Irish Journal of Agricultural and Food Research **47:** 171–185, 2008

The effect of boar breed type on reproduction, production performance and carcass and meat quality in pigs

M.E.E. McCann[1,2,3]†, V.E. Beattie[4], D. Watt[1] and B.W. Moss[2,3]

[1]*Agri-Food and Biosciences Institute, Hillsborough, Co Down, Northern Ireland, BT6 6DR*
[2]*Agriculture, Food and Environmental Science Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, Northern Ireland, BT9 5PX*
[3]*Department of Agricultural and Environmental Science, The Queen's University of Belfast, Newforge Lane, Belfast, Northern Ireland, BT9 5PX*
[4]*Devenish Nutrition Ltd, 96 Duncrue Street, Belfast, Northern Ireland, BT3 9AR*

A total of 720 sows were inseminated with semen from eight commercially available boar breed types (Landrace, Large White, Duroc, Landrace × Large White, Landrace × Duroc, Landrace × Large White × Duroc, Large White × Duroc and Landrace × Large White × Pietrain). There were no effects of purebred versus crossbred boar breed type on reproductive performance or on production performance of progeny. The only carcass evaluation parameter affected was V measurement (backfat thickness at the edge of the eye muscle) which was 2 mm thicker ($P < 0.05$) for the progeny of crossbred boars. Meat from pigs of purebred boars breed had a higher proportion of intramuscular fat than that from crossbred boars breed (26.5 v 21.1 g/kg, respectively, $P < 0.05$). There were inconsistent effects of individual boar breed type on performance, carcass quality and meat quality. Producers should consider the variation between the progeny of individual boars to achieve improved production performance. There was also a lack of relationship between backfat at the P_2 position and eye muscle area or depth ($r = -0.03$ and -0.01, respectively) which suggests that carcass characteristics other than P_2 backfat need to be included in the selection of breeding animals. Similarly, the weak correlations between carcass and meat quality traits ($r < 0.3$) indicate that if meat quality is to be improved, it must be specifically included in the selection criteria.

Keywords: boar; carcass; meat quality; performance; pigs; sire

†Corresponding author: Agri-Food and Biosciences Institute, Hillsborough, Co Down, Northern Ireland, BT26 6DR. E-mail: elizabeth.mccann@afbini.gov.uk

Introduction

The aim of genetic selection is to improve performance and ultimately profitability by incorporating the beneficial traits from a breed type while eliminating undesirable traits. During the last 30 years a large number of genetic studies have been carried out to improve the traits which determine performance and carcass traits in pig production. Selection has primarily focused on traits such as growth rate, feed conversion ratio (FCR), kill-out proportion and backfat thickness.

Meat quality is assessed by a number of variables which include: intramuscular fat, drip loss, water holding capacity, tenderness (shear force) and pH of semi-membranosus muscle. Fortunately many of these traits are heritable and the generation interval for pigs is short enough to allow rapid improvement (Rauw *et al*., 1998). However, within the United Kingdom there is at present no system for direct genetic selection based on meat quality traits. Therefore, any change in meat quality has been the result of correlation with the selection indices used (i.e. backfat, growth rate and FCR).

Terminal sire line has been shown to affect the reproductive traits of the sows with which they are mated. Edwards *et al*. (1992) compared the progeny from Large White and Duroc boars and reported that Duroc-sired litters were larger at birth (+0.9 pigs) and at weaning (+0.4 pigs). However, this was associated with lower birth and weaning weights for individual piglets. The Duroc breed type has also been reported to be older at puberty (Young, 1998), which is in contrast to the work of Irgang *et al*. (1992).

One of the main objectives of pig breeding programmes has been to increase the carcass lean to fat ratio. Progress has been made in reducing subcutaneous fat during the last three decades. For example, in Northern Ireland, pigs tested at the Central Testing Station in 1976 had an average P_2 of 14 mm, whereas in 2000 the average was 6.6 mm. Percentage lean meat increased from 61.5 to 67.6% over the same period and feed conversion ratio (FCR) declined from 3.0 to 2.27 (P.I.G., 2000). Another important carcass trait altered via selective breeding is cross-sectional area of the eye muscle (*longissimus dorsi*). A large eye muscle is not a notable feature of the Duroc boar breed type in comparison with Large White and Landrace boar breed types (Smith, Pearson and Purchas, 1990). Pietrain pigs have a large eye muscle but are associated with poorer performance and are subject to porcine stress syndrome (PSS). Recent studies on the carcass quality of different breed types have produced conflicting results. Candek-Potokar *et al*. (1998) reported that there was no difference in the carcass quality of Duroc and Large White pigs. However, Blanchard *et al*. (1999) reported that backfat was higher for Duroc pigs and lean percentage was lower.

Selection for high carcass quality (e.g. increased lean meat percentage) has been associated with a lower meat quality (Kempster *et al*., 1986). It has been suggested that the use of the Duroc in pig breeding programmes may help to improve eating quality of meat due to the higher levels of intramuscular fat. Cameron *et al*. (1990) compared the meat and eating quality of Duroc and British Landrace pigs. These workers reported that Duroc eye muscle was darker, redder and contained more intramuscular fat and less moisture than Landrace muscle. Blanchard *et al*. (1999) compared graded levels of Duroc inclusion with Large White × Landrace crosses and obtained similar results.

The primary objective of this study was to examine the different boar breed types available commercially and to establish possible associations with reproduction, production performance, and carcass and meat quality. A secondary objective was to investigate differences between crossbred and purebred boars.

Material and Methods

Three main Northern Ireland-based semen suppliers were used, Deerpark Pedigree Pigs, Elite Sires and Hermitage AI, in order to ensure that results obtained were representative of the genetic material used across Northern Ireland. These companies were chosen on the basis that each company had each of the eight boar breed types to be evaluated. The boar breed types (number of boars) evaluated were: Landrace (n = 9); Large White (n = 11); Duroc (n = 8); Landrace × Large White (n = 8); Landrace × Duroc (n = 8); Large White × Duroc (n = 5); Landrace × Large White × Duroc (n = 8) and Landrace × Large White × Pietrain (n = 7).

A list of all available boars, within each boar breed type, was obtained from the companies and individual boars were selected from the lists at random with equal representation from each supplier. The study ran continuously over a 3-year period. As the objective of the experiment was to evaluate the effects of boar breed type, not supplier, all data were pooled across suppliers. A total of 720 (151 first cross Landrace × Large White, 482 ¾ Landrace and 87 pure Landrace) sows were inseminated during the experimental period.

Reproductive performance

The 720 sows used were inseminated with semen from boars from the eight different boar breed types. Reproductive performance was assessed using the following criteria: number of pigs born alive; number of pigs stillborn; birth weight; pre-weaning mortality and weaning weight.

Production performance

All pigs were born in crated farrowing accommodation and were offered a commercially available creep feed from 10 days of age in a forward creep area. Piglets were weaned at 4 weeks of age and allocated to pens according to their boar breed type. Over eight weanings eight groups of 10 pigs, balanced for gender, from each of the eight boar breed types, giving a total of 640 pigs, were housed in post weaning accommodation until 10 weeks of age. Five pigs were selected from two litters by the same boar breed type for each of the eight weanings. Thus, pigs from 128 litters were involved in the performance study. Pigs were weighed at weaning and at 10 weeks of age on transfer to finishing accommodation, where they remained in their original groups. Feed intake, average daily gain (ADG) and feed conversion ratio (FCR) were recorded for the 6-week period in post weaning accommodation and over the finishing period from 10 weeks of age until slaughter at approximately 20 weeks of age. All pigs were offered identical diets and were subject to the same management regime.

Carcass quality

Pigs were weighed weekly prior to slaughter and were selected for slaughter at approximately 90 kg live weight (approximately 20 weeks of age) to represent the average weight of the pen and provide a representative sample for carcass evaluation between progeny of each of the eight boar breed types. There was only one slaughter day per batch for the purpose of carcass evaluation. A total of 366 pigs (representative of the average growth of pigs in each pen on the performance trial) were used to determine the effects of boar breed type on selected carcass traits and consisted of the following per boar breed type: Landrace (n = 39); Large White (n = 59); Duroc (n = 39); Landrace × Large White (n = 52); Landrace × Duroc (n = 42); Large White × Duroc (n = 45); Landrace × Large White × Duroc (n = 43) and Landrace × Large White × Pietrain (n = 47).

One chop (100 mm thick) was removed from the cross section of the loin at the last rib from each carcass collected at the factory. An image of each chop was captured using a digital camera. This image was downloaded on to a computer and total chop area, eye muscle (*longissinus dorsi*) area, tail area, percentage surface fat in the chop, percentage surface fat in the chop tail, V measurement (backfat thickness at the edge of the eye muscle), eye muscle depth and P_{2ARINI} (backfat 65 mm from the mid line where the last rib joins the spinal column) were calculated using image analysis software (PC image – Foster Associates Ltd). As back-bacon cuts are approximately 200 mm in length, this was the standard applied to the digital photographs. The total chop area was subdivided into tail and eye muscle sections following the line of the V measurement to the ventral boundary of the eye muscle and then to the internal surface of the chop. The areas of muscle and subcutaneous fat were measured in each section together with the area of intermuscular surface fat in the tail section. The programme was able to recognise areas of fat by selecting the colour on the photograph corresponding to a preset range of wavelengths. In addition, $P_{2FACTORY}$ was measured at the factory using an optical probe (intrascope) and kill-out (g/kg) was determined (Cold weight/final weight). Lean meat (g/kg) was calculated from backfat measurements according to EC Decision (94/567/EC).

Meat quality

At transfer to the finishing accommodation, equal numbers of boars and gilts from each pen on the performance trial were chosen for meat quality analysis. The number per boar breed type was: Landrace (n = 30); Large White (n = 57); Duroc (n = 36); Landrace × Large White (n = 52); Landrace × Duroc (n = 44); Large White × Duroc (n = 35); Landrace × Large White × Duroc (n = 38) and Landrace × Large White × Pietrain (n = 53). The set of pigs used for meat quality analyses represented a subset of those used for carcass measurements.

It is well known that meat quality is dependent on slaughter date due to specific conditions at the factory on that day. Therefore, sample pigs from any given batch were slaughtered on the same day regardless of weight. Meat quality variables measured were colour coordinates X, Y and Z – these were later converted to CIELAB colour values for L^*, a^*, b^*, chroma and hue – ultimate pH (pH_u), shear force (Warner Bratzler), cooking loss and drip loss (according to the methods outlined in Beattie *et al.,* 1999). A representative sample of the progeny of each boar breed type (in total n = 137) was taken at slaughter for intramuscular fat determination: Landrace (n = 15); Large White (n = 25); Duroc (n = 10); Landrace × Large White (n = 13); Landrace × Duroc (n = 17); Large White × Duroc (n = 14); Landrace × Large White × Duroc (n = 13) and Landrace × Large White × Pietrain (n = 30).

Statistical analysis

All data were analysed using one-way analysis of variance (ANOVA Genstat 6) to test for differences between purebred and crossbred boars and for the effect of boar breed type. The model included the effect of boar breed type (purebred, crossbred or individually). Litters from individual sows were taken as the experimental unit for reproductive traits. For production performance, the pen was taken as the experimental unit and initial weight used as a covariate to eliminate any effect of batch. Individual pigs were taken as the experimental unit for carcass and meat quality assessments. Any differences in live weight at slaughter were accounted for by covariate analysis. Pairwise differences between boar breed types were tested, when the overall F-test for variation among boar breed types was significant, using the LSD method. Simple correlations were estimated to establish the relationships between production, carcass and meat quality traits.

Results

Reproductive and production performance
None of the measured reproductive characteristics were affected by whether the boar was purebred or crossbred and no difference in production performance was found between the progeny of purebred and crossbred boars (data not presented).

Data for production and reproductive performance are presented in Table 1. When individual boar breed types were compared, sows mated with Duroc and Large White × Duroc boars had a greater number of pigs born alive than those mated with Large White, Landrace × Duroc and Landrace × Large White × Pietrain. Progeny of the two Duroc crosses (Landrace × Duroc and Large White × Duroc) and Large White boars had higher feed intake up to 10 weeks of age, than progeny of the other boar breed types (apart from Duroc and Landrace × Large White and Duroc) but this was not maintained during the finishing period. However, FCR during the finishing period for pigs sired by Duroc (2.77) and Landrace × Large White × Pietrain (2.78) boars was higher than that for pigs sired by Large White × Duroc (2.26) boars.

Carcass and meat quality
Progeny from purebred boars had a smaller measurement for V fat depth than progeny from crossbred boars (19.6 v 21.6 mm, $P < 0.05$). There were no other statistically significant differences in carcass quality traits between the progeny of purebred and crossbred boars. The progeny from purebred boars contained much higher levels of intramuscular fat (26.5 v 21.1g/kg, $P < 0.05$).

The comparison of carcass and meat quality characteristics between the progeny of the boar breed types is shown in Table 2. Backfat depth (P_2), relative fat area in the chop, kill-out proportion and carcass lean proportion varied significantly among the boar breed types. Progeny of Landrace boars had the lowest P_2 and the highest proportion of lean. Kill-out proportion was highest for progeny of Landrace × Large White and Landrace × Large White × Pietrain and lowest for progeny of Landrace × Duroc boars ($P < 0.05$). Progeny of Landrace × Large White boars had a lower relative fat area in the chops than progeny of Large White, Landrace × Large White × Pietrain and Landrace ($P < 0.05$).

There were significant differences in cooking loss and pH_u between the boar breed types. Meat from Duroc progeny had the lowest pH_u, while that from Landrace, Landrace × Large White × Pietrain and Landrace × Large White × Duroc progeny had the highest pH_u. This corresponds with cooking loss, as the meat of Landrace progeny had the lowest value for cooking loss.

Relationship between carcass quality measurements
The correlations between the various carcass quality variables are given in Table 3. Eye muscle area was positively correlated with eye muscle depth and V fat measure-

Table 1. Reproductive performance of sows (n = 720) mated with boars from eight different breed types and production performance of the progeny

	Boar breed type[1]								s.e.	F test
	LR	LW	D	LR × LW	LR × D	LW × D	LR × LW × D	LR × LW × P		
Reproductive performance										
No. born alive	10.6^{abc}	10.4^{ab}	11.4^{c}	11.2^{bc}	10.0^{a}	11.5^{c}	10.5^{abc}	10.2^{ab}	0.605	< 0.05
No. stillborn	1.1^{b}	0.7^{ab}	0.6^{a}	1.0^{b}	0.9^{ab}	0.5^{a}	0.8^{ab}	1.5^{c}	0.25	< 0.01
Birth weight (kg)	1.7	1.7	1.6	1.7	1.7	1.6	1.6	1.6	0.05	
Pre-weaning mortality (%)	12.1	7.7	8.7	9.8	9.7	7.7	9.7	13.3	2.19	
Weaning weight (kg)	9.3	9.2	9.3	9.6	9.2	9.0	9.1	9.2	0.15	
Production performance[2]										
Weaning to 10 weeks										
Daily feed intake (g)	730^{a}	807^{b}	795^{ab}	753^{a}	828^{b}	842^{b}	774^{ab}	743^{a}	26.0	< 0.05
Daily live-weight gain (g)	466	490	513	463	528	490	476	459	18.8	
FCR[3] (kg/kg)	1.57	1.65	1.55	1.63	1.57	1.72	1.63	1.62	0.046	
Week 11 to finish										
Daily feed intake (g)	2022	2033	2382	2028	2345	1932	2028	2252	153.5	
Daily live-weight gain (g)	846	810	860	828	859	855	886	810	29.6	
FCR[3] (kg/kg)	2.39^{ab}	2.51^{ab}	2.77^{b}	2.45^{ab}	2.73^{ab}	2.26^{a}	2.29^{ab}	2.78^{b}	0.174	< 0.05
Wean to finish										
Daily feed intake (g)	1556	1594	1818	1599	1808	1562	1570	1777	103.5	
Daily live-weight gain (g)	714	699	739	705	744	729	738	689	18.1	
FCR[3] (kg/kg)	2.18	2.28	2.46	2.27	2.43	2.14	2.13	2.58	0.157	

[1] LR = Landrace; LW = Large White; D = Duroc; LR × LW = Landrace × Large White; LR × D = Landrace × Duroc; LW × D = Large White × Duroc; LR × LW × D = Landrace × Large White × Duroc; LR × LW × P = Landrace × Large White × Pietrain.

[2] For production performance the pen (n = 64) was taken as the experimental unit with 10 animals per pen.

[3] FCR = Food conversion ratio (feed/gain).

^{abc} Means within rows with the same superscript are not significantly different.

Table 2. Comparison of carcass and meat quality characteristics of progeny by different boar breed types

	Boar breed type[1]								s.e.	F test
	LR	LW	Dr	LR × LW	LR × Dr	LW × Dr	LR × LW × Dr	LR × LW × P		
Carcass traits (n = 366)										
Carcass weight (kg)	70.7^{abc}	70.1^{ab}	70.6^{abc}	71.6^{c}	69.7^{a}	71.0^{bc}	70.2^{ab}	71.5^{c}	1.197	< 0.01
Eye muscle area (cm^2)	38.8	40.3	39.5	39.1	40.5	39.7	40.5	39.5	0.770	
Eye muscle depth (mm)	47.5	47.9	47.4	48.3	45.2	48.5	48.6	48.4	0.082	
Surface fat in chop (%)	26.9^{b}	28.3^{b}	25.8^{ab}	23.8^{a}	25.6^{ab}	26.4^{ab}	26.7^{ab}	28.2^{b}	1.053	< 0.05
Surface fat in chop tail (%)	42.2	46.6	44.3	44.3	44.4	39.1	45.4	53.1	1.657	
V fat (mm)	17.3	21.3	19.6	22.9	23.3	20.2	19.5	21.6	0.135	
Kill-out (g/kg)	764^{ab}	758^{ab}	763^{ab}	774^{b}	754^{a}	768^{ab}	760^{ab}	773^{b}	4.3	< 0.01
$P_{2FACTORY}$ (mm)	10.5^{a}	11.6^{b}	11.8^{bc}	11.8^{bc}	11.8^{bc}	11.8^{bc}	11.2^{ab}	12.7^{c}	0.364	< 0.05
P_{2ARINI} (mm)	10.4^{ab}	11.4^{bc}	11.3^{bc}	11.6^{c}	11.4^{bc}	10.3^{ab}	9.6^{a}	11.1^{bc}	0.421	< 0.01
Lean meat (g/kg)	577^{c}	562^{ab}	561^{ab}	563^{ab}	560^{ab}	561^{ab}	565^{b}	553^{a}	1.9	< 0.05
Meat quality (n = 345)										
*L** (Lightness)	53.76	54.63	55.79	55.70	55.23	54.30	54.99	53.82	0.681	
*a** (Redness)	3.56^{a}	4.61^{bc}	4.77^{bc}	5.06^{c}	4.12^{ab}	4.37^{abc}	3.98^{ab}	4.20^{ab}	0.296	< 0.05
*b** (Yellowness)	8.25	9.01	9.20	8.98	8.88	8.71	8.53	8.68	0.276	
Chroma	9.07	10.21	10.45	10.40	9.89	9.87	9.47	9.72	0.352	
Hue	67.18^{c}	63.80^{abc}	63.34^{ab}	61.75^{a}	66.67^{bc}	64.73^{abc}	65.68^{bc}	65.39^{bc}	0.690	< 0.05
pH_u	5.57^{b}	5.52^{ab}	5.48^{a}	5.52^{ab}	5.51^{ab}	5.50^{ab}	5.56^{b}	5.58^{b}	0.023	< 0.05
Shear force (N)	36.22	38.00	35.71	37.49	36.09	37.75	36.86	35.45	1.148	
Cooking loss (g/kg)	228^{a}	248^{cd}	236^{abc}	234^{ab}	235^{ab}	245^{bcd}	249^{cd}	250^{d}	2.25	< 0.01
Drip loss (g/kg)	56.3	60.4	66.5	54.8	56.6	57.3	57.9	58.9	3.40	
Intramuscular fat[2] (g/kg)	23.0	26.8	30.1	19.3	22.3	21.9	20.8	24.0	2.50	

[1] See footnotes Table 1.

[2] n = 137 for intramuscular fat measurement.

[abc] Means with the same superscripts are not significantly different.

Table 3. Correlations[1] between carcass quality variables (n = 366)

	Eye muscle depth	Surface fat in chop	Surface fat in chop tail	V fat (mm)	P_{2ARINI}	$P_{2FACTORY}$	Kill-out proportion	Lean meat proportion
Eye muscle area	**0.27**	0.10	0.08	**0.20**	0.03	−0.03	−0.09	0.03
Eye muscle depth		−0.08	−0.09	−0.16	**−0.23**	−0.01	0.03	0.05
Surface fat in chop			**0.32**	**0.38**	**0.25**	**0.21**	−0.08	−0.18
Surface fat in chop tail				**0.61**	**0.36**	**0.26**	0.12	−0.14
V fat					**0.51**	**0.34**	−0.02	**−0.23**
P_{2ARINI}						**0.58**	0.02	**−0.43**
$P_{2FACTORY}$							0.10	**−0.90**
Kill-out proportion								0.04

[1] Values ≥ 0.194, 0.254, 0.321 are significant at P < 0.05, < 0.01 and < 0.001, respectively. Significant correlations are highlighted in bold.

ment (P < 0.01 and P < 0.05, respectively). The relative fat area in the chop was significantly positively related to the relative fat area in the chop tail, V fat, and P_2. There was a strong positive correlation between the relative fat area in the chop tail and V fat depth (P < 0.001). Backfat determined at the factory ($P_{2FACTORY}$) was positively correlated with P_2 measured by image analysis (P_{2ARINI}) (P < 0.001). Both $P_{2FACTORY}$ and P_{2ARINI} were negatively correlated with carcass lean (P < 0.001). Although there were significant relationships between the variables, the actual value for r in the majority of cases was low, indicating that the relationships were not strong. However, there were strong relationships between the V fat depth and relative fat area in the chop tail (r = 0.61, P < 0.001), between lean meat and $P_{2FACTORY}$ (r = 0.91, P < 0.001), and between $P_{2FACTORY}$ and P_{2ARINI} (r = 0.58, P < 0.001).

Relationship between meat quality traits

Table 4 presents the correlation matrix for the meat quality measurements. The lightness of meat colour (L^*), was positively related to a^*, b^* and chroma (P < 0.001). L^* was negatively related to pH_u (P < 0.05) as were b^* and chroma (P < 0.01). Strong correlations were observed between a^* and values for b^*, chroma and hue. Cooking loss and drip loss were positively correlated (P < 0.001). Both of these variables were negatively correlated (P < 0.001) with pH_u. Intramuscular fat was only significantly correlated with drip loss (P < 0.05). Again, it is important to note that many of the correlations were low; therefore the relationships were not particularly strong.

Relationship between carcass and meat quality traits

The strongest correlation (r = –0.33, P < 0.001) was a negative relationship

Table 4. Correlations[1] between meat quality variables (n = 345 except for intramuscular fat where n = 137)

	a^*	b^*	Chroma	Hue	pH_u	Shear force	Cooking loss	Drip loss	Intra-muscular fat
L^* (lightness)	**0.32**	**0.54**	**0.50**	−0.10	**−0.25**	0.05	0.05	0.167	0.10
a^* (redness)		**0.77**	**0.90**	**−0.90**	−0.12	0.05	0.11	**0.24**	0.14
b^* (yellowness)			**0.97**	**−0.49**	**−0.32**	−0.04	0.19	**0.30**	0.16
Chroma				**−0.66**	**−0.26**	−0.01	0.16	**0.29**	−0.10
Hue					−0.03	−0.10	0.04	−0.17	0.16
pH_u						0.09	**−0.35**	**−0.39**	−0.15
Shear force							0.02	0.02	−0.04
Cooking loss								**0.36**	0.17
Drip loss									**0.24**

[1] Values ≥ 0.089, 0.125, 0.166 are significant at P < 0.05, < 0.01 and < 0.001, respectively; for intramuscular fat n = 137 and therefore values ≥ 0.141, 0.199, 0.378 are significant at P < 0.05, < 0.01 and < 0.001, respectively. Significant correlations are highlighted in bold.

between eye muscle area and drip loss. Drip loss was also inversely related (–0.23, P < 0.05) to lean meat proportion which was positively correlated (P < 0.05) with L^* and chroma (r = 0.21 and 0.20, respectively). Statistically significant (P < 0.01) but low positive relationships were observed between the relative fat area in the chop tail and the quality traits L^*, b^* and chroma (r = 0.29, 0.22 and 0.20, respectively).

Relationship between production traits and carcass and meat quality

The correlations between production performance (week 11 to finish) and carcass and meat traits are presented in Table 5. Although some relationships were significant the r values obtained were generally weak (i.e. r < 0.5). Daily feed intake was positively correlated with surface fat area in the chop tail (P < 0.01) and with P_{2ARINI} (P < 0.001). Daily live-weight gain was significantly related to eye muscle depth (P < 0.01), surface fat area in the chop tail (P < 0.001), V fat (P < 0.001), P_{2ARINI} (P < 0.001) and $P_{2FACTORY}$ (P < 0.001). In line with this, FCR was inversely related to eye muscle depth (P < 0.05), V fat (P < 0.01) and $P_{2FACTORY}$ (P < 0.001).

Daily feed intake (week 11 to finish) was positively correlated with L^*, a^*, b^*, chroma and shear force (P < 0.01). A negative relationship was observed between daily feed intake and hue (P < 0.001) and cooking loss (P < 0.01). There was a weak positive relationship between daily live-weight gain and b^* (P < 0.05) but no other significant correlations between daily live-weight gain and meat quality measurements. FCR was positively correlated with a^* (P < 0.01), chroma (P < 0.01) and pH_u (r = 0.123, P < 0.05). There was a significant inverse relationship between FCR and hue (P < 0.01).

Table 5. Correlations[1] between production performance (daily feed intake, daily live-weight gain and FCR – 11 weeks to finish) and carcass and meat quality variables (n = 64)

	Daily feed intake	Daily live-weight gain	Feed conversion ratio
Carcass quality			
Eye muscle area (cm^2)	–0.038	0.095	–0.101
Eye muscle depth (mm)	–0.041	**0.136**	**–0.125**
Surface fat in chop	0.016	0.011	0.010
Surface fat in tail	**0.163**	**0.232**	–0.082
V fat (mm)	0.052	**0.298**	**–0.210**
P_{2ARINI} (mm)	**0.223**	**0.338**	–0.118
$P_{2FACTORY}$ (mm)	0.114	**0.476**	**–0.291**
Kill-out proportion	–0.028	0.001	–0.044
Lean meat proportion	–0.001	**–0.128**	0.095
Meat quality			
L^* (Lightness)	**0.202**	0.103	0.093
a^* (Redness)	**0.310**	0.104	**0.178**
b^* (Yellowness)	**0.232**	**0.120**	0.098
Chroma	**0.277**	0.118	**0.139**
Hue	**–0.269**	–0.051	**–0.185**
pH_u	0.104	0.037	**0.123**
Shear force	**0.172**	0.030	0.117
Cooking loss	**–0.158**	–0.008	–0.116
Drip loss	0.030	0.044	–0.017
Intramuscular fat	0.099	0.064	0.005

[1] Values ≥ 0.120, 0.136, 0.202 are significant at $P < 0.05$, < 0.01 and < 0.001, respectively. Significant correlations are highlighted in bold.

Discussion

Reproductive performance

It has been reported that the use of crossbred boars may improve conception rate by between 6 and 20% resulting in a greater number of piglets per litter (McLaren, Buchanan and Johnson, 1987). It has also been suggested that hybrid vigour in the boar can increase average litter size by 0.25 to 0.75 of a piglet per year (Whittemore, 1993). However, the results of this present study are in accord with Buchanan and Johnson (1984) who also reported no significant difference in the reproductive performance of sows mated to purebred or crossbred boars. These workers suggested that parity, season and dam breed have a greater effect on reproductive performance than the breed of the boar.

When individual boar breed types were compared, sows mated with Duroc boar breed types did not consistently produce greater numbers of live pigs than sows mated with the other boar breed types. This is in contrast to previous work which has shown that Duroc-sired litters are larger (Smith, *et al.,* 1990; Edwards *et al*., 1992). Edwards *et al*. (1992) compared Large White and Duroc terminal sires and reported that Duroc-sired litters were larger at birth and at weaning. However, this corresponded to lower birth and weaning weights; an effect not observed in this study. This may be a result of the greater effect of parity and season which was highlighted by Buchanan and Johnson (1984). Indeed, the wide variation in reproductive performance within a boar breed type observed in the present study supports this finding.

Production performance

It has been reported (Rempel, Cornstock and Enfield, 1964) that pigs sired by crossbred boars were significantly fatter and slower gaining than those sired by purebred boars. The results obtained in this study are in contrast to this finding but are in keeping with reports by other researchers. For example Lishman *et al*. (1975) found no significant difference between average daily gain and FCR for pigs sired by Large White compared to those sired by Large White × Landrace boars. Similarly, McLaren *et al.* (1987) detected no significant difference between the growth rate of pigs sired by purebred and crossbred boars.

When the boar breed types were compared for production traits, there was a lack of consistent response for any trait. This suggests that variation between boar breed types is limited and that boar breed type does not have a major influence on feed intake, growth rate or FCR. However, the large variation within the progeny of the different boar breed types suggests that appropriate selection of individual boars is economically important in terms of production performance.

Carcass quality

The progeny of crossbred boars had deeper backfat at the end of the eye muscle (V fat) than those by purebred boars. However, the actual numerical difference was small (2 mm). The fact that there were no significant differences in P_2, kill-out proportion or lean meat proportion between the progeny of purebred and crossbred boars is in keeping with the literature. Kennedy and Conlon (1978) reported that the progeny of crossbred boars yielded carcasses that were equal to the average carcass quality of pigs sired by both the parent breeds.

The present finding that progeny from Duroc and 50% Duroc boars had higher P_2 than progeny by Landrace, is in keeping with results reported by Wood (1993). As the carcass lean proportion is determined by a formula based on fat depth, there are corresponding differences in this variable. Whittemore (1993) reported that Pietrain pig types show benefits over White types by up to 40 g/kg more lean and 30 g/kg better kill-out proportion. However, in the present study the progeny of Landrace × Large White × Pietrain boars had the lowest lean meat proportion (553 g/kg) and a high overall fat proportion in the chop area. Consistent with previous work, kill-out proportion was higher (10 g/kg) than the average of the other boar breed types. The present results indicate that there were no consistent differences between the boar breed types for the majority of carcass quality measurements, even though the means for some variables differed by up to 30%. Such differences between boar breed types were not significant because the variation within a boar breed type was greater than the variation among boar breed types.

Meat quality

The finding that the progeny of purebred boars contained a higher level of intramuscular fat is an important difference since fat is a key component in flavour and, therefore, meat with a low intramuscular fat is reported to be insipid, strawy and dry (Affentranger *et al*., 1996). A positive relationship between intramuscular fat and tenderness, juiciness and taste has been established by Casteels *et al*. (1995). Interestingly, there were no statistically significant differences between the individual boar breed types for the amount of intramuscular fat, although progeny of

Duroc boars contained a much higher proportion (30.1 g/kg) than most of the other groups. Several researchers have reported that Duroc-sired pigs have a higher level of intramuscular fat than progeny from other boar breed types (e.g. Simpson, Webb and Dick, 1987). Blanchard *et al.* (1999) compared graded levels of Duroc inclusion with Landrace × Large White crosses and reported that intramuscular fat increased with increasing levels of Duroc (1.04, 1.12 and 1.82% for 0, 25 and 50% Duroc ancestry, respectively). These workers also stated that Duroc meat was more tender than Landrace × Large White meat. This contrasts with the present finding that there was no difference in shear force between any of the boar breed types.

There is ambiguity in the literature regarding the threshold level of intramuscular fat required to improve meat quality. Bejerholm and Barton-gade (1986) reported that 2% intramuscular fat was the minimum level required for satisfactory meat quality. However, De Vol *et al.* (1988) reported the threshold was between 2.5 and 3% and Wood (1993) hypothesized that intramuscular fat levels of 1% and greater were adequate. The levels of intramuscular fat observed in the present study fall within these reported values and it is therefore concluded that intramuscular fat proportion in the progeny of all boar breed types was adequate for satisfactory meat quality in terms of juiciness.

Jeremiah and Weiss (1984) stated that measurement of pH 24 h after slaughter can predict the incidence of DFD (dark, firm and dry) pork with values of 5.9 and above classed as DFD. In the present study the mean pH_u at 24 h post mortem was below this value in all cases; therefore, the significant differences between the boar breed types are of little practical significance.

Relationship between carcass and meat quality parameters

Examination of the correlation matrix presented in Table 4 revealed some interesting points. For example, there was a lack of relationship between P_2 values and eye muscle area or depth (r = –0.03 and –0.01, respectively). Demo (1994) also reported poor relationships between P_2 and eye muscle area (r = 0.09). Similarly, Walker (2002) observed a poor relationship between P_2 and eye muscle area (r = –0.01). These findings highlight the fact that although breeders have concentrated on lowering backfat depth there is no indication that other traits have been improved. Currently the market requires low backfat, minimal inter-muscular fat and a large eye muscle area. If these objectives are to be met it is essential that selective breeding schemes take all these factors into account. Grading on fat depth alone erroneously discriminates against 'blocky', meat-type pigs. Measurements such as eye muscle depth could be included in carcass grading, since eye muscle depth and P_2 can be simultaneously determined by use of a Hennesy probe, to provide an incentive for producers to improve carcass quality.

The CIELAB variables L^*, b^* and chroma were negatively correlated with pH, which is in keeping with Garrido *et al.* (1994) and Hermesch, Luxford and Graser (2000). The negative relationship between pH and drip loss is also in agreement with Hermesch *et al.* (2000). Intramuscular fat was correlated with percentage drip loss but not with shear force. This is in line with Eikelenboom, Hoving-Bolink and Van Der Wal (1996) who reported a poor relationship between shear force and intramuscular fat (r = 0.01) which is in contrast to the theory that increased intramuscular fat content in meat leads to a lower shear force and an increase in tenderness (Blanchard *et al.*, 1999).

The correlations between carcass and meat quality measurements were weak. Demo, Letkovicova and Hetenyi (1993) reported a high negative correlation between eye muscle area and colour (r = –0.82) but no such relationship was found in this study (r = 0.07). However, the lack of relationship between P_2 values and meat quality is in keeping with the work of Hermesch *et al.* (2000).

Shear force values depend on a complex interaction of factors and an interaction between amount of connective tissue in the muscle and the breakdown of muscle protein. The latter is influenced by the temperature and pH profile post mortem, which also have an influence on the occurrence of pale, soft, exudative pork, water-holding capacity and cooking loss. Thus, as in the present study, where several of these factors may be influenced by genetic factors, poor correlations between any one carcass trait and meat quality are to be expected and are in keeping with those reported by Ellis *et al*. (1996).

Relationship between production performance and carcass and meat quality traits

There was a lack of any consistent relationship between performance and carcass quality traits. However, some of the significant, although weak, relationships are in keeping with those reported in the literature. For example, the positive relationship between daily feed intake and backfat (P_2) is in line with the conclusion reached by Affentranger *et al*. (1996). These workers investigated the performance of three crossbred genotypes and found that Duroc × Landrace and Large White × Landrace pigs had higher daily feed intakes and greater subcutaneous fat depth at slaughter. Hermesch *et al.* (2000) also reported a positive relationship (r = 0.53) between feed intake and backfat in a large study involving 3321 boars.

There is evidence to suggest that average daily gain is related to meat quality; faster growing animals produce more tender meat which is a result of a more rapid and extensive proteolysis of muscle post mortem (Whipple *et al*., 1990). Ellis *et al.* (1996) examined the performance of pigs housed under *ad libitum* or restricted feeding regimes and found that pigs offered feed *ad libitum* had higher daily live-weight gain and produced more tender meat. However, no such relationship was observed in the present study and there was no correlation between ADG and meat quality. Findings of the present study are in line with Casteels *et al*. (1995) and Hermesch *et al.* (2000). Casteels *et al*. (1995), who investigated the relationship between carcass, meat and eating quality traits of three pig genotypes, reported that there was a lack of relationship between ADG and pH, L^* and a^*. Hermesch *et al.* (2000) concluded that there were no clear genetic relationships between growth rate and meat quality but did find a negative relationship with intramuscular fat (r = –0.21) which suggested that rapid growth rate may reduce eating quality. The relationships between feed intake and meat quality in the present study are in line with those reported by De Vries *et al*. (1994), where a negative relationship was observed between feed intake and water holding capacity and darkness.

Conclusions

There are no consistent differences in reproduction, production, carcass or meat quality characteristics between the main boar breed types commonly used in Northern Ireland. Consequently, genetic selection should be focused on identifying the best available boars within each boar breed type. Backfat depth at the P_2 position was poorly related to eye muscle area indicating that P_2 may not be the most suitable method of grading. Furthermore, the correlations between carcass and meat quality variables were weak, suggesting that meat quality could not be improved by selecting on carcass measurements. The results also indicated a lack of consistent relationships between performance and carcass quality traits. Given the selection pressures which have resulted in lean, fast-growing pigs and the fact that there are conflicting reports on relationships with meat quality, it is vital that meat quality measurements be included in selection indices for pigs.

Acknowledgements

The authors gratefully acknowledge joint funding for this research from the Pig Production Development Committee in conjunction with the Ulster Farmers' Union Pigs Committee and the Department of Agriculture and Rural Development for Northern Ireland. The authors would also like to acknowledge the help of Dr. M. Burrows, Dr. N. Weatherup and the staff of the Pig Unit at the Agri-Food and Biosciences Institute, Hillsborough.

References

Affentranger, P., Gerwig, C., Seewer, G.J.F., Schwörer, D. and Künzi, N. 1996. Growth and carcass characteristics as well as meat and fat quality of three types of pigs under different feeding regimens. *Livestock Production Science* **45:** 187–196.

Beattie, V.E., Weatherup, R.N., Moss, B.W. and Walker, N. 1999. The effect of increasing carcass weight of finishing boars and gilts on joint composition and meat quality. *Meat Science* **52:** 205–211.

Bejerholm, C. and Barton-gade, P.A. 1986. Effect of intramuscular level on eating quality of pig meat. *Proceedings of 32nd Meeting of European Meat Research Workers*, *Gent, Belgium*, 389–391.

Blanchard, P.J., Warkup, C.C., Ellis, M., Willis, M.B. and Avery, P. 1999. The influence of the proportion of Duroc genes on growth, carcass and pork eating quality characteristics. *Animal Science* **68:** 595–501.

Buchanan, D.S. and Johnson, R.K. 1984. Reproductive performance for four breeds of swine: crossbred females and purebred and crossbreed boars. *Animal Science* **59:** 948.

Cameron, N.D., Warriss, P.D., Porter, S.J. and Easer, M.B. 1990. Comparison of Duroc and British Landrace pigs for meat and eating quality. *Meat Science* **27:** 227–247.

Candek-Potokar, M., Zlender, B., Lefaucheur, L. and Bonneau, M. 1998. Effects of age and/or weight at slaughter on *longissimus dorsi* muscle: biochemical traits and sensory quality in pigs. *Meat Science* **48:** 287–300.

Casteels, M., Van Oeckel, M.J., Boschaerts, L., Spincemaille, G. and Boucque, V.C. 1995. The relationship between carcass, meat and eating quality of three pig genotypes. *Meat Science* **40:** 253–269.

De Vol, D.L., McKeith, F.K., Bechtel, P.J., Novakovski, J., Shanks, R.D. and Carr, T.R. 1988. Variations in composition and palatability traits and relationship between muscle characteristics and palatability in a random sample of pork carcasses. *Journal of Animal Science* **66:** 385–395.

De Vries, A.D., Van Der Wal, P.G., Long, T., Eikelenboom, G. and Merks, J.W.M. 1994. Genetic parameters of pork quality and production traits in Yorkshire populations. *Livestock Production Science* **40:** 277–289.

Demo, P., Letkovicova, A.M. and Hetenyi, L. 1993. Analyses of relationships between the parameters of fattening performance, carcass value and meat quality in hybrid pigs. *Zivocisna Vyroba* **38:** 21–30.

Demo, P. 1994. Evaluation of pig carcasses according to percentage of valuable lean cuts by means of regression equations. *Zivocisna Vyroba* **39:** 629–642.

Edwards, S.A., Wood, J.D., Moncrieff, C.B. and Porter, S.J. 1992. Comparison of the Duroc and Large White as terminal sire breeds and their effect on pig meat quality. *Animal Production* **54:** 289–297.

Eikelenboom, G., Hoving-Bolink, A.H. and Van Der Wal, P.G. 1996. The eating quality of pork. 2. The influence of intramuscular fat. *Fleishwirtschaft* **76:** 517–518.

Ellis, M., Webb, A.J., Avery, P.J. and Brown, I. 1996. The influence of terminal sire genotype, sex, slaughter weight, feeding regime and slaughter-house on growth performance and carcass and meat quality in pigs and on the organoleptic properties of fresh pork. *Animal Science* **62:** 521–530.

Garrido, M.D., Pedauye, J., Banon, S. and Laencina, J. 1994. Objective assessment of pork quality. *Meat Science* **37:** 411–420.

Hermesch, S., Luxford, B.G. and Graser, H.-U. 2000. Genetic parameters for lean meat yield, meat quality, reproduction and feed efficiency traits for Australian pigs 2. Genetic relationships between production, carcase and meat quality traits. *Livestock Production Science* **65:** 249–259.

Irgang, R., Scheid, I.R., Favero, J.A. and Wentz, I. 1992. Daily gain and age and weight at puberty in purebred and crossbred Duroc, Landrace and Large White gilts. *Livestock Production Science* **32:** 31–40.

Jeremiah, L.E. and Weiss, G.M. 1984. The effects of slaughter weight and sex on the cooking losses from and palatability of pork loin chops. *Canadian Journal of Animal Science* **64:** 39–43.

Kempster, A.J., Dilworth, A.W., Evans, D.G. and Fisher, K.O. 1986. The effects of fat thickness and sex on pig meat quality with special reference to the problems associated with overleanness. 1. Butcher and Consumer panel results. *Animal Production* **43:** 517–533.

Kennedy, B.W. and Conlon, P.D. 1978. Comparison of crossbred and purebred boars for progeny growth and carcass merit. *Animal Production* **27:** 29–34.

Lishman, W.B., Smith, W.C., Bichard, M. and Thompson, R. 1975. The comparative performance of purebred and crossbred boars in commercial pig production. *Animal Production* **21:** 69.

McLaren, D.G., Buchanan, D.S. and Johnson, R.K. 1987. Growth performance for four breeds of swine: crossbred females and purebred and crossbred boars. *Journal of Animal Science* **64:** 99–108.

P.I.G. 2000. *Production sheets from the Northern Ireland Pig Testing Station*. Pig Industry Genetics Co. Ltd, 4 pages.

Rauw, W.M., Kanis, E., Noordhuizen-Stassen, E.N. and Grommers, F.J. 1998. Undesirable side effects of selection for high production efficiency in farm animals: review. *Livestock Production Science* **56:** 15–33.

Rempel, W.E., Cornstock, R.E. and Enfield, F.D. 1964. Comparison of performance of crossbred pigs sired by purebred and crossbred boars. *Journal of Animal Science* **23:** 87–89.

Simpson, S.P., Webb, A.J. and Dick, S. 1987. Evaluation of Large White and Duroc boars as terminal sires under two different feeding regimes. *Animal Production* **45:** 111–116.

Smith, W.C., Pearson, G. and Purchas, R.W. 1990. A comparison of the Duroc, Hampshire, Landrace and Large White as terminal sire breeds as crossbred pigs slaughtered at 85 kg live weight. *New Zealand Journal of Agricultural Research* **33:** 89–96.

Walker, N. 2002. *Carcass quality of Northern Ireland pigs compared with those originating in the Republic of Ireland and Great Britain.* A report commissioned by the Department of Agriculture and Rural Development for Northern Ireland, February 2002, pages 59–87.

Whipple, G., Koohmaraie, M., Dikeman, M.E., Crouse, J.D., Hunt, M.C. and Klemm, R.D. 1990. Evaluation of attributes that affect *longissimus* muscle tenderness in Bos taurus and Bos indicus cattle. *Journal of Animal Science* **68:** 2716–2728.

Whittemore, C. 1993. *The Science and Practice of Pig Production*. Longman Group UK Limited, Harlow, Essex, pages 184–188.

Wood, J.D. 1993. Consequences of changes in carcass composition on meat quality. In: "Recent Developments in Pig Nutrition *2"*. (Eds. D.J.A. Cole, W. Haresign and P.C. Garnsworthy), pp. 20–29. Nottingham University Press, Nottingham, UK, pages 20–29.

Young, L.D. 1998. Reproduction of ¾ White Composite and ¼ Duroc, ¼ Meishan, ¼ Fengjing or ¼ Minzhu gilts and sows. *Journal of Animal Science* **76:** 1559–1567.

Received 21 March 2008