.88	5.98	0.283	
LAB : Coliform Ratio				
Ileal	1.08	1.17	0.034	0.014
Caecal	1.37	1.37	0.026	
Colon	1.43	1.46	0.047	
Yeast Count				
Ileal	4.08	4.14	0.340	
Caecal	3.97	3.79	0.274	
Colon	3.76	3.65	0.127	

[a] Analysed using rooms as units, with 13 error degrees of freedom.

Table 10 Ammonia and dust emission and dust concentration

	Fully slatted	Straw based
n	3	3
Ammonia		
Emission (g NH_3-N per lu hour)	1.04	0.92
Dust		
Concentration (mg per m^3)	1.4	1.1
Emission (g per lu hour)	0.41	0.37

Table 11 Meat quality

	Fully slatted	Straw based	s.e.d.	P
n	3	3		
Fresh				
Drip loss (%)	4.91	4.39	0.478	
Colour Saturation				
At carcase butchery	7.25	6.70	0.162	0.076
Retail display				
Day 1	9.48	8.78	0.219	0.086
Day 2	9.15	8.65	0.208	
Taints (ppm)				
Indole	0.029	0.036	0.0026	
Skatole	0.046	0.054	0.0098	
Eating				
Lean				
Juiciness	29.24	29.08	0.346	
Tenderness	32.24	32.62	1.349	
Pork flavour	26.89	27.87	0.542	
Boar flavour	6.64	5.94	0.423	
Fat				
Pork odour	15.71	16.64	0.534	
Androstenone odour	7.36	5.68	1.006	
Skatole odour	2.65	1.99	0.417	

Table 12 Subcutaneous fat characteristics and fatty acid profile of the lean

	Fully slatted	Straw based	s.e.d.	P
n	3	3		
Fat characteristics				
Backfat P2 (mm)	11.85	11.70	0.261	
Fat Firmness (shoulder)	4.52	4.63	0.111	
Mean penetrometer score	739.1	728.3	2.90	0.065
g fatty acids/100g lean	1.27	1.28	0.142	
g/100g fatty acids				
Saturated	32.90	32.86	0.691	
Monounsaturated	35.61	35.67	1.022	
Polyunsaturated	25.94	25.78	1.606	
Aldehydes	1.86	1.78	0.168	

GLOSSARY

A detailed glossary can be found in the first report under the Finishing Pigs Systems Research Programme (MLC, 2004), which should be used in reference to this report. Additional terms are described below.

Statistical

Mann-Whitney nonparametric test

Parametric implies that a distribution is assumed for the population. Often, an assumption is made when performing a hypothesis test that the data are a sample from a certain distribution, commonly the normal distribution. **Nonparametric** implies that there is no assumption of a specific distribution for the population. **Nonparametric tests** are analogous to the parametric t-tests and analysis of variance procedures in that they are used to perform tests about population location or center value. The center value is the mean for parametric tests and the median for nonparametric tests. Mann-Whitney test performs a hypothesis test of the equality of two population medians.

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