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Introduction

The pig research programme at the Agri-Food and Biosciences Institute, Hillsborough addresses key issues within the areas of production, nutrition, welfare and meat quality. This integrated approach ensures that effects are monitored from the productivity and welfare of the pig through to the quality of the carcass and the eating quality of the pork we eat.

This seminar has been specifically designed to highlight current research from this integrated programme. The objective of this seminar is to ensure that results of research undertaken at the Institute are disseminated as widely as possible to the agri-food industry in Northern Ireland. In particular, the target audience for the seminar are those directly involved in provision of specialist technical support to pig producers. This seminar enables a more in-depth insight into the current research programme at AFBI, as well as providing an excellent opportunity for those closely involved in the industry to comment on our current research programme and to suggest priorities for future research.

The integrated pig research programme at AFBI is primarily funded by the Department of Agriculture and Rural Development for Northern Ireland (DARD). However we also acknowledge the very significant practical and financial support from a number of producer groups, particularly the Pig Production Development Committee and more recently the British Pig Executive (BPEX). The long standing partnership between AFBI, John Thompson and Sons Ltd and Devenish Nutrition Ltd also enables very effective interaction between AFBI scientists and leading industry specialists, in addition to providing valuable financial support.

Since the last seminar, the pig unit manager, Mr Dennis Watt, has retired after almost 47 years service to the pig unit at AFBI, Hillsborough. However, the pig research team are very committed to the pig industry in Northern Ireland and I am confident they will continue to provide the NI pig industry with practical and relevant research in a timely manner.

The theme of the current seminar is ‘Pig Research – An Integrated Approach’.

The papers being presented in the seminar and published here in full address a wide spectrum of current issues, ranging from the variable growth of pigs in commercial herds, through to the social interactions between pigs, the use of cereals in pig diets and finally the effect of production aspects on pig meat quality.

It is our objective that today’s seminar will provide an opportunity to discuss results of the latest research work undertaken at AFBI and that the information presented will assist pig producers, and the entire industry in Northern Ireland, to move forward into a more profitable future.

George McIlroy
Chief Executive Officer
Agri-Food and Biosciences Institute (AFBI)

The Speakers

Dr Elizabeth McCann: Elizabeth is the Monogastric Project Leader. She is responsible for both the poultry and pig research programmes based at AFBI, Newforge and AFBI, Hillsborough respectively. After graduating from Queen's University Belfast, with a degree in Agricultural Science (Biochemistry) Elizabeth completed her PhD on pig nutrition through Queen's University at AFBI, Newforge. Elizabeth has been involved in the pig research programme at AFBI, Hillsborough for 6 years and is particularly interested in pig nutrition.

Dr Elizabeth Magowan: Elizabeth is head of pig research and the pig unit at AFBI, Hillsborough. Elizabeth also graduated from Queen's University Belfast, with a degree in Agricultural Science (Biochemistry) and completed her PhD through Queen's University at AFBI, Newforge. However, Elizabeth's PhD focused on adding value to milk through the natural manipulation of the cows' diet. Elizabeth has been involved in pig research for 4 years and her key focus areas are production and carcass quality.

Dr Niamh O'Connell: Niamh is the Animal Behaviour and Welfare Project Leader at AFBI Hillsborough. Niamh graduated from University College Dublin with a degree in Agricultural Science, from Wageningen Agricultural University with a Master of Science degree and from Queen's University with a PhD. Niamh's PhD focused on pig welfare, and she has been involved in pig research for over 10 years. In recent years her research programme has expanded to include most of the main farm animal species.

Dr Bruce Moss: Bruce is a Project Leader in the area of meat quality at AFBI, Newforge. With over 30 years experience, he has gained international recognition as a meat scientist. Earlier research focused on the effect of animal welfare, particularly in relation to pre-slaughter stress, on pig meat quality. Current research interests include the meat quality attributes of colour and texture of all farm animal species, with particular interest in the link between production parameters and quality. Bruce is also interested in the development of rapid online measurements for the prediction of meat quality.

Making best use of high cost cereals for pig production

M. E. E. McCann

Summary

- Wheat variety has no effect on pig performance
- Under the conditions of this study, exogenous enzyme addition of wheat-based diets does not improve pig performance
- Near infrared reflectance spectroscopy has the potential to be a rapid and accurate means of predicting nutritive value

General Introduction

With the current crisis in the pig industry, resulting from rising cereal prices, the possibility of reducing cereal inclusion and increasing the use of by-products in pig diets is being given serious consideration. By-products such as rapeseed extract, sunflower and copra are available, and their use in pig diets has been investigated in research at the Agri-Food and Biosciences Institute (AFBI), Hillsborough. One of the first studies co-funded by the Pig Production Development Committee and Department of Agriculture and Rural Development for Northern Ireland conducted at AFBI, Hillsborough (then ARINI) investigated the use of by-products as alternatives to wheat and barley in diets for finishing pigs. A trend towards reduced performance was observed when cereal inclusion was reduced from 70% to 30%, despite the fact that both diets were formulated to contain 13.7 MJ/kg (fresh basis) of digestible energy (DE) (Weatherup and Beattie, 1997). When wheat and barley were reduced to 20%, and the levels of by-products correspondingly increased, it was not possible to maintain DE at 13.7 MJ/kg and a diet of a lower formulated DE content (13.4 MJ/kg) was produced. Offering this diet significantly reduced performance but this may not be entirely attributable to the by-products – the reduction in DE would also have been a contributory factor. It was concluded that, at 1997 dietary ingredient prices, cereal/soya-based diets were optimum but that cereals could be replaced with by-products if it was economically viable. This conclusion was supported by further studies on the use of by-products plus oil as an alternative to high levels of cereal inclusion (McCracken, 2001). In this investigation it was found that supplementation of by-product-based diets with vegetable oil increased DE and improved performance of growing pigs in comparison to performance of pigs offered diets containing less oil. However, cereal-based diets resulted in higher levels of feed intake and liveweight gain and therefore the use of cereal-based diets was recommended if economically viable. In September 2007, wheat and barley were £185 and £170 per tonne which has resulted in significantly higher feed costs for pig producers. Martin (2007) stated that for Irish producers the feed cost per kg of carcass was €1.01 which is similar to the 76 p/kg estimated for the Northern Ireland industry. On average, feed costs have increased by over 20p/kg during the past 12 months and this represents a major threat to the pig industry.

Given these high grain prices, and consequently the increased cost of by-products, it is vitally important to ensure that the best possible use of cereal grain is achieved in order to maximise margin over feed. There are a number of factors which influence utilisation of grain by pigs and this paper is a compilation of the key findings of several studies which have been conducted in this area. In addition to understanding the factors influencing cereal utilisation, research has focused on how to predict nutritive value of cereal for pigs. This will potentially be of use to both feed compounders and home mixers.

Study 1 – Utilisation of Cereals – The Effect of Variety

Introduction

Although wheat is a major component of many pig diets, it is a highly variable component in terms of chemical composition and nutritive value. This variation arises from a number of factors, including variety, environmental conditions, maturity at harvest and level of fertiliser applied during crop growth (McDonald *et al.,* 1995). The work of Lewis (1999) indicated that wheats produced in Northern Ireland vary in terms of chemical composition and nutritive value for growing pigs but that pig performance was not affected by wheat variety *per se*. This is in contrast to the results of research conducted in Australia, where Cadogan *et al.* (1999) reported that wheat variety had a significant influence on pig performance and dry matter (DM) digestibility. The aim of this study was to investigate the effect of wheat variety on nutrient digestibility in, and production performance of growing pigs.

Materials and methods

Performance trial

Eight locally produced wheat varieties (Falstaff, Napier, Savannah, Malacca, Buchan, Claire, Consort and Riband) were obtained from the Agri-Food and Biosciences Institute, Plant Testing Centre, Crossnacreevy. Experimental diets were formulated from each variety to contain 700 g/kg wheat (Table 1). A total of 144 crossbred (Large White x Landrace) pigs were used in this trial resulting in 18 pigs/treatment. Pigs were placed in individual pens, weighed at the start of the experiment and allocated to experimental diets on the basis of weight and gender. Pigs were offered feed *ad libitum* and DM intake (DMI), liveweight gain (LWG) and feed conversion ratio (FCR) were determined weekly for a 4-week period (8 to 12 weeks of age).

Table 1 Ingredient composition of experimental diets (g/kg fresh basis)

Component	Inclusion rate
Wheat	700
Soyabean meal (48%)	217
Soya oil	20
Lysine HCL	4.6
L-Threonine	2
DL-Methionine	1.4
Minerals and vitamins†	25
Molaferm	30

† Colborn Growplus 25 (Roche Vitamins Europe Ltd) supplying (per kg diet): Vitamin A 12000 IU (international units); Vitamin 03 2000 IU; Vitamin E 100 IU; copper from copper sulphate 156.25 mg; selenium from sodium selenite 0.3 mg; sodium 0.15%; phosphorus 0.17%

Digestibility trial

Six of the wheat varieties used in the performance trial (Falstaff, Napier, Savannah, Claire, Consort and Riband) were selected for further investigation. At 8 weeks of age, 12 male Large White x Landrace) pigs had cannulae inserted (according to the post-valve-T-Caecum (PVTC) cannulation procedure developed by Van Leeuwen *et al.* (1991)) to enable determination of digestibility at the ileal and total tract level. The wheat, diets, faeces and ileal were analysed (McCann *et al.,* 2006b) to determine total-tract and ileal digestibility coefficients of DM, energy, crude protein (CP), oil and neutral detergent fibre (NDF).

Results

There was no significant difference in pig performance due to variety (Table 2). Similarly, apparent total-tract digestibility coefficients of DM and energy were not affected by variety. However, there were small, but significant differences among varieties for apparent total-tract digestibility of CP, oil and NDF. Apparent total-tract digestibility of oil and NDF were lower ($P<0.05$) for variety Consort than for variety Claire. The varieties Consort, Napier and Falstaff resulted in lower apparent total-tract digestibility of CP than the variety Claire. Ileal digestibility of NDF was also lower ($P<0.001$) for variety Consort than for the other varieties (Table 3), but there were no other significant effects.

Table 2 The effect of wheat variety on production performance of growing pigs

	Initial weight (kg)	Finish weight (kg)	LWG (g/d)	DMI (g/d)	FCR
Wheat variety					
Falstaff	20.2	45.3	895	1271	1.43
Napier	20.1	45.1	892	1253	1.41
Savannah	20.3	46.0	918	1212	1.33
Malacca	19.9	45.7	922	1254	1.38
Buchan	20.0	44.9	889	1240	1.41
Claire	20.0	44.9	889	1232	1.40
Consort	19.8	45.6	923	1299	1.41
Riband	19.9	45.7	921	1274	1.39
s.e.m.	0.22	0.73	24.4	25.4	0.036
P	NS	NS	NS	NS	NS

Table 3 The effects of wheat variety on apparent total tract and ileal digestibility

	Claire	Consort	Riband	Falstaff	Napier	Savannah	SED	P
Apparent total tract digestibility								
DM	0.930	0.913	0.923	0.922	0.919	0.921	0.0059	NS
CP	0.930^{b}	0.914^{a}	0.918^{ab}	0.909^{a}	0.914^{a}	0.920^{ab}	0.0069	<0.05
Oil	0.858^{b}	0.819^{a}	0.823^{ab}	0.843^{ab}	0.846^{ab}	0.824^{ab}	0.0132	<0.05
NDF	0.750^{c}	0.667^{a}	0.700^{ab}	0.721^{bc}	0.708^{abc}	0.728^{bc}	0.0214	<0.01
Energy	0.929	0.913	0.922	0.923	0.919	0.922	0.0587	NS
Apparent ileal digestibility								
DM	0.784	0.774	0.794	0.785	0.790	0.791	0.0072	NS
CP	0.823	0.804	0.818	0.807	0.812	0.818	0.0110	NS
Oil	0.831	0.815	0.817	0.839	0.842	0.835	0.0114	NS
NDF	0.462^{b}	0.388^{a}	0.442^{b}	0.462^{b}	0.507^{c}	0.498^{c}	0.0159	<0.001
Ash	0.410	0.414	0.428	0.422	0.378	0.421	0.0269	NS
Starch	0.998	0.998	0.999	0.998	0.999	0.999	0.0001	NS
Energy	0.794	0.785	0.802	0.796	0.800	0.800	0.0069	NS

$^{a, b, c}$ values within a row without a common superscript are significantly different ($P < 0.05$)

Conclusions
No significant differences in performance were observed as a result of variety. This is in contrast to the work of Pearce *et al.* (1997) and Cadogen *et al.* (1999) who reported that variety had a significant influence on performance. The significant effects of variety on apparent total-tract digestibility of CP, oil and NDF, are in line with previous work by Lewis (1999). The digestibility coefficients in the current study were higher than those reported for other studies. For example, the average apparent total-tract digestibility of DM was 0.921, but in the study by Lewis (1999) the average value was slightly lower (0.906). This difference may be explained by the higher level of wheat inclusion in the present study (700 vs. 500 g/kg). However, Millar *et al.* (2001) also reported lower coefficients for apparent total-tract digestibility of wheat-based diets (670 g/kg) than the present study. This may be attributed to the higher level of NDF for the wheats used in their study (161.7 vs. 132.7 g/kg DM), probably resulting in a greater level of hind gut fermentation.

Although nutrient digestibility was significantly affected, there was no significant effect of wheat variety on pig performance.

Study 2 – Utilisation of Cereals – The Effect of Enzyme Addition

Introduction
The major non-starch polysaccharides (NSP) in wheat are the pentosans which comprise approximately 85% of the total NSP, with the two most abundant pentosans being arabinoxylan and xylan (Baidoo and Liu, 1998; Goodlad and Mathers, 1991). NSP are said to be anti-nutritive (Steenfeldt *et al*., 1995) as they increase the viscosity of the digesta, slowing down the rate of digestion and inhibiting enzyme accessibility (Ikegami *et al*., 1990). Some researchers have reported a beneficial effect of supplementing wheat diets with exogenous NSP degrading enzymes. For example, Yin (1997) reported that xylanase inclusion with wheat bran diets significantly increased ileal digestibility of CP and energy. However, research conducted by Lewis (1999) indicated that xylanase addition had little effect on apparent digestibility coefficients at either the total-tract or ileal level. The objective of this study was to determine the effects of enzyme addition on production performance of growing pigs.

Materials and methods
Six wheat varieties (Falstaff, Napier, Savannah, Claire, Consort and Riband) were formulated into 12 diets, differing in wheat variety, with or without supplementation with exogenous enzyme (Porzyme 9100, inclusion rate 1 g/kg). Wheat was included at 597g/kg. A total of 120 crossbred (Large White x Landrace) individually housed pigs were used in this trial. At eight weeks of age, pigs were weighed and allocated to experimental diets on the basis of their weight and gender. Pigs were fed *ad libitum* and DMI, LWG and FCR were determined weekly for a 4-week period.

Results
There were no significant effects on pig performance as a result of enzyme addition (Table 4). However, wide ranges in LWG, DMI and FCR were observed for pigs offered the 12 experimental diets (650 to 772 g/d, 1063 to 1171 g/d and 1.52 to 1.72, respectively).

Table 4 The effect of enzyme addition on pig performance

	Initial wt (kg)	Finish wt (kg)	LWG (g/d)	DMI (g/d)	FCR
Enzyme +	17.3	36.7	694	1117	1.64
Enzyme -	18.1	38.3	720	1127	1.58
s.e.m.	0.31	0.61	14.4	17.9	0.029
P	NS	NS	NS	NS	NS

Conclusions
The objective of this study was to investigate the effect of enzyme supplementation on performance. It has been widely reported that there is a larger response to supplementation when used in conjunction with diets of reduced nutritive value. For this reason, the amount of wheat was reduced in the diets for this experiment and replaced by wheat pollards. Despite this, there was no significant effect of enzyme addition. This is in contrast to Choct *et al*. (1999) who reported improvements in daily gain and intake with xylanase addition. However, these workers conducted their studies on younger pigs (initial weight 7 kg) whereas the average initial weight in the current studies was 18.5 kg. Moughan and Ravindran (2001) stated that exogenous enzymes are more effective in young pigs. However, the research by Lewis (1999) appears to contradict this as no significant improvement in performance of pigs from 10 to 20 kg was reported when xylanase was added to the diet. Furthermore, McCann (2001) indicated that addition of β-glucanase to barley-based diets had no effect on performance of pigs between 7 and 11 weeks of age.

It can be concluded that, enzyme addition to wheat-based diets was not beneficial under the conditions of this study.

Study 3 – Predicting Nutritive Value – The Use of NIRS

Introduction
Animal feeds are composed of a number of different feedstuffs combined in specific ratios to produce a final product that provides the optimum balance of amino acids, energy and other nutrients (Van Kempen and Simmons, 1997). The production of unbalanced feeds results either in energy being fed in relative excess to amino acids, which leads to undesirable fat accretion, or in amino acids being fed in relative excess to energy which leads to wastage of expensive amino acids and increased nitrogen excretion. Other nutrients can also be over or undersupplied, increasing cost of production. It is therefore important to the feed industry to have a rapid and accurate means of evaluating the nutritive value of feedstuffs. Historically, specific weight (or bushel weight) has been used to predict nutritive value of cereal grain. However, it has been well established that there is a poor relationship between

specific weight and nutritive value. For example, McCann, (2001) reported an extremely weak relationship between specific weight and barley DE content (R^2 = 0.17). Therefore, near infrared reflectance spectroscopy (NIRS) has been suggested as an alternative method of predicting cereal nutritive value for pigs. The aim of this trial was to investigate the potential of using NIRS to predict DE content of barley for growing pigs.

Materials and methods

Pig diets containing 650 g/kg barley were formulated using 39 samples of locally produced barley. These diets were fed to growing pigs and the DE concentration of the barley was calculated (McCann, 2001). The 39 samples were scanned using a Foss NIRSystem 6500 instrument (Perstorp Analytical, Silver Spring, Maryland, USA). Samples were scanned and spectral data recorded as log 1/Reflectance values (log 1/R). The spectral data for the 39 samples (n = 78 in duplicate) were subjected to a range of mathematical treatments to develop the optimum prediction methods. Appropriate cross-validation was performed by removing six groups of spectra from the population and forming a calibration on the remaining spectra and using this to predict the excluded samples. This was done several times until all the spectra were used in the validation. Full details on the mathematical treatment of the spectral data are given in McCann *et al.* (2006a).

Results

Table 5 shows the calibration and validation statistics for DE. Predicted DE values ranged from 14.4 to 16.6 MJ/kg DM. The 1,4,4 derivative combined with SNVD gave the best result in terms of SECV (0.277). The relationship for the calibration set was strong (R^2 = 0.93). With validation, the relationship was lower but still reasonably strong (R^2 = 0.69).

Table 5 Calibration and validation statistics for the prediction of digestible energy (DE) (MJ/kg DM) concentration of barley using modified partial least squares

Derivative option	Transformation procedure	n	SEC	R^2	SECV	1 - VR	Terms in model
1,4,4	WMSC	73	0.128	0.93	0.277	0.69	10

14.4 – 16.6 = The range in DE concentration for the dataset
SEC = Standard error of calibration, SECV = Standard error of cross validation.
1 - VR = Similar to R^2 for validation set, WMSC = Weighted multiplicative scatter correction

Conclusions

As Table 5 shows, the correlation between actual and predicted DE values for the calibration set was high (R^2 = 0.93) with the SEC being low (0.128). The correlation based on validation was also strong (R^2 = 0.69) with the SECV staying low (0.277). High correlations between actual and predicted DE concentrations have been reported in the literature. For example, Aufrere *et al.* (1996) and Zijlstra *et al.* (1999) reported relationships of 0.87 and 0.96 respectively. However, these workers did not report the validation statistics. Xiccato *et al.* (1999) predicted the DE concentration of rabbit diets and reported the correlation between actual and predicted DE (via calibration) to be high (R^2 = 0.90). With validation, this relationship was weakened and the SECV increased. This effect has also been shown by George (2000) who studied the correlation between predicted and actual AME values of wheat for poultry and found that the R^2 declined dramatically (> 0.90 to 0.09) between calibration and validation. This trend has been observed in the current study. However, it must be stated that the R^2 for validation is reasonably robust and the SECV relatively low. This high correlation for validation may be an effect of the small sample number as it is well known that small datasets produce high correlations due to less variability (Valdes and Leeson, 1992). Future work should include a greater number of samples in the regression equations, although this would require considerable resources to carry out the necessary *in vivo* studies.

In conclusion, the prediction of DE concentration appears to be accurate as small SECV and strong correlations of validation were obtained. However, as the sample set included in the regressions was relatively small, more work is required in this area to enable firm conclusions to be drawn.

General Conclusion

The variety of wheat grown in Northern Ireland does not effect pig performance and there appears to be no benefit of supplementation of exogenous enzyme to wheat-based diets. However, digestibility and nutritive value of cereal can be influenced by wheat sample and other factors. Therefore, it is important to have a means of predicting nutritive value of cereals used in pig diets. Specific weight is not a good indicator of nutritive value but NIRS has potential to be a rapid and accurate means of predicting barley nutritive value.

Future Research Priorities

With increased production of biofuel across the world and plans for bioethanol plants in GB, cereal availability is likely to reduce and by-products of biofuel production will become more widely available. Bioethanol is produced from the fermentation of cereals to alcohol and yields dried distillers grains with solubles (DDGS).

Biodiesel is produced from the transesterification of vegetable oil (mostly oil seed rape oil) and results in the production of glycerol. Relatively little work has been conducted on the use of DDGS and glycerol and it is the intention of AFBI, Hillsborough to initiate a research programme in these areas. A trial has already been planned in collaboration with John Thompson and Sons Ltd and Devenish Nutrition Ltd to investigate the use of glycerol in pig diets.

Acknowledgements

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Influence of social factors on feed intake in pigs

N. E. O'Connell and V. E. Beattie

Summary
This paper assesses how group housing, and method of group management, influence feed intake in pigs. Housing pigs in groups rather than individually did not appear to have a negative effect on feed intake behaviour over short-term periods. However, the way in which groups were managed significantly influenced feed intake levels. In particular, reducing space allowance during the initial post-weaning period led to reductions in feed intake that persisted even after additional space had been provided. These effects were exacerbated when large group sizes were combined with reduced space allowances. In addition, increasing the number of litters used to form groups of weaned pigs had linear, adverse effects on feed intake and growth rate. It is suggested that these effects were related to increased levels of aggression that were shown.

Introduction
Low voluntary feed intake is a key factor limiting the ability of pigs to reach their genetic potential for growth (Curtis, 1999). It also appears to adversely affect the health of pigs. For example, reduced levels of feed intake have been associated with a reduction in gut integrity and the development of diarrhoea in weaned pigs (McCracken *et al*., 1995; Pluske *et al*., 1996). While genetic factors are important in determining levels of voluntary feed intake (Whittemore *et al*., 2001), approximately half of variation in feed intake levels is related to environmental factors, and interactions between environmental and genetic factors (Curtis, 1999). Of these environmental factors, social factors appear to be particularly important. This is evidenced by the fact that individual housing leads to improvements in feed intake relative to group housing (Spicer and Aherne, 1987; Gonyou *et al*., 1992). The reason for the lower level of feed intake in group housed pigs is unclear, however it is likely that adverse effects associated with group housing are exacerbated by the way in which groups are managed.

The present paper describes a number of studies aimed at gaining a better understanding of how social factors influence feed intake behaviour, and how management decisions affect feed intake and productivity of group-housed pigs.

How does group-housing compromise feed intake?
As previously stated, research shows that pigs consume less feed when housed in groups rather than individually (Spicer and Aherne, 1987; Gonyou *et al*., 1992). This reduction in feed intake may be simply due to the *presence* of other pigs in the pen. For example, pigs may be distracted from feeding by penmates, or may be reluctant to leave group members to feed due to 'group cohesion' factors (Bornett *et al*., 2000). However, factors such as increased competition at the feeder, or increased 'social workload' associated with getting to the feeder (Walker, 1995) may also compromise feed intake. It is likely that these latter factors could be manipulated by management factors to a greater extent than the former factors. In order to promote feed intake in group situations, it is firstly important to understand why levels are reduced.

An initial study was carried out at AFBI, Hillsborough to assess if the *presence* of penmates has a negative effect on the feed intake behaviour of pigs.

Electronic feed recording
An electronic feeder, designed to record individual feed intake patterns within group situations, was used in this study. The feeder was similar in design to a normal single-space feeder (See Plate 1). It allowed only one pig to feed at a time and had a panel at the back of the trough that the pig had to press to gain a 4g 'drop' of feed. Pigs were fitted with a transponder tag in the ear, and a receiver in the trough recorded when a pig had its head in the feeder. The feeder also recorded the number of times the pig pushed the panel to gain feed.

Plate 1 Electronic feeder used to record individual feed intake patterns of pigs

Treatments
This study used the following treatment structure:
- First pig added to pen on day 1
- Second pig added to pen on day 4
- Third pig added to pen on day 7
- Fourth pig added to pen on day 10
- Fifth pig added to pen on day 13
- Sixth pig added to pen on day 16

The study finished at the end of day 18 when there were 6 pigs in the pen. Pigs were housed with access to one electronic feeder in a pen measuring 2.7 x 2.2 m. Feed intake patterns were recorded for 24-hour periods on days 3, 6, 9, 12, 15 and 18 (i.e. on the third day after new pigs were added). This process was replicated six times, using a total of 36 pigs. In each replicate the pigs were 10 weeks old at the start of the study, and had been housed together for a 2 week period prior to the start of the study.

Results
The influence of number of pigs per pen on feed intake patterns is displayed in Figure 1. In general, the pigs adapted their feeding style and appeared to eat faster as group size increased. When just considering the first pig added into the pen (Pig 1), the number of feeding bouts did not differ significantly between day 1 and day 18 (average of 21 bouts; $P>0.05$), however the average length of feeding bout

decreased by 1 minute (3.5 versus 2.5 minutes; P<0.05). Although not significantly different, the average amount of feed used per bout, and the average amount of feed used per day increased between days
1 and 18 for Pig 1.

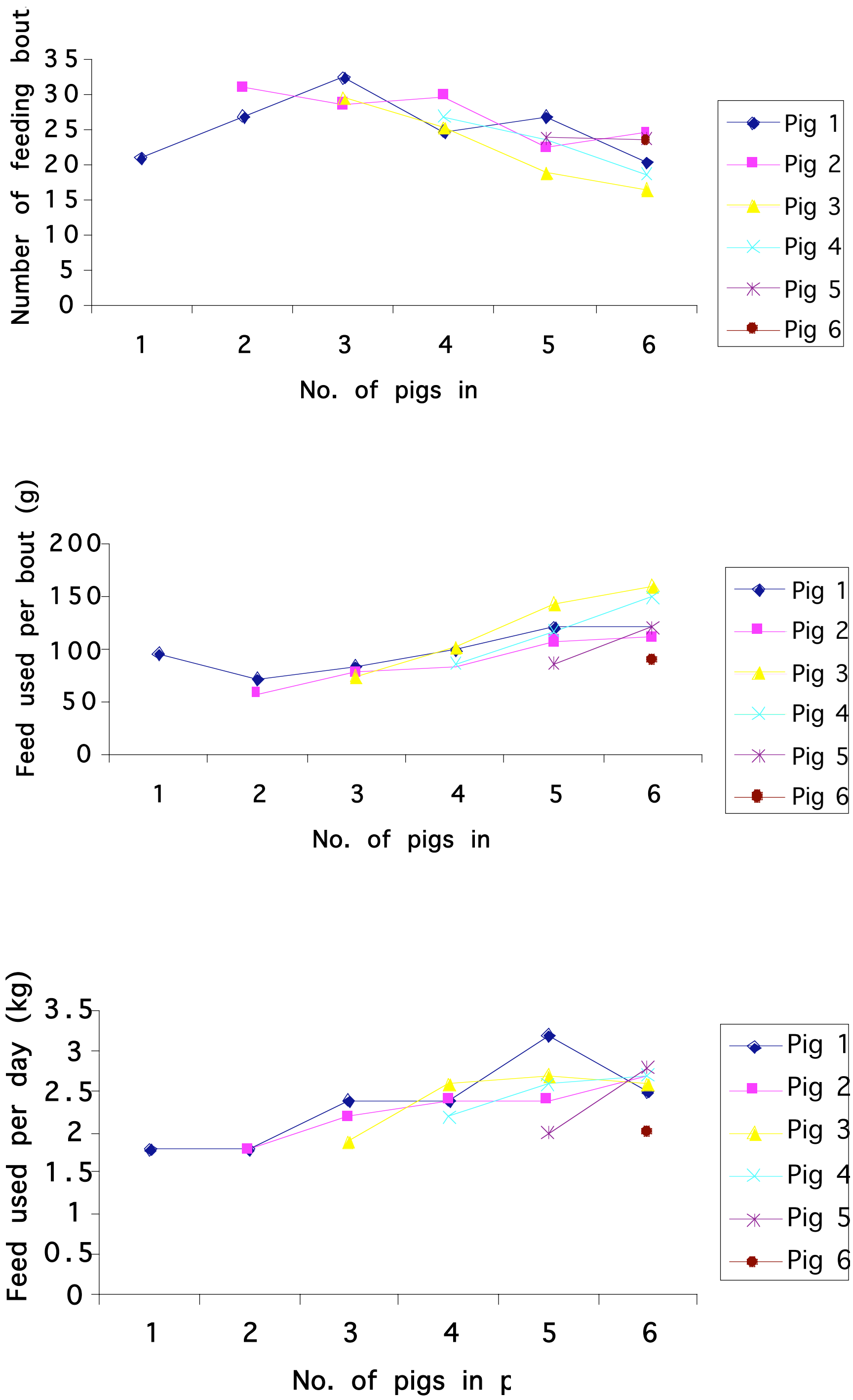

Figure 1 Influence of number of pigs in the pen on different feed usage parameters measured in individual pigs over 24-hour periods

This study was repeated to assess if the influence of group mates on feed intake behaviour was affected by feed being more difficult to access. In this subsequent study the pig had to 'work' for feed by pressing the panel three times in order to gain one 4g 'drop' of feed (after an initial training period). The results of this study were similar to those described above. When just considering Pig 1, the average number of feeding bouts did not differ significantly between days 3 and 18 (average of 27 feeding bouts, P>0.05), however the duration per bout decreased by approximately 1 minute (4.2 versus 3.1 minutes, non-significant). The amount of feed dispensed by Pig 1 increased significantly between days 3 and 18 (P<0.05), and the amount of feed dispensed per bout increased non-significantly over this period.

Discussion

These results show considerable flexibility in the feeding behaviour of pigs. In accordance with previous studies, as group size increased, pigs appeared to respond by increasing their feeding rate (Hyun and Ellis, 2001), and consuming feed in fewer, larger bouts (de Haer and Merks, 1992). Unexpectedly, however, feed usage appeared to increase rather than decrease as group size increased, and this effect was significant when feed became harder to access. It must be acknowledged that feed usage in the present study does not necessarily equate with true feed intake, and it is likely that pigs released more feed from the feeder than they actually ate. It is possible that as group size increased, level of food wastage also increased (Walker, 1991). However, it is also possible that feed intake was stimulated in the present study by 'social facilitation', whereby pigs are stimulated to feed by the sight of other pigs eating (Hsia and Wood-Gush, 1984).

Pigs prefer to feed within defined feeding periods (O'Connell *et al*., 2002; 2004), and there is a limit to the speed in which they can consume feed. Therefore, if group size had increased any further in the present study, without any increase in feeder access, it is likely that reductions in feed intake would have occurred. In addition, although the pigs maintained and appeared to increase feed intake levels, differing feed intake patterns may have adverse effects on other performance parameters. For example, evidence suggests that large meals, eaten infrequently, lead to reduced efficiency of feed use (Cohn *et al*., 1962; de Haer and de Vries, 1993). Therefore, if the trend in feed intake patterns shown in the present trial were to continue, then it is possible that reduced growth performance and poorer feed efficiency would be observed.

Summary

These results suggest that the presence of other pigs in the pen does not automatically lead to reductions in feed intake levels. It is likely that the way in which groups are managed is more important in determining feed intake levels than the mere presence of other pigs in the pen.

How important is space allowance?

The previous study suggested that group housing *per se* does not compromise feed intake. However, the degree to which animals are *crowded* within a group could be more pertinent in terms of effects on feed intake. This may be particularly relevant in the initial post weaning period where producers may wish to house more pigs than normal in a pen in order to reduce heat and space requirements. This would make more efficient use of resources, however there is little evidence of the effects of these factors on performance and behaviour of pigs. Housing pigs in larger social groups leads to increased levels of 'free' or available space in the pen (Spoolder *et al*., 1999). Therefore there may be greater opportunities to reduce space allowances in larger rather than smaller groups. A study was carried out to assess the effects of different space allowances during the initial post-weaning period on performance and behaviour of pigs housed in two different group sizes.

Treatments
A total of 1,440 pigs were used in this study, which was carried out over eight replicates. Pigs were weaned at 4 weeks of age at an average weight of 9.4 (SD 1.53) kg and assigned to one of the following four treatments as follows:

1. Group of 20 pigs housed at 0.2m^2 per pig ('20-0.2m^2')
2. Group of 20 pigs housed at 0.4m^2 per pig ('20-0.4m^2')
3. Group of 40 pigs housed at 0.2m^2 per pig ('40-0.2m^2')
4. Group of 40 pigs housed at 0.4m^2 per pig ('40-0.4m^2')

Treatments lasted until the pigs were 7 weeks of age. The pigs were housed in combined Stage 1/Stage 2 accommodation with plastic slatted floors. One 4-space feeder supplying dry feed and a separate drinking bowl was provided per 20 pigs. The same feeder was supplied for groups of 10 pigs, however 2 of the feeding spaces were blocked off to maintain a constant level of feeding space/pig across treatments.

Pigs were individually weighed at weaning at 4 weeks of age, and at 7 weeks of age. Individual growth rates and group feed intake and food conversion ratios were calculated. Within-group coefficient of variation in body weight was calculated for body weight and growth rate parameters. Aggressive behaviour was recorded during a number of observations each week.

Results
Performance results are presented in Table 1. Pigs housed in the '40-0.2m^2' treatment had lower feed intake levels than pigs housed in the '20-0.4m^2' or the '40-0.4m^2' treatment (P=0.01). Pigs housed in the '20-0.2m^2' treatment showed lower levels of feed intake than pigs housed in the '20-0.4m^2' treatment (P<0.05). Feed conversion ratios, body weight at 7 weeks of age, growth rate and coefficient of variation in growth rate were not significantly affected by treatments (P>0.05).

Average levels of aggression, and in particular fighting, did not differ significantly between treatments (P>0.05).

Table 1 Influence of treatments on performance between 4 and 7 weeks of age (using weaning weight, or COV in weaning weight as a covariate)

	Group size (and space allowance)				SEM	P
	20 ($0.2m^2$)	20 ($0.4m^2$)	40 ($0.2m^2$)	40 ($0.4m^2$)		
Feed intake (g/day)	361^{ab}	414^{c}	347^{a}	391^{bc}	14.5	0.01
Feed conversion ratio	1.20	1.29	1.20	1.30	0.046	NS
Growth rate (g/day)	290	311	278	289	12.4	NS
7 week weight	15.3	15.7	15.0	15.2	0.25	NS
COV growth rate	27.9	32.9	33.5	33.8	2.64	NS
COV 7 week weight	14.5	16.6	15.7	16.7	0.98	NS

COV = coefficient of variation

Discussion

The results of this study correspond with previous research which shows that increasing group size from 20 to 40 pigs does not adversely affect welfare or productivity when feeder and floor space allocations per pig are kept constant (O'Connell *et al*., 2004; Schmolke *et al*., 2003). Previous research suggests that space allowances can be reduced in larger groups to a greater extent than in smaller groups. For example, McGlone and Newby (1994) found that the space requirements of pigs decrease slightly as group size increases (because of increased levels of 'free' space in larger groups). However, the adverse effects of reduced space allowance on feed intake behaviour were shown in both group sizes in the present study. In fact, the lowest level of feed intake was shown when the smaller space allowance was used in the larger group.

The reduced level of feed intake at the small space allowance did not appear to be due to increased aggression, but was probably related to increased 'social workload' associated with getting to the feeder in more crowded pens (Walker, 1995).

Although no significant differences were shown, increasing space allowance led to 7% and 4% increases in growth rates in groups of 20 and 40 pigs, respectively.
In addition, increased levels of feed intake in the post-weaning period are likely to have beneficial effects on the health of the pigs (McCracken *et al*., 1995; Pluske *et al*., 1996). The lower space allowance used in this trial is within current legislative limits for pigs of up to 20kg body weight (Council Directive 2001/88/EC), and producers using separate accommodation for Stage 1 and Stage 2 weaners are likely to be restricted in terms of changes to space allowance that they can make. However, the present study suggests that producers using combined Stage 1/Stage 2 accommodation should not restrict space offered to pigs in the initial post weaning period.

Summary
Reducing floor space allowance during the post-weaning period appears to restrict the ability of pigs to consume feed. It is likely that further reductions in floor space would significantly compromise growth rate.

What effect does splitting groups have on feed intake?
If pigs are housed at reduced space allowances during the initial post-weaning period then it is likely that pens would have to be expanded, or more realistically groups would have to be split, as the pigs get larger. The effect of splitting groups of pigs on feed intake behaviour is unclear. Individual recognition between pigs is likely to become more difficult as group size increases (Spoolder *et al.*, 1999). Therefore it is possible that splitting larger groups of pigs leads to more aggression and poorer productivity than splitting smaller groups, due to a failure of pigs to recognise each other in larger groups. The study described above was extended into the current study to assess the effects of different management practices, such as splitting groups or expanding pens, on performance and welfare of weaned pigs. In addition, the long-term effects of reduced space allowance in the initial post-weaning period were also assessed.

Treatments:
This study used the Stage 1 treatments described in the previous section. Treatments are described in full as follows:

Table 2 Description of treatments used

Treatment	Stage 1 (4 to 7 weeks)	Stage 2 (7 to 10 weeks)
1	Group size 20 – space allowance 0.2m^2	Pen expanded – space allowance 0.4m^2
2	Group size 20 – space allowance 0.4m^2	Same as Stage 1
3	Group size 40 – space allowance 0.2m^2	Split into two groups of 20 – space allowance 0.4m^2
4	Group size 40 – space allowance 0.4m^2	Split into two groups of 20 – space allowance 0.4m^2
5	Group size 40 – space allowance 0.4m^2	Same as Stage 1
6	Group size 20 – space allowance 0.4m^2	Split into two groups of 10 – space allowance 0.4m^2

Shaded treatments are those that used reduced space allowance during the initial post weaning period. Space allowances equate to m^2 per pig.

Results
Performance results are presented in Table 3. Pigs in Treatment 3 showed lower growth rates during Stage 2 than pigs in all other treatments except those in Treatment 1 and 5 ($P<0.001$). Similarly, pigs in Treatment 3 showed lower growth rates over the whole treatment period (Stages 1 and 2) and lower body weights at 10 weeks of age than pigs in Treatments 2, 4 and 6 ($P<0.01$). Average daily feed intake

over the whole treatment period was also lower in Treatment 3, and this differed significantly from Treatments 4 and 6 ($P<0.05$). Feed conversion levels and coefficient of variation in growth rate or body weight were not significantly affected by treatments ($P>0.05$).

Average levels of aggression or fighting did not differ significantly between treatments during Stage 2 ($P>0.05$).

The influence of moving into a new pen versus staying in the resident pen among pigs in Treatment 3 was also assessed. Pigs that moved into a different pen rather than staying in the same pen did not show any differences in feed intake, growth rate, feed conversion ratio or 10-week weight, or in coefficient of variation in growth rate during Stage 2 (7 to 10 weeks of age) ($P>0.05$). In addition, behavioural parameters did not differ significantly between treatments ($P>0.05$).

Discussion
The low growth rate in Stage 2 for pigs in Treatment 3 appeared to be predominantly due to reduced levels of feed intake. Although no significant differences were shown, feed intake levels were 62 g/day lower in Treatment 3 than in other treatments. This suggests that feed intake traits adopted during periods of environmental stress during the first half of the post weaning period (where pigs were housed at reduced space allowances in large groups), were retained even when that stressor was removed.

The space allowance and group size used for pigs in the initial post-weaning period was the most important management factor affecting productivity in this study. Comparison between Treatments 4 and 5, and between Treatments 2 and 6, show that splitting groups of 40 or 20 pigs, respectively, has no adverse effects on productivity or aggressive behaviour. In addition, comparison within Treatment 3 showed no adverse effects on welfare or productivity associated with moving pens. However it should be noted that pigs moved to an identical pen close to their original pen.

Summary
Housing large groups of pigs at reduced space allowances during the initial post weaning period has long-term adverse effects on productivity even when pigs are provided with additional space and moved into smaller groups.

Table 3 Influence of treatments on performance during Stage 2 and overall (Stages 1 and 2) (using weaning weight, or COV in weaning weight as a covariate).

	Treatment						SEM	P
	1	2	3	4	5	6		
	20-0.2m² expanded	*20-0.4m²*	*40-0.2m² split*	*40-0.4m² split*	*40-0.4m²*	*20-0.4m² split*		
Stage 2 (7 to 10 weeks of age)								
Feed intake (g/day)	1115	1100	1058	1130	1118	1136	27.4	NS
Feed conversion ratio	1.67	1.60	1.63	1.58	1.64	1.66	0.038	NS
Growth rate (g/day)	669^{ab}	689^{bc}	645^{a}	715^{c}	681^{abc}	686^{bc}	12.6	<0.001
COV growth rate	16.9	17.3	15.6	14.4	16.4	16.6	1.25	NS
10 week weight (kg)	29.3^{ab}	30.0^{b}	28.6^{a}	30.3^{b}	29.5^{ab}	30.1^{b}	0.41	<0.01
COV 10 week weight	14.5	15.5	13.7	12.7	15.2	13.6	0.87	NS
Stages 1 and 2 (4 to 10 weeks of age)								
Feed intake (g/day)	729^{ab}	742^{ab}	694^{a}	757^{b}	739^{ab}	769^{b}	18.2	<0.05
Feed conversion ratio	1.55	1.52	1.53	1.52	1.55	1.57	0.028	NS
Growth rate (g/day)	472^{ab}	490^{b}	455^{a}	497^{b}	476^{ab}	492^{b}	9.8	<0.01
COV growth rate	16.6	20.2	18.1	16.8	18.7	16.8	1.27	NS

How important is number of litters per group on feed intake?
Mixing unfamiliar pigs together leads to fighting as dominance relationships are established (McGlone *et al*., 1987). The stress associated with this fighting can have negative effects on food conversion efficiency (Barnett *et al*., 1983). Mixing pigs together also increases aggression at feeding (Tan *et al*., 1991), and this may negatively affect feed intake levels. The relative importance of the composition of the groups at mixing is unclear however. This study aimed to get a better understanding of the relationship between number of litters per group and performance and welfare parameters. In particular, whether parameters were affected in a linear manner by number of litters per group was assessed.

Treatments:

1. Group of eight pigs formed from 1 litter
2. Group of eight pigs formed from 2 litters
3. Group of eight pigs formed from 3 litters
4. Group of eight pigs formed from 4 litters

Two hundred and twenty-four pigs were used from weaning at 4 weeks of age, at an average weight of 9.2 (±0.92) kg, until 10 weeks of age. The groups were balanced for gender and weight and were housed at a space allowance of 0.43 m^2 per pig. Each group had access to one single-space wet and dry feeder and were offered pelleted ration on an *ad libitum* basis. Production performance was assessed across the treatment period and injury levels were measured at the start and end of the trial.

Results

The effect of treatment on the production performance of pigs is highlighted in Table 4. Although every effort was made to ensure that variability in weight within groups at weaning remained similar across treatments, a linear increase in this parameter was shown with increasing litter number ($P<0.05$). Overall across the treatment period, increasing the number of litters per group led to a linear decrease in feed intake and growth rate ($P<0.05$). In addition, variability in growth rate and in body weight at 10 weeks of age increased linearly with increasing numbers of litters ($P<0.05$). Feed conversion ratio was not affected in a linear manner but was poorer across the treatment period in Treatment 4 than in all other treatments except Treatment 1 ($P<0.05$). In general, treatment differences were more evident in Stage 2 (7 to 10 weeks) than in Stage 1 (4 to 7 weeks).

Injury results are presented in Table 5. Average injury levels were significantly lower in Treatment 1 than in all other treatments at 1 week post mixing ($P<0.001$), and increased linearly as number of litters per group increased ($P<0.001$). However there were no significant differences between treatments in injury levels recorded at 6 weeks post mixing ($P>0.05$).

Table 4 Influence of number of litters per group on the performance of pigs in groups of eight during the post weaning period (analysed using weaning weight, or COV weaning weight as a covariate).

	Number of litters per group				SEM	P (T)	P (L)
	1	2	3	4			
Stage 1 (4 to 7 weeks)							
4 week weight (kg)	9.0	9.3	9.1	9.2	0.148	NS	NS
COV 4 week weight	0.07	0.07	0.10	0.10	0.011	<0.07	<0.05
Feed intake (g/day)	488	455	442	441	18.43	NS	NS
Growth rate (g/day)	381	366	371	351	18.39	NS	NS
Feed conversion ratio	1.28	1.24	1.20	1.26	0.036	NS	NS
7 week weight (kg)	16.8	16.5	16.5	16.2	0.353	NS	NS
COV 7 week weight	0.10	0.12	0.11	0.15	0.016	NS	NS
COV growth rate	0.19	0.25	0.23	0.31	0.033	NS	<0.05
Stage 2 (7 to 10 weeks)							
Feed intake (g/day)	1196^{b}	1060^{a}	1127^{ab}	1039^{a}	34.5	<0.05	<0.05
Growth rate (g/day)	722^{b}	659^{ab}	701^{b}	606^{a}	22.8	<0.05	<0.01
Feed conversion ratio	1.65	1.61	1.62	1.72	0.031	NS	NS
10 week weight (kg)	31.7	30.3	31.2	28.9	0.73	<0.07	<0.05
COV 10 week weight	0.09	0.12	0.10	0.14	0.015	NS	<0.05
COV growth rate	0.14	0.17	0.14	0.19	0.023	NS	NS
Stages 1 and 2 (4 to 10 weeks)							
Feed intake (g/day)	847^{b}	765^{a}	792^{ab}	744^{a}	23.7	<0.05	<0.05
Growth rate (g/day)	555^{b}	516^{ab}	545^{b}	482^{a}	17.1	<0.05	<0.05
Feed conversion ratio	1.53^{bc}	1.48^{ab}	1.45^{a}	1.54^{c}	0.018	0.01	NS
COV Growth rate	0.11^{a}	0.16^{ab}	0.13^{a}	0.20^{b}	0.021	<0.05	<0.05

COV: Coefficient of variation, P (T): probability value for treatment comparison, P (L): probability of linear effect

Table 5 Influence of treatment on injury scores measured at 1 and 6 weeks post mixing

	Number of litters per group				SEM	P (T)	P (L)
	1	2	3	4			
1 week post mixing	2.8^{a}	6.6^{b}	8.8^{c}	9.8^{c}	0.54	<0.001	<0.001
6 weeks post mixing	8.1	7.6	7.8	8.4	0.46	NS	NS

P (T): probability value for treatment comparison, P (L): probability of linear effect

Discussion

Increasing the number of litters per group had significant negative effects on feed intake and growth rate. It could be argued that increased variability in weight within groups at weaning also influenced these parameters. However, previous research showed that increasing within-group coefficient of variation in weaning weight from 0.07 to 0.16 did not affect mean production performance (O'Connell *et al*., 2005). It could also be argued that increased variability in weaning weight led to increased variability in growth rate and body weight at 10 weeks of age. However, variability in weaning weight was used as a covariate in the analysis of these parameters, therefore these effects should have been minimised.

It is likely that the reduced performance and increased variability in performance were related to the increased aggression associated with increasing the number of litters per group. Interestingly, however, productivity was affected to a greater extent in the second half of the post weaning period rather than the first half (where treatment effects on injury levels were greater). The reason for this is not clear, however it is possible that some level of social stress associated with mixing unfamiliar animals together remained in the group, and was even exacerbated as animals got larger.

Summary

These results clearly show that increasing the number of litters per group leads to linear reductions in performance and welfare. Future research will determine whether this is also the case with larger groups. The magnitude of effects on productivity were quite large in this study, for example forming a group from 3 rather than 4 litters led to a 12% improvement in growth rate.

Overall Conclusions

- The presence of group mates does not appear to adversely affect feed intake levels in pigs over short-term periods
- Reducing floor space allowance in the post-weaning period from $0.4m^2$ to $0.2m^2$ per pig reduces feed intake levels by 13% and 11% in groups of 20 and 40 pigs, respectively
- Housing groups of 40 pigs at low space allowances during the initial post weaning period has long-term adverse effects on productivity, even after group size has been reduced and additional floor space provided
- Splitting groups of 20 or 40 weaned pigs, or moving pens, does not appear to adversely affect welfare or productivity
- Increasing the number of litters per group has linear, adverse effects on production performance and welfare of weaned pigs

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Variable Growth – How big a problem is it?

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Summary
Large variation in growth rate between pigs within herds is a major contributor to poor herd performance and reduced profitability. A difference of 18 days was observed between the top and bottom 25% of herds to reach an average live weight of 100kg. This growth rate difference between herds equated to a difference in return of 9 p/kg of carcass or £32,000 on a herd capable of finishing 1100 pigs per year. Within a breed, major variations in feed intake can contribute to the variation in growth rate.

Introduction
Variation in growth rate of individual pigs occurs both within and between litters (Kennedy, 1984) and is most likely a reflection of variable feed intake. Variable feed intake can be a result of, for example, birth weight, sex, weaning age, management system, disease status or diet composition (Pajor *et al*., 1991; Bruininx *et al*., 2001; Whittemore and Green, 2001; O'Connell *et al*., 2002). Profitability is also highly variable between herds (Stein *et al*., 1990). Within Northern Ireland the average number of pigs produced per sow per year can vary by 4.4 pigs and the overall profitability of herds by £461 per sow per year (Donnelly, 2006). Practices such as fostering, creep feeding and split weaning have been used in an attempt to reduce variation in the weaning weight of pigs (Mahan 1993; Lawlor *et al*., 2002; Milligan *et al*., 2001). Attempts have also been made to reduce the variation of weight of pigs at various ages, for example, by offering 'high density diets' or grouping pigs uniformly (Lawlor *et al*., 2002; O'Connell *et al.,* 2005).

The aim of this study was to provide quantifiable information on both within and between herd variation in pig growth rate from birth to slaughter on commercial herds and to examine how this was influenced by moving pigs at a common age to a common environment.

Materials and Methods
A full account of the materials and methods used in this paper is reported by Magowan *et al.* (2007).

Herds and animals
Eight herds with varying growth performance, offered the same diets from birth to slaughter, were selected from pig herds in Northern Ireland. Pigs were ¾ Landrace × ¼ Large White with their sires being from Northern Ireland studs. All herds were quality assured under the Assured British Pigs Scheme. All pigs were offered a creep feed (diet 1) pre-weaning. In stage 1/stage 2, pigs were offered dry pelleted feed from dry multi space feeders (Etra Feeders, Northern Ireland). In the finishing stages pigs were offered dry pelleted feed through wet and dry single space feeders (Verba, Verbakel^{TM}, The Netherlands). All herds were diagnosed as enzootic pneumonia and porcine reproductive and respiratory syndrome (PRRS) (blue-ear disease) positive, one herd was *Haemophilus parasuis* positive and another herd suffered occasional infections of *E. Coli* in post weaned pigs. All herds were vaccinated for porcine parvovirus and leptospirosis and were medicated in stage 1 with zinc oxide and chlorotetracycline (CTC) 10%.

Five litters were randomly selected from each of the eight herds all born within a 3 day period. Within each litter, five pigs (three boars and two gilts) were selected at weaning and tagged. The pigs selected were those closest to the median of the litter. In total, 25 pigs were selected at weaning from each herd, of which 22 remained on the farm for performance testing and the remaining three (non sibling boars) were transferred to a common controlled environment where they were housed with the seven other sets of 'three pigs' in order to test their performance under controlled conditions.

On-farm performance testing
In each herd, the aforementioned selected 22 pigs (12 boars and 10 gilts) were randomly distributed across a number of pens of mixed weight pigs. These pigs were weighed individually every 4 weeks, during the period 4 to 20 weeks of age. The average daily gain (ADG) and coefficient of variation for weight of pigs in each herd was calculated. All pigs were offered the same commercial diets (Table 1) *ad libitum.*

Economic evaluation
Data on feed usage, efficiency and pig mortality for the top herd and the bottom herd were collected and these data, together with the average growth rate of the pigs on farm were inputted to an economic model (Devenish Nutrition Ltd) based on 1100 finishing places, to establish differences in profitability between herds. According to the herd average daily gain, the throughput of pigs from 1100 finisher pig places was calculated and hence equated to the financial output from the respective units. The model also included fixed costs per sow totalling £202/year

Performance testing under controlled conditions
The three non-sibling boars per herd selected at weaning were transferred to a common controlled environment. A total of 24 boars were transferred and mixed at 4 weeks of age in a common environment. They were group-housed to 6 weeks of age, after which they were individually housed until slaughter (115 kg live weight).

Pigs were offered (*ad libitum)* the same commercial pig diets as on farm (Table 1) in the following controlled manner: (as fed basis) – diet 1, 3 kg per pig; diet 2, 7 kg per pig; diet 3, offered until pigs were 20 kg; diet 4, offered from 20 to 40 kg live weight and diet 5, offered from 40 kg live weight to slaughter. All pigs received in-feed medication through diets 1, 2 and 3 (3.1 kg/t Zn (Pigzin), 2 kg/t Stabox, 2 kg/t Pulmotil G100 in each diet). Pigs were weighed individually and feed intakes calculated twice weekly until pigs reached 115kg.

Table 1 Formulated composition of diets offered to pigs (as fed basis)

	Diet†				
	1 (starter)	2 (starter)	3 (link)	4 (grower)	5 (finisher)
Dry matter (g/kg)	896	885	890	877	877
Digestible energy (MJ/kg)	16.6	16.0	15.1	14.8	14.0
Crude protein (g/kg)	21.4	22.7	19.9	18.9	18.0
Oil A (g/kg)	9.7	7.8	6.5	6.1	4.7
Fibre (g/kg)	2.4	2.5	2.8	2.9	4.5
Ash (g/kg)	4.7	3.6	5.2	4.7	5.2
Digestible lysine (g/kg)	1.21	1.26	1.10	0.97	0.86

†The diets were commercially manufactured by Devenish Nutrition Ltd (Belfast) (Diets 1 and 2) and John Thompson and Sons Ltd (Diets 3, 4, and 5).

Calculations and statistical analysis

The effects of treatment were analysed by Analysis of Variance using Genstat 6 (Genstat release 6.1, 2002). The estimated time taken for individual pigs to attain a live weight of 100 kg was calculated from individual pig average daily gain values. Correlations were established between the weights of pigs at various ages for pigs in the top quartile of herds and separate correlations were established for pigs in the bottom quartile of herds using Genstat 6, and taking into consideration farm effects. The coefficient of variation was calculated by dividing the standard deviation by the mean of a given dataset.

Results

On-farm performance

The ADG of herds differed significantly (P<0.001) at all stages of growth. Data from the two herds which displayed the best performance were amalgamated to represent the top quartile of herds and data from the two herds which displayed the poorest performance were amalgamated to represent the bottom quartile of herds (Table 2). Growth rate differed significantly between the top and bottom quartile of herds by 61, 112 and 170 g/day for the growth periods of 4-8 (P<0.001), 8-12 (P<0.01) and 12-20 weeks of age (P<0.001) (Table 2). This resulted in the pigs from the top quartile of herds attaining a live weight of 100 kg on average 18 days earlier than those from the bottom quartile of herds. The coefficient of variation for weight was lower at any stage of growth for pigs in the top quartile of herds than in the bottom quartile of herds (Figure 1). Overall the correlations between the weights of pigs at different ages were weaker for pigs from the top quartile of herds than for those from the bottom quartile of herds (Table 3). The correlations between the weights of pigs at different ages from the bottom quartile of herds were strong, highly significant (P<0.001) and similar. The correlations between the weights of pigs from the top quartile of herds tended to weaken as pigs got older and the correlations between the weaning weight and 16 and 20 week weight were not significant.

Table 2 The average growth rate (g/day) and estimated days to 100 kg of pigs in the top and bottom quartile of herds

	Top quartile	Bottom quartile	SEM	Significance
4-8 weeks	404	343	12.5	<0.001
8-12 weeks	593	481	15.4	<0.01
12-20 weeks	810	640	19.9	<0.001
Estimated days to 100 kg	162	180	4.6	<0.001

Figure 1 The coefficient of variation for weight of pigs on farm from 4 to 20 weeks of age in the top and bottom quartile of herds.

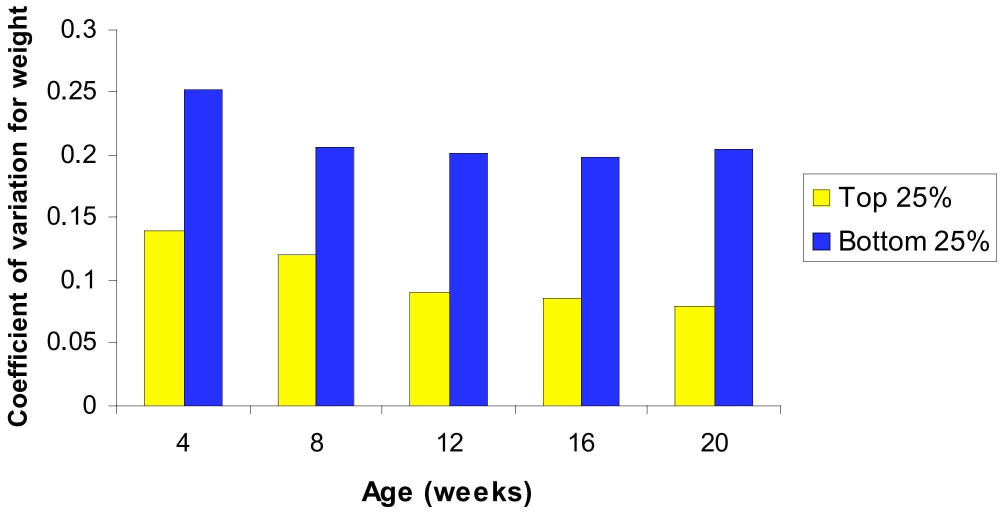

Table 3 Correlations between the weight of pigs at various ages in the top and bottom quartile of herds (n=44 each) with farm effects included

Age (weeks)	4	8	12	16	20
4	†	0.863 ***	0.733 ***	0.812 ***	0.800 ***
8	0.565 ***		0.884 ***	0.844 ***	0.836 ***
12	0.461 **	0.816 ***		0.886 ***	0.874 ***
16	0.278 NS	0.610 ***	0.663 ***		0.917 ***
20	0.077 NS	0.447 **	0.463 **	0.861 ***	

NS = not significant, * P<0.05; ** P<0.01; *** P<0.001.
†*Values below the diagonal, report correlations between the weights of pigs in the top quartile of herds whereas values above the diagonal report correlations between the weights of pigs in the bottom quartile of herds.*

Economic evaluation

The total feed cost per pig was greater on the bottom farm (£51 vs £48) due to poorer feed efficiency. Fewer pigs could be produced per year using 1100 finisher places on the bottom farm due to the slower growth rate (3200 pigs vs 4500 pigs). A lower average carcass weight was also attained due to higher post-weaning mortality on the bottom farm (78.45kg vs 79.9kg). Overall the difference in herd net profit between the top and bottom herds was £30,682 per year which equated to a difference in carcass value of 9p per kg.

Performance of pigs in the common environment

The ADG ($P<0.01$) and average daily feed intake (8-12 weeks $P<0.05$; 12-20 weeks $P<0.001$) of pigs from the eight herds differed significantly between herds through both stages of growth in the common environment whereas feed conversion efficiency differed significantly ($P<0.01$) only in the early stages (8-12 weeks). Data from the two herds which displayed the best performance in the common environment were amalgamated to represent the top quartile of herds and data from the two herds which displayed the poorest performance were amalgamated to represent the bottom quartile of herds (Table 4). The ADG and average daily feed intake of the top quartile of pigs was significantly higher from 8-12 ($P<0.01$) and 12-20 ($P<0.001$) than that of the bottom quartile of pigs (Table 4). The top quartile of pigs reached a live weight of 100 kg on average 19 days earlier ($P<0.001$) than pigs in the bottom quartile. There was no significant difference in the FCR of pigs in the top or bottom quartile.

Table 4 Performance of pigs in the top and bottom quartile of herds when managed in a common environment

	Top quartile	Bottom quartile	SEM	Significance
Average daily gain (g/day)				
8-12 weeks	831	688	16.9	<0.01
12-20 weeks	1064	821	41.2	<0.001
Estimated days to 100 kg	139	158	5.1	<0.001
Average daily feed intake (g/day)				
8-12 weeks	1614	1285	52.8	<0.01
12-20 weeks	2628	1973	78.0	<0.001
Feed conversion ratio				
8-12 weeks	1.94	1.87	0.035	NS
12-20 weeks	2.47	2.40	0.042	NS

Discussion

The financial impact of variable growth is not commonly recognised by producers but is a very real and often a hidden cost to the pig industry that is difficult to quantify (Payne *et al*., 1999). Some attempts have been made to quantify the economic effect of growth rate variation within a group of pigs. Using the AUSPIG simulation model, Payne *et al.* (1999) estimated that if 100% of pigs in a group had a level of performance classified as medium, then 'profitability' was £6 per pig sold. However, if the distribution of pigs was such that 20%, 60% and 20% of the pigs were classified as low, medium and high respectively, then overall 'profitability' was reduced by 37p per pig sold. In the current study, the difference in performance between the top and bottom producers equated to an average difference in cost of production of 9p per kg of carcass on a birth to bacon herd which equated to a herd net profit difference of £30,682 between the top and bottom quartile of herds assuming 1100 finishing places. In addition larger weight variation occurred at all stages of growth within poorer performing herds, suggesting large variation in growth rate of individual pigs.

Frey (1998) listed a number of potential factors which may explain variation in the growth rate of grower/finisher pigs including genotype; disease; management system; weight at entry; group size; space allocation; dominant or submissive behaviour; stockmanship and season. In the current study, all of the above factors varied between herds except season. However when pigs were brought to a common environment, the only differences were genotype, pre-weaning environment, health status and weight at entry, yet similar differences in growth rate still occurred between pigs from different herds. In addition, within a herd, factors like management system, disease exposure, group size, space allocation, and stockmanship should have been constant but variation in growth rate within herds was still observed with its extent varying dramatically between herds. It is possible that practices such as management system and disease exposure were better managed or kept more constant within herds with overall good performance and resulted in lower variable growth within the herd.

As highlighted above, variation in the performance of pigs from different herds was also noted when they were managed in a common environment, with variation being similar to that observed on farm. However, although trends were similar, the two top and bottom performing herds in the common environment were not the same as the two top and bottom performing herds 'on farm'. Three boars from each herd, representative of pigs being weaned on farm, were performance tested in the common environment and this, in addition to the medication pigs received on entry, may be a significant factor in the re-ranking of herd performance in the common environment. The top performing pigs in the common environment had a similar feed efficiency but ate significantly more than the poorer performing pigs. Although all the same breed, differences in pig genotype may be a significant contributor to the variable growth rate observed between pigs from different herds. Hall *et al*. (1999) reported coefficients of variation for food conversion ratio of 11%, average daily gain of 13% and daily feed intake of 13% from records of 1832 pigs of a Large White sire line selected for lean tissue growth. These differences were attributed to different phenotypes i.e. the same genotype interacting with different environments to cause variation (Hall *et al*., 1999). Similarly, it is possible that feed intake was reduced as a result of a lower voluntary feed intake, influenced mainly by differences in pig phenotype. Large variations in the performance of pigs within breeds have been shown by McCann and Beattie (2004).

Although the effect of disease on growth performance is well documented (Muirhead (1986) cited by English *et al.* (1988)), its effect on variable growth is not (Payne *et al*., 1999). Variation in growth rate within groups of pigs infected with pneumonia has been found to be up to 80% greater than that in a group of non-infected pigs (Skirrow, 1993). In addition, Patrick *et al*. (1993) found that pigs exhibiting clinical disease and then treated, took an additional 15.3 days to reach slaughter weight. The disease status of the pigs pre-environment, i.e. on farm from birth to wean, varied between herds and it was noted that pigs from the bottom quartile of herds had visibly more evidence of clinical disease on farm than pigs from the top quartile of herds. This is reflected in the variations in growth rate of pigs within the bottom quartile of herds being much greater than that observed with pigs in the top quartile of herds. Medication of pigs using tylosin and bacitracin methylene disalicylate has been found to decrease variable growth (Tillman, 1997; Deen *et al*., 1998). In the common environment, although pigs were medicated in order to equilibrate their disease status, it is highly possible that pre-environment disease exposure affected their subsequent growth rate in the common environment. It is possible that if pigs had not been medicated, variation in growth rate between herds in the common environment may have been even greater. The other major 'pre-environment' factor which may have affected the subsequent growth performance of pigs is their dam. The performance of sows can vary considerably and poor performance is often transposed into the litter (Horugel, 1999). In the current study, it was noted that pigs from the herd in the bottom quartile, both on farm and in the common environment, were derived from sows with poor mothering ability and high disease status.

Miller *et al*. (1999) demonstrated that the weaning weight of pigs in the first week after weaning was a significant predictor of subsequent performance, but Slade and Miller (1999) added that the significance of this factor reduced with time post-weaning. Results from the current study partially support these findings, although weaning weight was a good predictor of 20-week weight only for pigs in the bottom quartile of herds. It is also interesting to note that the significance of weaning weight on subsequent weight decreased with time with pigs in the top quartile of herds. The weaker correlation between the wean and 20-week weights for pigs from the top quartile of herds suggests that management factors on the top quartile of herds influenced growth performance to a larger extent than on the poorer herds and promoted faster growth of pigs.

The distribution of the weight of pigs within a group was not considered in this study. Research evidence suggests that a certain degree of variation in the weight of pigs in a group is necessary for the development and maintenance of a social order and, that in the absence of variation in weight when a group is formed, it will develop over time (Tindsley and Lean, 1984; Gonyou, 1998). In an attempt to test this hypothesis and try to reduce the variation in growth rate between pigs within a herd, a study has been instigated at the Agri-Food and Biosciences Institute, Hillsborough. This latter study investigates the effect of the method of grouping i.e. uniform weight groups versus mixed weight groups and the effect of nutrition from weaning through to slaughter on the variable weight and growth rate of pigs at different stages throughout their lifetime.

In conclusion, large variation in growth rate between pigs within herds is a major contributor to poor herd performance and reduced profitability. Within a breed, major variations in feed intake can contribute to the variation in growth rate. More research is required to investigate the effect of management, nutrition and disease on the wide variation in growth performance between and within herds. It appears that in order to provide a foundation to minimise the variation in the slaughter weight of pigs, variation in the weaning weight of pigs should be minimised.

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Do on farm production factors affect pigmeat quality?

B.W. Moss, E. Magowan & M.E.E. McCann

Summary
This paper outlines how meat quality, that is appearance, texture and flavour is measured. The effect of on farm pig production factors on the eating quality of pork is also investigated. In general the growth rate of pigs has little or no effect on the quality of pork.

Review of the Literature
The quality of pork can be assessed by using instrumental methods or by using sensory assessment; the latter may use highly trained assessors for detailed evaluation such as a sensory profile, or may use consumer panels when evaluating the acceptability of the meat. The main attributes evaluated in sensory assessment of the cooked product are texture, juiciness and flavour.

<u>*Measuring meat quality*</u>
Appearance
The consumer acceptability of pig meat depends on the amount of fat and lean and the colour of the fat and lean. A large consumer study, involving several countries, was undertaken using a range of photographs representing different proportions of fat and lean, different colours of lean and amount of drip (Ngapo *et al.,* 2007). The majority of consumers preferred low fat cover. Overall the most consistent choices were based on colour, followed by fat with drip loss the least important. Irish consumers preferred images with light colour, and no drip (Ngapo *et al.,* 2007). Consumers in Northern Ireland when asked to select chops differing in colour, but with no visible drip loss, preferred the paler chops (Moss and Kilpatrick, 1992).

The colour of the lean meat is related to the welfare of the pigs prior to slaughter, particularly from the time of selection on farm for slaughter, subsequent transport and lairage at the factory. Pale pork arises when the pigs are stressed in a short period just before slaughter or from breeds of pigs which are more susceptible to stress, particularly those with the halothane gene. The pale pork, referred to as the PSE condition (pale, soft and exudative), can be assessed by measuring the pH of the muscle 45 minutes post mortem (pH_1), carcases with pH_1 values of 5.9 or less are classified as PSE. PSE can also be assessed by measuring the colour using instrumental methods and by the amount of drip loss from sample chops. In AFBI we routinely measure the colour and drip loss of sample chops from pig production experiments. If the design of the experiment has a pre-slaughter welfare aspect then the pH_1 measurements would also be taken.

If the pre-slaughter stress is of longer duration e.g. long transport journeys, overnight lairage or long period from last feed to slaughter, the meat has high ultimate pH value (pH_u) measured 24 hour post slaughter and is dark in appearance and is referred to as dark, firm and dry (DFD). The meat is often sticky to touch, as opposed to 'wet' in normal conditions and is defined as DFD if the pHu is above 6.0. This high pH meat spoils more readily, has a short shelf life and if made into bacon has a dark 'glazy' appearance. Although there are some genetic factors influencing high pH_u meat, what may be of more practical importance is the higher incidence of DFD in boars compared to gilts (Moss and Robb 1978). This arises from the more aggressive nature of the boars and attempts at sexual mounting in the pre-slaughter period (Moss 1978) and can lead to a considerable number of blemishes on the carcases resulting in downgrading for certain markets (Moss and Trimble 1988 a, b).

Texture and juiciness
The toughness of pig meat is often not considered as critical as may be the case for beef. However when undertaking sensory analysis we often find strong relationships between toughness, juiciness and flavour. Tougher meat is often assessed as less juicy and sometimes less flavour. This initial chewing may influence the person's sensory evaluation. In AFBI we routinely measure tenderness using an instrumental method after the meat has been cooked under standard cooking conditions. This method is called Warner Bratzler Shear force (WBSF), and is an internationally recognised standard technique for assessment of toughness. Workers in the USA (Platter *et al.,* 2005) have suggested that for beef, values of WBSF of less than 2.3 kg/cm^2 would be extremely tender and those above 3.3 kg/cm^2 would be tough.

There is a strong link between the intramuscular fat content of pork and it's juiciness. In the UK, Wood (1990) recommended a minimum of 1% intramuscular fat to obtain satisfactory eating quality. Other workers have suggested higher levels of intramuscular fat to obtain satisfactory eating quality (Bejerholm and Barton-Gade, 1998, 2 %; De Vol *et al*., 1988, 2.5 to 3%). The current recommendation of the National Pork Board USA is between 2 to 4% (Meisinger, 2002). Fortin *et al*., (2005) obtained a high correlation between intramuscular fat and shear force and concluded that for a pleasing eating experience the intramuscular fat level should be over 1.5%. The differences between these quoted values depend to some extent on the method of both chemical and sensory analysis used and may also reflect differences between countries in consumers.

Intramuscular fat is positively related to backfat thus to get desirable juiciness with low backfat thickness we must consider genetic lines which have a higher ratio of intramuscular fat to backfat, for example, Duroc crosses have a higher content of marbling fat at the same P_2 measurement than most other breeds.

Flavour
The development of flavour for a cooked meat product is extremely complex depending on biochemical molecules developed during the aging of the meat, the method and temperature of cooking. There is no simple instrumental method developed to assess flavour. Abnormal flavours and off odours can be produced by certain feeding regimes, for instance a high content of fish oils can lead to abnormal fishy flavours (Wood *et al*., 2003). Changing the pig's diet to increase the proportion of unsaturated fatty acids in the adipose tissue and lean to meet guidelines for human nutrition can lead to problems in shorter shelf life and oxidation of the fat giving rise to off odours. Thus when feeding such diets it is common to include elevated levels of Vitamin E in the diet to act as an antioxidant and improve shelf life for both colour and off flavours (Teye *et al*., 2006).

A common off flavour is 'Boar Taint'. Boar taint can arise from two different compounds, androstenone and skatole. In general, if the boars are slaughtered at a young age then boar taint from androstenone is not a major problem. Whilst androstenone is related to the sex hormones and sexual maturity of the boars, skatole is derived from microbial degradation of the amino acid tryptophan in the gut. Hawe *et al*. (1992) showed that microbial activity in the gut could be reduced by increasing the dietary fibre content of the diet i.e. inclusion of sugar beet pulp and addition of lactose to the pig diet. Other workers have shown that sources of fermentable starch, including sugar beet (Knarreborg *et al.,* 2002), raw potato starch (Chen *et al.,* 2007, Losel *et al*., 2006) and chicory root or inulin (Hansen *et al*., 2006) could reduce microbial production of skatole and hence the boar taint derived from skatole. For both androstenone and skatole, instruments based on electronic nose technology have been developed, however these still remain in the research lab as they do not meet the requirements for online measurement in meat plants.

Experimental Investigation
Effect of diet, gender and growth rate on meat quality.
Many recent studies, reviewed by Wood *et al.* (2004) have focused on the effect of diet on the fatty acid profile of meat. There have been limited studies on the effect of diet on other aspects of meat quality such as tenderness.

Experimental design
The effect of gender (gilt or boar) and diet (1 or 2) on meat quality was assessed using a 2 x 2 factorial design. A range of growth rates were observed within this design and hence correlations between growth rate and meat quality were evaluated. A total of 120 pigs were commercially housed from 10 weeks of age to slaughter (on average 105kg). The diets were offered to pigs during the finishing period (11 weeks of age to 105kg). Diet 1 represented a normal finishing pig diet and contained 13.5MJ/kg of digestible energy and 0.95% total lysine.

Diet 2 represented a higher nutritional diet and contained 14.5MJ/kg digestible energy and 1.1% total lysine. Both diets contained the same ingredients with the higher energy in diet 2 being derived from a higher content of wheat and lower content of barley and the inclusion of soya oil in comparison to diet 1. On the day before slaughter, pigs were weighed and slap marked. On the day of slaughter pigs were in transport for 1 hour and in lairage for a further hour before they were slaughtered. Pigs were sent to slaughter over 5 time periods. Pigs were slaughtered as per the normal abattoir procedure. The longissimus dorsi muscle was dissected from the left loin of each pig and used for subsequent meat analysis (colour, tenderness and drip loss).

Results

There was no statistically significant effect of either dietary treatment or gender on the colour parameters of the longissimus dorsi muscle (*L Dorsi*). There was however a significant interaction (between gender and diet) for redness values (a*, $p<0.01$), hue ($p<0.01$) and chroma ($p<0.05$). These interactions show that the mean a* values were significantly higher for boars than gilts when offered diet 1, but lower for boars than gilts when offered diet 2. Similarly hue angles were lower for boars than gilts when offered diet 1 and higher than gilts when offered diet 2. The results indicate that the longissimus dorsi muscle for boars was redder (higher a*, lower hue angle) than gilts on diet 1 but on diet 2 the longissimus dorsi muscle from gilts was redder than boars.

Shear force, drip loss and cooking loss were not significantly affected by either dietary treatment or gender (Table 1). Although the ultimate pH (pH_u) is significantly higher in boars than gilts ($p<0.05$) the difference between the two means (5.49 boars and 5.45 gilts) is of little practical consequence in terms of meat quality. None of the pigs would be classified as DFD on the basis of having a pHu of 6.0 or greater, three of the boars had pHu values of greater than 5.75, however, all other values were within the normal expected range of 5.4 to 5.6. The sarcomere length was significantly longer ($p<0.05$) in boars than gilts (Table 2).

The relationship between a number of growth related measures including liveweight at 10,15, 20 weeks and final weight and also growth rate between various stages (e.g. 10 to 15 weeks, 15 to 20 weeks etc) and meat quality parameters was evaluated statistically. A number of statistically significant relationships were obtained, however the variation in meat quality explained was very low suggesting that in the main growth rate had little effect on meat quality parameters over the range studied. There were no statistically significant relationships between any of the average daily gains calculated over different time periods and Warner Bratzler shear force (Figure 1 - Relationship between ADG from 10 to 20 weeks and WBSF). Although cooking loss was significantly correlated ($p<0.01$) with ADG from 10 to 20 weeks this relationship only explained 7.7% of the variation in cooking loss (Figure 2).

The best statistically significant relationship obtained, which was between finish weight and hue angle (a measure of redness), only explained 12% of the variation in colour. A statistically significant (p<0.001) relationship was obtained between 20 week weight and cooking loss, however this relationship only explained 9.8% of the variability in cooking loss due to weight at 20 week.

Table 1 Effect of diet and gender on colour of the longissimus dorsi muscle

Factor	L*	a*	b*	hue	Chroma
Gender					
Boar	55.42	1.43	7.10	79.9	7.33
Gilt	55.75	1.37	7.23	80.8	7.47
Sed	0.783	0.247	0.265	1.84	0.291
Significance	NS	NS	NS	NS	NS
Diet					
1	55.81	1.37	7.09	80.7	7.35
2	55.36	1.43	7.24	80.1	7.46
Sed	0.782	0.247	0.266	1.85	0.292
Significance	NS	NS	NS	NS	NS
Interaction					
Gender X diet	NS	<0.01	(0.06)	<0.01	<0.05

L*= lightness, a* = redness, b* = yellowness, hue- a measure of redness where lower values indicate greater redness, Chroma – lower values indicate the sample is more grey.

Table 2 Effect of Diet and Gender on meat quality parameters of the longissimus dorsi muscle

Factor		WBSF (kg/cm^2)	Cooking Loss (%)	pHu	Drip Loss (%)	Sarcomere (µm)
Gender						
	Boar	3.23	30.8	5.49	5.82	1.96
	Gilt	3.32	30.6	5.45	6.64	1.89
	Sed	0.097	0.57	0.016	0.430	0.037
Significance		NS	NS	<0.05	NS	<0.05
Diet						
	1	3.32	30.7	5.46	6.23	1.92
	2	3.23	30.7	5.47	6.22	1.92
	Sed	0.097	0.57	0.016	0.432	0.037
Significance		NS	NS	NS	NS	NS
Interaction						
Gender X diet		NS	NS	<0.05	NS	NS

WBSF Warner Bratzler Shear Force

Figure 1. Relationship between average daily gain from 10 to 20 weeks (ADG10-20) and Shear force (kg.cm^{-2})

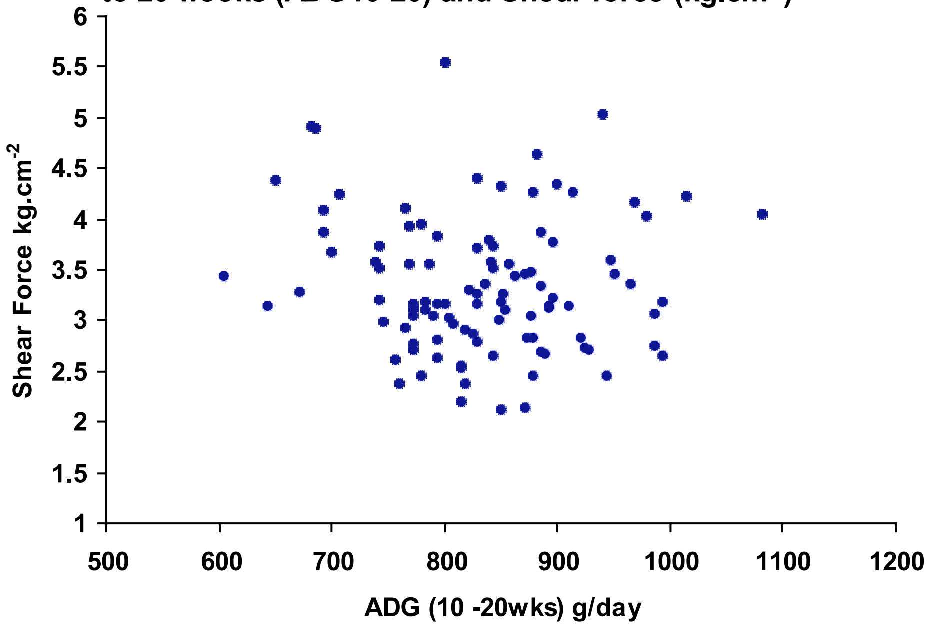
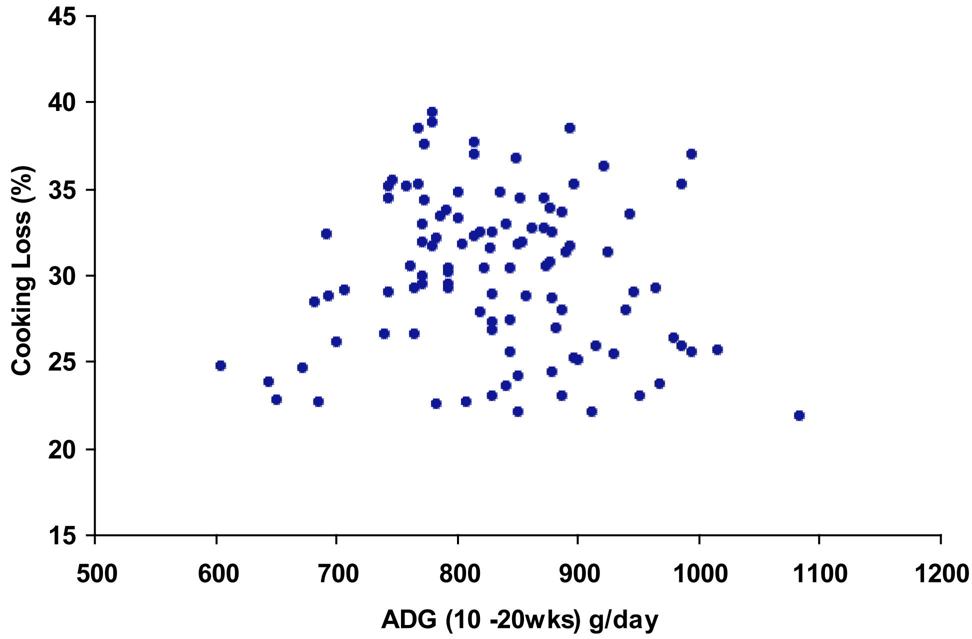


Figure 2. Relationship between average daily gain from 10 to 20 weeks (ADG10-20) and Cooking Loss



Discussion

The dietary treatments used in this study had no effect on any of the meat quality parameters measured. Teye *et al*. (2006) found that a high protein diet resulted in significantly lower L*, a* and b* values, but no change in shear force. When assessed using sensory panels the low protein diet used by Teye *et al.* (2006) significantly increased tenderness and juiciness, but there were no changes in flavour intensity or flavour liking. Teye *et al.* (2006) suggested that increased juiciness in the low protein diet may be due to higher intramuscular fat, since Wood *et al.* (2004) showed that a low protein diet could increase marbling fat without an increase in backfat. The gender x diet interaction may be explained by a differential effect of the diet on intramuscular fat levels, since increased colour intensity of the longissimus dorsi has been attributed to increased intramuscular fat content (Teye *et al*., 2006). Gilts tend to be fatter than boars at slaughter weight and diet 2 would have had the potential to increase the fatness of the pig since it contained a higher energy content. Therefore it is possible that gilts offered diet 2 had an increased colour intensity compared to boars due to a higher deposition of fat which seems to have been placed intramuscularly. However, it is not clear why gilts had a lower colour intensity compared to boars when offered diet 1. It may be that the lower a* values of the boars on diet 2 are related to the higher aggressive activity of the boars and the influence of energy content of the diet in glycogen (energy) reserves in the muscle. The diet gender interaction for pH_u values may be explained by a small number of boars showing higher pH_u levels due to their aggressive nature or attempts at mounting during lairage (Moss, 1978). However, the average pH_u values overall are well within the normal range and do not show any major influence of pre slaughter handling or stress on muscle glycogen depletion. Due to the slightly different methodology used by different workers to measure drip loss it is not valid to compare these with those of other workers. The values obtained seem to be slightly higher than normal indicating either the pigs were susceptible to stress or were stressed during the period just before slaughter. Measurement of pH_1 values would have been needed to confirm this.

The current studies show little effect of average daily gain on meat quality parameters, the statistical approach may be confounded by the relationship between daily gain and finish weight since it appears that around 20% of variability in finish weight may be explained by variation in daily gain. Latorre *et al*. (2007) used 3 different breeds to study the relationship between performance and meat quality. In his studies around 16% of the variability in a* could be explained by average daily gain. Faster growing pigs had more soluble collagen and produce more tender meat, however, the relationships only explained 16% of the variability in soluble collagen (Latorre *et al*., 2007).

In conclusion over the range of average daily gains studied here and live weights at slaughter, there is little effect of production parameters on meat quality. There is need for further evaluation of the effects of performance characteristics on a wider range of genotypes and relationship between meat quality attributes measured.

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Notes