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The effects of sire type on reproduction, production performance and carcass quality of pigs

Report prepared for: UFU and PPDC Committees

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TABLE OF CONTENTS

			Page
1.	Executive Summary		1
2.	Introduction		2
	2.1	Reproductive performance	2
	2.2	Production performance	3
	2.3	Carcass quality	3
	2.4	Meat quality	4
	2.5	Objective of study	4
3.	Materials and methods		4
	3.1	Reproductive performance	5
	3.2	Production performance	5
	3.3	Carcass quality	5
	3.4	Meat quality	9
4.	Statistical Analysis		9
5.	Results		10
	5.1	Reproductive performance	10
	5.2	Production performance	10
	5.3	Carcass quality	12
	5.4	Meat quality	16
	5.5	Relationship between carcass quality parameters	19
	5.6	Relationship between meat quality parameters	19
	5.7	Relationship between carcass and meat quality parameters	19
	5.8	Relationship between production performance and carcass quality	22
	5.9	Relationship between production performance and meat quality	22
	5.10	The effect of dam on the production performance of progeny	23
6.	Discussion		29
	6.1	Reproductive performance	29
	6.2	Production performance	29
	6.3	Carcass quality	29
	6.4	Meat quality	30
	6.5	Relationship between carcass and meat quality parameters	31
	6.6	Relationship between production performance and carcass and meat quality parameters	32
	6.7	The effect of dam on production performance of progeny	32
7.	Conclusions		33
8.	References		34
	Appendices		37

INDEX OF TABLES

		Page
1.	Heritability estimates for pigs	2
2.	Genetic correlation between production and reproduction traits	3
3.	Sire types used in the evaluation study	5
4.	Number of progeny from each sire type selected for detailed carcass evaluation	6
5.	Carcass characteristics measured to evaluate carcass quality	6

6.	Number of progeny from each sire type selected for detailed meat quality evaluation	9
7.	Number of progeny from each sire type selected for intramuscular fat analysis	9
8.	Reproductive performance of purebred and crossbred boars	10
9.	Reproductive performance of boars from eight different sire types	11
10.	Comparison of production performance of progeny from purebred and crossbred sires in group housing	10
11.	Comparison of production performance of progeny from different sire types in group housing	11
12.	Variation in production performance of pigs from weaning to slaughter	12
13.	Comparison of carcass characteristics of progeny from purebred and crossbred sires	12
14.	Comparison of carcass characteristics of progeny from different sire types	13
15.	Comparison between top 10% of progeny and bottom 10% of progeny for various carcass characteristics	14
16.	Comparison of meat quality characteristics of progeny from purebred and crossbred sires	17
17.	Comparison of carcass characteristics of progeny from different sire types	18
18.	Comparison between the top 10% of progeny and bottom 10% of progeny for meat quality characteristics	17
19.	Correlation between carcass quality evaluation parameters	20
20.	Correlation between meat quality evaluation parameters	20
21.	Correlation between carcass and meat quality evaluation parameters	21
22.	Correlation between production performance (11 weeks – finish) and carcass quality	22
23.	Correlation between production performance (11 weeks – finish) and meat quality	23
24.	Variation in daily liveweight gain, P_2 and KO% in progeny from 3 sows served with the same sire	24

INDEX OF FIGURES

		Page
1.	Typical Chop	7
2.	Total Chop Area	7
3.	Eye Muscle Area	7
4.	Tail Area	7
5.	% Fat in Chop	7
6.	% Fat in Tail	7
7.	Eye Muscle Depth, P_2 and V Measurement	8
8.	Cross Section at Last Rib	8
9.	Variation in fat content	15
10.	Variation in eye muscle area	16
11.	Variation in ADG (weaning to slaughter) within and between progeny of 3 sows sired by the top sire in each sire type	25-28

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1. EXECUTIVE SUMMARY

The work presented in this report summarises the results of an investigation on the effects of sire type on reproduction, production, carcass and meat quality. This study was jointly funded by the Pig Production Development Committee (PPDC) and the Department of Agriculture and Rural Development for Northern Ireland (DARD), and undertaken by staff at the Agricultural Research Institute of Northern Ireland. The aim of this work was to evaluate different sire types available in Northern Ireland.

To ensure the results were representative of genetics across Northern Ireland, three main semen suppliers were used: Elite sires; Deerpark Pedigree Pigs; and Hermitage AI. As the objective of the study was to evaluate the effects of sire type, not breeder, all data were pooled across companies. A total of 720 dams (21% first cross Landrace x Large White, 67% ¾ Landrace and 12% pure Landrace) were inseminated during the experimental period, November 1998 to July 2000.

Eight sire types were evaluated; 3 purebred and 5 crossbred. There were no effects of purebred versus crossbred sire on reproductive performance or on production performance of progeny. The only carcass evaluation parameter affected was V measurement (backfat thickness at the edge on the eye muscle) which was 2 mm thicker for the progeny of crossbred sires. Meat from pigs of purebred sires contained a higher level of intramuscular fat than that from crossbred sires (2.65 vs. 2.11% respectively).

There were inconsistent effects of individual sire type on performance, carcass quality and meat quality. The main finding arising from this work is that the variation between sires within a sire type is greater than the variation between sire types. For example, there was a variation of greater than 25% for production performance between the top 15% and bottom 15% of pigs. There were also wide variations in carcass and meat quality parameters e.g. % fat in the tail ranged from 25.7 to 69.1% for the top and bottom 10% of pigs respectively.

The results also demonstrate a lack of relationship between P_2 values and eye muscle area and depth (r=-0.03 and -0.01 respectively) which suggests that carcass characteristics other than P_2 values need to be included in the selection of breeding animals. Similarly, the weak correlations between carcass and meat quality parameters (r<0.3) indicate that if meat quality is to be improved, it must be specifically included in the selection process.

Finally, although the study was designed to examine the effect of sire type there is evidence to suggest that the sow may also contribute to the variation observed in performance within this study. The challenge in pig production is to reduce this variation by the identification and selection of individual sires and sows in order to attain optimum performance and high carcass and meat quality.

2. 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. There are two ways of achieving this improvement in the genetic make-up of the pig; within breed selection for a given character (or characters), and the incorporation of new genes from pigs of different breeds. During the last 30 years a large number of genetic studies have been carried out to improve the traits which determine performance and carcass parameters in pig production. Selection has primarily focused on traits such as a superior growth rate, low feed conversion, high killing out % (KO%) and minimum backfat thickness.

Meat quality is assessed by a number of parameters which include: intramuscular fat (IMF), drip loss, water holding capacity (WHC), tenderness (shear force) and pH measurements of semi-membranous muscle. Fortunately many of these traits are heritable and the generation interval for pigs is short enough to allow rapid improvement in pigs (Rauw *et al*., 1998). Table 1 shows the heritability (h_2) values for some important traits. However, within NI there is at present no system for selecting on the basis of meat quality parameters. Therefore, any change in meat quality has been the result of correlation of the selection indices used in NI (i.e. P_2, growth rate and FCR).

Table 1 Heritability estimates for pigs (Whittemore, 1993)

Characteristic	h_2*
Numbers born	0.10 – 0.20
Survivability of the young	0.05 – 0.10
Daily liveweight gain	0.30 – 0.60
Appetite	0.30 – 0.60
Backfat depth	0.40 – 0.60
Eye muscle area	0.40 – 0.60
Ham shape	0.40 – 0.60
Meat quality	0.30 – 0.50

* Heritability ranges from 0.0 to 1.0. The better the heritability the higher the value.

2.1 Reproductive performance

A number of studies have demonstrated an inverse relationship between production traits and reproductive characteristics, therefore selection to improve production parameters will have detrimental effects on reproductive performance. Hutchen *et al*. (1981) reported that gilts with a higher percentage lean had genetically delayed onset of puberty, showed shorter pro-oestrus and had less intense and shorter reddening and swelling of the vulva at puberty. The correlation between average daily gain (ADG), percentage lean, backfat and reproductive traits are shown in Table 2. Pigs with good growth rates have poor standing reflex, have short standing oestrus, are later to reach puberty and are older at first parturition (Rauw *et al*., 1998). These findings support the work of Ten Napel and Johnson (1997) who reported a prolonged interval between weaning and farrowing for Large White pigs with a high ADG and low backfat. However, Kerr and Cameron (1995) observed that selection for lean growth did not significantly affect reproductive performance.

Terminal sire line has been shown to affect the reproductive traits of progeny. Edwards *et al*. (1992) compared the progeny from Large White and Duroc terminal sires and reported that Duroc sired litters were larger at birth (+0.9 pigs) and at weaning (+0.4 pigs). However, this corresponded to 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). These workers compared daily gain, age and weight at puberty in purebred and crossbred Duroc, Landrace and Large White gilts and reported that neither growth rate or sexual maturity were significantly affected by breed type.

Table 2 Genetic correlation between production and reproduction traits (Rauw *et al*., 1998)

Trait	**Average daily gain**	**% Lean**	**Backfat**
Intensity of vulvar symptoms	0.19	0.17	-
Duration pro-oestrus (d)	0.03	0.09	-
Standing reflex	-0.61	0.10	-
Duration standing oestrus (d)	-0.49	0.02	-
Age at puberty (d)	-0.38	0.20	0.27
Age at farrowing	-0.61	-	0.16
Piglet weight	0.50	0.14	0.19

2.2 Production performance

Numerous studies have examined the effect of sire type on the production performance of pigs with contrasting results being obtained. For example, McLaren *et al*. (1987) studied the growth performance of pigs sired by different breeds: Duroc, Large White, Duroc x Large White, Landrace and Spotted (Gloucester) and reported that the Duroc sired pigs were more efficient ($P<0.01$) than those from other sires (3% improvement in FCR). These workers also reported that Duroc sired pigs had lower backfat levels than other sire groups. Several research reports (e.g. McGloughlin *et al*., 1988; Smith *et al*., 1990; Edwards *et al*., 1992) have supported this finding. In contrast, Blanchard *et al*. (1999) compared graded levels of Duroc (0, 0.25 and 0.5) with Landrace/Large White crosses, and noted that intake decreased and percentage lean decreased for Duroc sired progeny. In addition, a recent study (Armero *et al*., 1999) reported no significant difference in killing out percentage (KO%) between Duroc, Dutch Large White, English Large White and Belgian Landrace sired pigs.

The incorporation of Pietrain genes to improve performance has been investigated. Whittemore (1993) reported that Pietrain pig types show benefits over White types of up to 4% more lean and 3% better KO%. However, Pietrain pig types also have negative characteristics associated with the halothane gene, e.g. slower growth rates and a higher susceptibility to stress (Porcine Stress Syndrome, PSS).

2.3 Carcass quality

One of the main objectives of pig breeding programmes has been to increase the lean to fat ratio of pig carcasses. 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 has increased from 61.5 to 67.6 over the same period and feed conversion ratio (FCR) has fallen from 3.0 to 2.27 (P.I.G. 2000). Another important carcass trait altered via selective breeding is the size of the loin or eye muscle area (*longissimus dorsi*). A large eye muscle is not a notable feature of the Duroc sire type in comparison with Large White and Landrace sire types (Smith *et al*., 1990). Pietrain pigs have a large eye muscle but are associated with poorer performance and are subject to 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 but lean percentage was lower.

2.4 Meat quality

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 x Landrace crosses and obtained similar results. It was also reported that intramuscular fat increased with increasing levels of Duroc (10.4, 11.2 and 18.2 g/kg) for 0, 0.25 and 0.50 incorporation of Duroc genes respectively. Duroc meat was also reported to have a lower shear force, stronger pork odour, more tender and overall be more acceptable than Large White x Landrace meat.

2.5 Objective of study

The challenge in pig production is to produce a pig which achieves optimum performance while maintaining reproductive viability and optimum carcass and meat quality. As discussed above, genetic selection can help to achieve this, however all the research reviewed has been based on a genetic pool based in GB, USA or Canada. There is limited research evaluating the effects of sire breeds available to the NI producer. Consequently the primary objective of this study was to examine the different sire types available within NI and to establish possible effects on reproduction, production performance, and carcass and meat quality.

3. MATERIAL AND METHODS

Three main semen suppliers were used – Deerpark Pedigree Pigs, Elite Sires and Hermitage AI in order to ensure that results obtained were representative of genetics across NI. At the beginning of the experiment, in 1998, these companies were chosen on the basis that each company had each of the eight sire types to be evaluated. The sire types which were evaluated are listed in Table 3.

Table 3 Sire types used in the evaluation study

Sire type	No of sires
Landrace (LR)	9
Large White (LW)	11
Duroc (Dr)	8
Landrace x Large White (LR x LW)	8
Landrace x Duroc (LR x Dr)	8
Large White x Duroc (LW x Dr)	5
Landrace x Large White x Duroc (LR x LW x Dr)	8
Landrace x Large White x Pietrain (LR x LW x P)	7

A list of all available sires, within each sire type, was obtained from the companies and individual sires were selected from the lists at random. The study ran continuously over a 3-year period. As the objective of the experiment was to evaluate the effects of sire type, not breeders, all data were pooled across breeders. A total of 720 (21% first cross Landrace x Large White, 67% ¾ Landrace and 12% pure Landrace) sows were inseminated during the experimental period.

Each supplier was allocated to a service week and each week a batch of 20 sows was mated with eight sire types from one supplier so that at least two sows were mated to an individual boar from each sire type on every service week. Due to the batch farrowing system in operation at the Agricultural Research Institute of Northern Ireland (ARINI) sows were inseminated every 3 weeks, thus semen from the individual companies was used in a pre-determined cycle which was repeated every 27 weeks (or 9 batches).

3.1 Reproductive performance

The 720 sows used were inseminated as described above with semen from boars from the eight different sire types. Reproductive performance was assessed using the following parameters: number born alive; number stillborn; birth weight; pre-weaning mortality and weaning weight.

3.2 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 treatments. Eight groups of 10 pigs from each of the eight sire types were housed in combined stage 1/stage 2 accommodation. Pigs were weighed at weaning and at 10 weeks of age on transfer to finishing accommodation, where they remained in their groups. Feed intake, ADG and FCR were recorded for the 6-week period in a stage1/stage 2 combined house 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.

3.3 Carcass quality

Pigs were selected for slaughter at 90 kg live weight (approximately 20 weeks of age) to provide a representative sample for carcass evaluation between progeny of each of the eight sire types. A total of 362 pigs were used to determine the effects of sire type on selected carcass parameters. A summary giving details of the progeny from each sire type used for carcass evaluation is presented in Table 4.

Table 4 Number of progeny from each sire type selected for detailed carcass evaluation

Sire type	No of progeny
Landrace (LR)	39
Large White (LW)	55
Duroc (Dr)	39
Landrace x Large White (LR x LW)	52
Landrace x Duroc (LR x Dr)	42
Large White x Duroc (LW x Dr)	45
Landrace x Large White x Duroc (LR x LW x Dr)	43
Landrace x Large White x Pietrain (LR x LW x P)	47

Table 5 lists the various characteristics measured after slaughter and refers to the appropriate descriptive figure. One chop (100 mm width) was removed at the site of the last rib from the cross section of the loin collected at the factory. A digital image of each chop was captured using a digital camera. This image was downloaded on to a computer and total chop area (Figure 2), eye muscle area (Figure 3), tail area (Figure 4), % fat in chop (Figure 5), % fat in tail (Figure 6), V measurement, eye muscle depth and $P_{2\ ARINI}$ (Figure 7) were calculated using Image Analysis Software (PC image – Foster Associates Ltd).

Table 5 Carcass characteristics measured to evaluate carcass quality

Characteristic	Description
Total chop area	Figure 2
Eye muscle area	Figure 3
Tail area	Figure 4
% fat in chop	Figure 5
% fat in tail	Figure 6
V measurement	Figure 7
Eye muscle depth	Figure 7
$P_{2\ ARINI}$	Figure 7
$P_{2\ FACTORY}$*	Figure 8
Kill out %**	

* Measured by factory using an optical probe (intrascope) at a point P_2 6.5 cm from edge of split side

** Measured by factory using the following equation:
KO% = (Cold weight/final weight) x 100

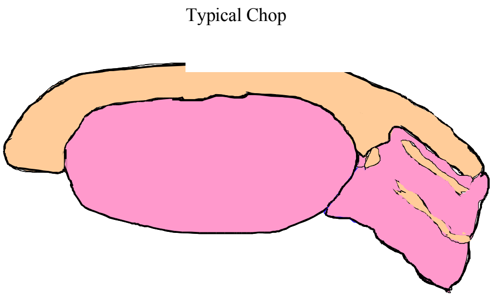


Figure 1 Typical Chop

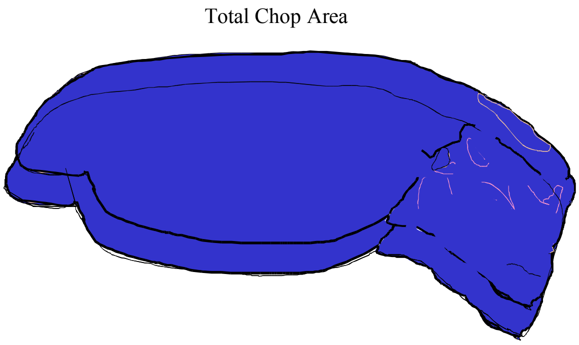


Figure 2 Total Chop area

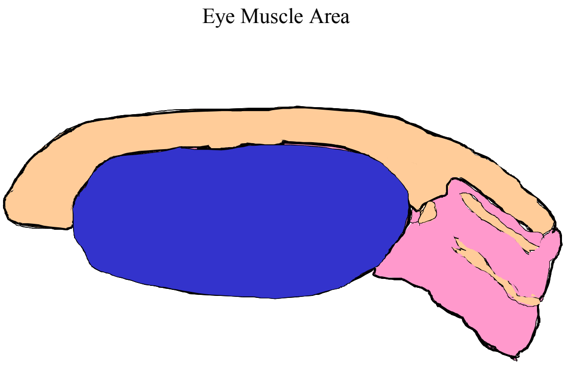


Figure 3 Eye Muscle Area

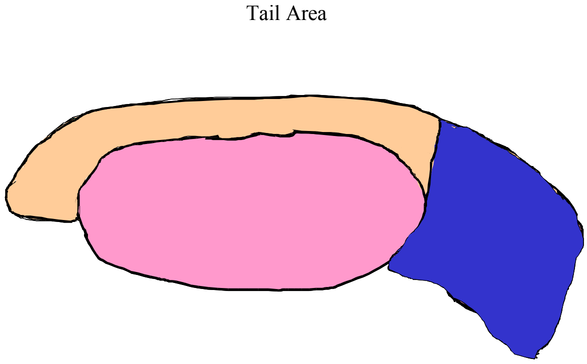


Figure 4 Tail Area

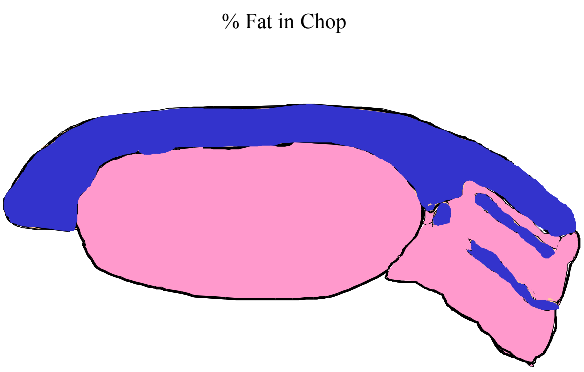


Figure 5 % Fat in Chop

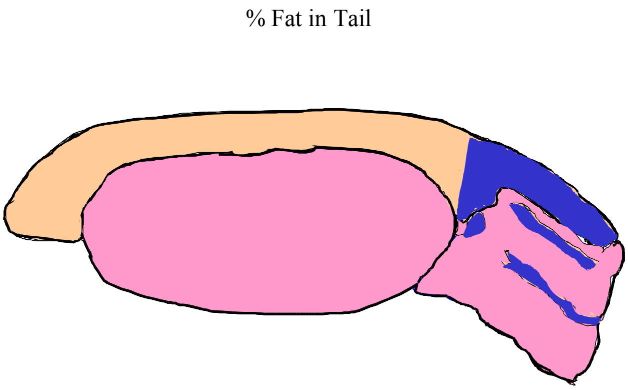


Figure 6 % Fat in Tail

Carcass characteristics measured are labeled dark grey in each diagram

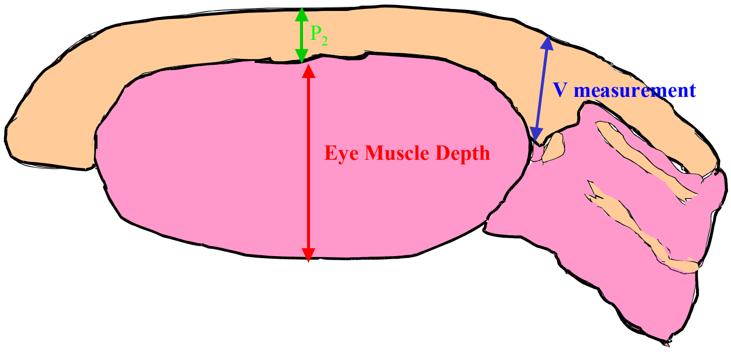


Figure 7 Eye Muscle Depth, P_2 and V Measurement

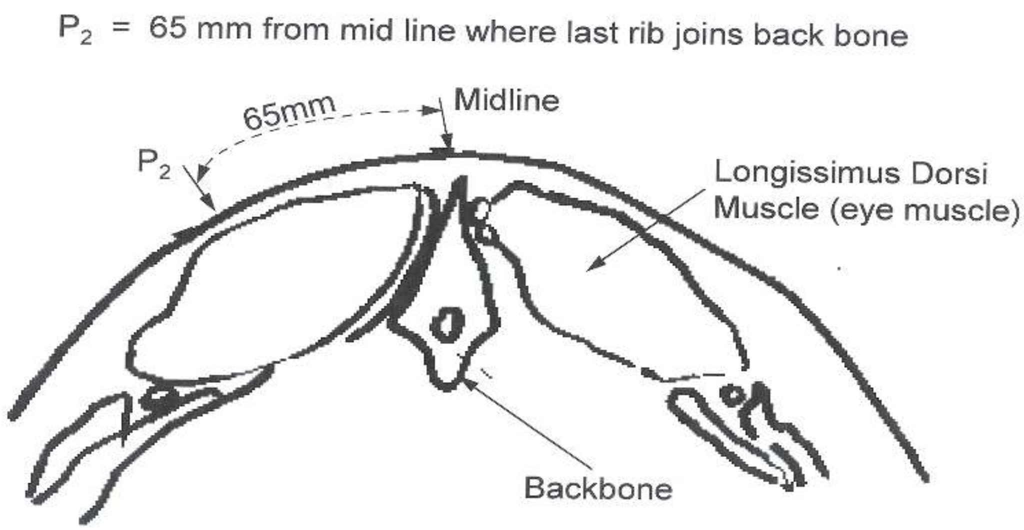


Figure 8 Cross Section at Last Rib

3.4 Meat quality

At transfer to the finishing accommodation, a boar and a gilt from each sow mated to each boar type were chosen for meat quality analysis (Table 6).

Table 6 Number of progeny from each sire type selected for detailed meat quality evaluation

Sire type	No of progeny
Landrace (LR)	30
Large White (LW)	57
Duroc (Dr)	36
Landrace x Large White (LR x LW)	52
Landrace x Duroc (LR x Dr)	44
Large White x Duroc (LW x Dr)	35
Landrace x Large White x Duroc (LR x LW x Dr)	38
Landrace x Large White x Pietrain (LR x LW x P)	53

Pigs were chosen close to average weight for the whole group and in good health. It is well known that meat quality data are dependent on slaughter date due to specific conditions at the factory on that date. Therefore, sample pigs from any given batch were slaughtered on the same day regardless of weight. Any differences in live weight at slaughter were accounted for by covariate analysis. Meat quality parameters measured were colour X, Y and Z – these were later converted to CIELB colour values for *L*, a*, b** chroma and hue; ultimate pH, Warner Bratzler shear force, cook loss and drip loss. Due to less variation in the parameter intramuscular fat it was not necessary to use all of the progeny selected above (Table 6). Hence, a representative sample of the progeny of the different sire types was taken at slaughter (Table 7).

Table 7 Number of progeny from each sire type selected for intramuscular fat analysis

Sire type	No of progeny
Landrace (LR)	15
Large White (LW)	25
Duroc (Dr)	10
Landrace x Large White (LR x LW)	13
Landrace x Duroc (LR x Dr)	17
Large White x Duroc (LW x Dr)	14
Landrace x Large White x Duroc (LR x LW x Dr)	13
Landrace x Large White x Pietrain (LR x LW x P)	30

4. STATISTICAL ANALYSIS

Analysis of variance (ANOVA) was used to compare the effects of sire type across the parameters measured.

Simple regression equations were applied to establish the relationships between parameters.

5. RESULTS

5.1 Reproductive performance

None of the measured reproductive characteristics were affected by whether the sire was purebred or crossbred (Table 8).

Table 8 Reproductive performance of purebred and crossbred boars

	Purebred	Crossbred	s.e.m.	P
No. born alive	11.0	10.6	0.18	NS
No. stillborn	0.9	0.9	0.09	NS
Birthweight (kg)	1.7	1.7	0.02	NS
% pre-weaning mortality	9.9	9.6	0.71	NS
Weaning weight (kg)	9.3	9.2	0.08	NS

When individual sire types were compared, sows mated with Duroc and Large White x Duroc boars had greater numbers of pigs born alive than the other sire types (Table 9).

5.2 Production performance

No difference in production performance was found between purebred and crossbred sires (Table 10). However, when individual sire types were examined, the progeny of the two Duroc crosses, (Landrace x Duroc and Large White x Duroc) and Large White sires had high feed intakes up to 10 weeks of age but this was not maintained during the finishing period (Table 11). However, FCR for Duroc (2.77) and Landrace x Large White x Pietrain (2.78) sired pigs was higher than that obtained for Large White x Duroc (2.26) sired pigs.

Table 10 Comparison of production performance of progeny from purebred and crossbred sires in group housing

	Purebred	Crossbred	s.e.m.	P
Wean to 10 weeks				
Daily feed intake (g)	785	777	12.2	NS
Daily liveweight gain (g)	491	477	8.6	NS
FCR	1.60	1.63	0.020	NS
11 weeks to finish				
Daily feed intake (g)	2156	2107	61.5	NS
Daily liveweight gain (g)	839	853	11.6	NS
FCR	2.57	2.47	0.070	NS
Wean to finish				
Daily feed intake (g)	1706	1672	42.0	NS
Daily liveweight gain (g)	717	721	7.4	NS
FCR	2.38	2.32	0.063	NS

Table 9 Reproductive performance of boars from eight different sire types

	LR	LW	Dr	LR x LW	LR x Dr	LW x Dr	LR x LW x Dr	LR x LW x P	s.e.m.	P
No. born alive	10.9^{ab}	10.7^{ab}	11.5^{b}	11.1^{ab}	9.8^{a}	11.4^{b}	10.4^{a}	10.2^{a}	0.38	<0.05
No. stillborn	1.2	1.0	0.6	0.9	0.9	0.6	0.8	1.3	0.17	NS
Birth weight (kg)	1.6	1.7	1.6	1.7	1.7	1.6	1.6	1.6	0.04	NS
% pre-weaning mortality	12.3	7.8	10.0	10.3	9.4	7.8	9.8	10.1	1.42	NS
Weaning weight (kg)	9.2	9.4	9.3	9.4	9.2	9.0	9.0	9.2	0.15	NS

Means with the same superscript are not significantly different

Table 11 Comparison of production performance of progeny from different sire types in group housing

	LR	LW	Dr	LR x LW	LR x Dr	LW x Dr	LR x LW x Dr	LR x LW x P	s.e.m.	P
Wean 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 liveweight gain (g)	466	490	513	463	528	490	476	459	18.8	NS
FCR	1.57	1.65	1.55	1.63	1.57	1.72	1.63	1.62	0.046	NS
11 weeks to finish										
Daily feed intake (g)	2022	2033	2382	2028	2345	1932	2028	2252	153.5	NS
Daily liveweight gain (g)	846	810	860	828	859	855	886	810	29.6	NS
FCR	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	NS
Daily liveweight gain (g)	714	699	739	705	744	729	738	689	18.1	NS
FCR	2.18	2.28	2.46	2.27	2.43	2.14	2.13	2.58	0.157	NS

Means with the same superscript are not significantly different

The lack of consistent response for any of the production parameters throughout the growing and finishing periods suggests that variation between sire types is limited. However, there were wide variations between pigs in performance. Over the period from weaning to slaughter the average growth rate of progeny across the eight sire types was 723 g/d. However, the best 15% of pigs had a growth rate of 811 g/d while the worst 15% of pigs had a growth rate of 601 g/d, hence the best 15% of pigs would go to slaughter at 129 days of age (105 kg) but the worst 15% would be 175 days old before reaching slaughter weight (Table 12). A similar comparison can be made for FCR. The average FCR from weaning to slaughter was 2.40, however the best 15% of pigs in terms of FCR, had a FCR of 1.98, while the worst 15% of pigs had a FCR of 2.99 (Table 12).

Table 12 Variation in production performance of pigs from weaning to slaughter

	Average	Top 15%	Bottom 15%	s.e.m.	P
Daily liveweight gain	723	811	601	9.02	<0.001
FCR	2.40	1.98	2.99	0.186	<0.001

5.3 Carcass quality

Progeny from purebred sires had a smaller measurement for V than progeny from crossbred sires (19.6 vs 21.6 mm, $P<0.05$). There were no other statistically significant differences between purebred and crossbred progeny (Table 13).

Table 13 Comparison of carcass characteristics of progeny from purebred and crossbred sires

	Purebred	Crossbred	s.e.m.	P
Eye muscle area (cm^2)	39.6	39.8	0.394	NS
Eye muscle depth (mm)	47.6	47.8	0.425	NS
% fat in chop	27.2	26.1	0.545	NS
% fat in tail	44.6	45.5	1.780	NS
V measurement (mm)	19.6	21.6	0.510	<0.05
KO%	76.1	76.7	0.223	NS
$P_{2\ FACTORY}$ (mm)	11.4	11.8	0.189	NS
$P_{2\ ARINI}$ (mm)	11.1	10.9	0.218	NS
% Lean	56.5	56.0	0.214	NS

The comparison of carcass characteristics between the progeny of individual sire types is shown in Table 14. Backfat (P_2), % fat in chop, KO% and % lean content were significantly different between the sire types. Progeny of Landrace boars had the lowest P_2 and the highest % lean content. KO% was highest for progeny of Landrace x Large White and Landrace x Large White x Pietrain and lowest for progeny of Landrace x Duroc sires. Progeny of Landrace x Large White boars contained the lowest % fat in chops (23.8%) while progeny of Large White (28.3%), Landrace x Large White x Pietrain (28.2%) and Landrace (26.9%) contained the highest.

Table 14 Comparison of carcass characteristics of progeny from different sire types

	LR	LW	Dr	LR x LW	LR x Dr	LW x Dr	LR x LW x Dr	LR x LW x P	s.e.m.	P
Eye muscle area (cm^2)	38.8	40.3	39.5	39.1	40.5	39.7	40.5	39.5	0.770	NS
Eye muscle depth (mm)	47.5	47.9	47.4	48.3	45.2	48.5	48.6	48.4	0.082	NS
% 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
% fat in tail	42.2	46.6	44.3	44.3	44.4	39.1	45.4	53.1	1.657	NS
V measurement (mm)	17.3	21.3	19.6	22.9	23.3	20.2	19.5	21.6	0.135	NS
KO%	76.4^{ab}	75.8^{ab}	76.3^{ab}	77.4^{b}	75.4^{a}	76.8^{ab}	76.0^{ab}	77.3^{b}	0.431	<0.01
$P_{2\ FACTORY}$ (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
$P_{2\ ARINI}$ (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	57.7^{c}	56.2^{ab}	56.1^{ab}	56.3^{ab}	56.0^{ab}	56.1^{ab}	56.5^{b}	55.3^{a}	0.194	<0.05

Means with the same superscripts are not significantly different

Landrace x Large White x Pietrain pigs also gave the highest value for P_2 and the lowest for % lean, whereas Duroc and Duroc cross boars produced progeny with a higher P_2 and lower % lean.

As Table 15 shows, there were wide variations between the top 10% and bottom 10% of progeny.

Table 15 Comparison between top 10% of progeny and bottom 10% of progeny for various carcass characteristics

	Mean value of top 10%	**Mean value of bottom 10%**	**s.e.m.**	**P**
Eye muscle area (cm^2)	49.1	31.1	0.58	<0.001
Eye muscle depth (mm)	56.9	37.3	0.35	<0.001
% fat in chop	13.8	38.8	0.52	<0.001
% fat in tail	25.7	69.1	1.17	<0.001
V measurement (mm)	10.4	43.6	1.07	<0.001
KO%	81.6	71.4	0.20	<0.001
$P_{2\ FACTORY}$ (mm)	7.3	17.4	0.26	<0.001
$P_{2\ ARINI}$ (mm)	6.5	17.3	0.24	<0.001
% Lean	60.4	50.4	0.23	<0.001

Figures 9 and 10 are examples of the wide variations found in eye muscle area and P_2 values across the sire types. Full records of the variation within and between the sire types, for all of the carcass parameters measured are recorded in Appendix I (Tables 1.1 – 1.9).

P_2 (mm)	6
V (mm)	12.8
Eye muscle area (cm^2)	30.8
% Fat in tail	25.5

Low fat content

P_2 (mm)	21
V (mm)	31.9
Eye muscle area (cm^2)	32.8
% Fat in tail	62.8

High fat content

Figure 9 Variation in fat content

P_2 (mm)	10
V (mm)	4.8
Eye muscle area (cm^2)	44.3
% Fat in tail	28.6

Large eye muscle

P_2 (mm)	11
V (mm)	34.6
Eye muscle area (cm^2)	29.8
% Fat in tail	28.9

Small eye muscle

Figure 10 Variation in eye muscle area (cm^2) and V measurement

5.4 Meat quality

The progeny from purebred terminal sires contained 17% higher levels of intramuscular fat. There were no differences in any of the other parameters measured (Table 16).

Table 16 Comparison of meat quality characteristics of progeny from purebred and crossbred sires

	Purebred	**Crossbred**	**s.e.m.**	**P**
*L** (Lightness)	54.74	54.83	0.351	NS
*a** (Redness)	4.39	4.39	0.553	NS
*b** (Yellowness)	8.87	8.77	0.696	NS
Chroma	9.99	9.90	0.182	NS
Hue	64.52	64.70	0.634	NS
E	55.68	55.76	0.359	NS
pH_u [#]	5.52	5.54	0.012	NS
Shear force (kg/cm^2)	2.89	2.88	0.046	NS
% Cooking loss	24.0	24.2	0.258	NS
% Drip loss	6.11	5.71	0.174	NS
% Intramuscular fat	2.65	2.11	0.125	<0.05

[#] pH_u – pH measurement 24 hours after slaughter (ultimate pH)

Table 17 shows the differences in meat quality between the different sire types. There were significant differences in cooking loss and pH between the sire types. Duroc sired meat had the lowest pH (5.48), while Landrace, Landrace x Large White x Pietrain and Landrace x Large White x Duroc sired pigs had the highest pH (5.57, 5.58 and 5.56 respectively). This corresponds with cooking loss, as the meat of Landrace progeny had the lowest value for % cooking loss (22.8%).

As was the case for carcass characteristics, there were wide variations between the top 10% and bottom 10% of progeny for meat quality (Table 18). Appendix II shows the complete variation between the sire types for the meat quality parameters (Tables 2.1 – 2.10).

Table 18 Comparison between the top 10% of progeny and bottom 10% of progeny for meat quality characteristics

	Mean value of top 10%	**Mean value of bottom 10%**	**s.e.m.**	**P**
*L** (Lightness)	46.43	62.83	0.400	<0.001
*a** (Redness)	8.22	1.18	0.116	<0.001
*b** (Yellowness)	11.94	5.41	0.118	<0.001
Chroma	14.24	5.94	0.141	<0.001
Hue	51.45	80.37	0.797	<0.001
E	47.1	63.9	0.391	<0.001
pH_u	5.34	5.88	0.023	<0.001
Shear force (kg/cm^2)	1.99	4.11	0.045	<0.001
% Cooking loss	17.58	29.54	0.227	<0.001
% Drip loss	2.22	10.29	0.186	<0.001
% Intramuscular fat	4.57	1.34	0.444	<0.001

Table 17 Comparison of carcass characteristics of progeny from different sire types

	LR	LW	Dr	LR x LW	LR x Dr	LW x Dr	LR x LW x Dr	LR x W x P	s.e.m.	P
*L** (Lightness)	53.76	54.63	55.79	55.70	55.23	54.30	54.99	53.82	0.681	NS
*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	NS
Chroma	9.07	10.21	10.45	10.40	9.89	9.87	9.47	9.72	0.352	NS
Hue	67.18^{c}	63.80^{abc}	63.34^{ab}	61.75^{a}	66.67^{b}	64.73^{abc}	65.68^{bc}	65.39^{bc}	0.690	<0.05
E	54.55	55.60	56.80	56.71	56.16	55.25	55.83	54.73	0.697	NS
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 (kg/cm^2)	2.84	2.98	2.80	2.94	2.83	2.96	2.89	2.78	0.090	NS
% Cooking loss	22.8^{a}	24.8^{cd}	23.6^{abc}	23.4^{ab}	23.5^{ab}	24.5^{bcd}	24.9^{cd}	25.0^{d}	0.225	<0.01
% Drip loss	5.63	6.04	6.65	5.48	5.66	5.73	5.79	5.89	0.340	NS
% Intramuscular fat	2.30	2.68	3.01	1.93	2.23	2.19	2.08	2.40	0.250	NS

Means with the same superscript are not significantly different

5.5 Relationship between carcass quality parameters

The correlations between the various carcass evaluation parameters measured in the present study are recorded in Table 19. Eye muscle area was found to be significantly positively correlated with eye muscle depth and V measurement (r = 0.27, P<0.01 and 0.20, P<0.05 respectively). The % fat in chop was significantly related to the % fat in tail, V measurement, and P_2. A strong positive correlation was determined between the % fat in tail and V measurement (r = 0.61, P<0.001). P_2 determined at the factory was significantly correlated (r = 0.58, P<0.001) with P_2 measured by Image Analysis ($P_{2\ ARINI}$). $P_{2\ FACTORY}$ and $P_{2\ ARINI}$ were negatively correlated with % lean (r = -0.91, P<0.001, -0.43, P<0.001). Although there are significant relationships between the parameters, it must be noted that the actual value for r in the majority of cases is low indicating that the relationships are not robust.

5.6 Relationship between meat quality parameters

Table 20 presents the correlation matrix for the meat quality evaluation parameters. The CIELAB parameter *L** was positively related to the parameters *a*, b** and chroma (r = 0.32, 0.54 and 0.50 respectively, P<0.001). *L** was found to be negatively related to pH_u (r = -0.25, P<0.05) as was *b** and chroma (r = -0.32 and -0.26, P<0.01). Strong correlations (P<0.001) were determined between *a** and *b**, chroma and hue (r = 0.77, 0.90, and -0.90 respectively). Percentage cooking loss and % drip loss were positively correlated (r = 0.36, P<0.001). Both of these parameters were negatively correlated (P<0.001) with pH_u (-0.35 and -0.39). Intramuscular fat was only significantly correlated with % drip loss (r = 0.24, P<0.05). Again, it is important to note that some of the correlation values are low, therefore the relationships are not particularly strong.

5.7 Relationship between carcass and meat quality parameters

There were statistically significant relationships between carcass and meat quality, however these were generally weak (Table 21). The strongest correlation (r = -0.33, P<0.001) was a negative relationship between eye muscle area and % drip loss. Percentage drip loss was also inversely related (-0.23, P<0.05) to % lean meat which was positively correlated (P<0.05) with *L** and chroma (r = 0.21 and 0.20 respectively). Statistically significant but low positive relationships (P<0.01) were observed between the CIELAB parameters of *L**, *b** and chroma and % fat in tail (R= 0.29, 0.22 and 0.20 respectively).

Table 19 Correlation between carcass quality evaluation parameters

	Eye muscle area (cm^2)	Eye muscle depth (mm)	% Fat in chop	% Fat in tail	V measurement (mm)	P_{2ARINI} (mm)	$P_{2FACTORY}$ (mm)	KO%	% Lean
Eye muscle area (cm^2)		**0.271**	0.096	0.075	**0.198**	0.034	-0.034	-0.092	0.029
Eye muscle depth (mm)	**0.271**		-0.079	-0.093	-0.161	**-0.232**	-0.006	0.030	0.050
% Fat in chop	0.096	-0.079		**0.323**	**0.380**	**0.252**	**0.213**	-0.085	-0.175
% Fat in tail	0.075	-0.093	**0.323**		**0.609**	**0.363**	**0.264**	0.122	-0.144
V measurement (mm)	**0.198**	-0.161	**0.380**	**0.609**		**0.510**	**0.336**	-0.020	**-0.228**
P_{2ARINI} (mm)	0.034	**-0.232**	**0.252**	**0.363**	**0.510**		**0.577**	0.022	**-0.434**
$P_{2FACTORY}$ (mm)	-0.034	-0.006	**0.213**	**0.264**	**0.336**	**0.577**		0.103	**-0.905**
KO%	-0.092	0.030	-0.085	0.122	-0.020	0.022	0.103		0.044
% Lean	0.029	0.050	0.175	-0.144	**-0.228**	**-0.434**	**-0.905**	0.044	

Correlation values ≥ 0.194, 0.254, 0.321 are significant (P < 0.05, 0.01 and 0.001 respectively). Significant correlations are highlighted in bold.

Table 20 Correlation between meat quality evaluation parameters

	*L**	*a**	*b**	Chroma	Hue	pH_u	Shear force (kg/cm^2)	% cooking loss	% drip loss	% Intra-muscular fat
*L**		**0.321**	**0.543**	**0.499**	-0.097	-0.246	0.053	0.052	0.167	0.101
*a**	**0.321**		**0.771**	**0.899**	-0.902	-0.116	0.053	0.111	**0.243**	0.140
*b**	**0.543**	**0.771**		**0.970**	**-0.487**	**-0.320**	-0.041	0.187	**0.295**	0.160
Chroma	**0.499**	**0.899**	**0.970**		**-0.658**	**-0.261**	-0.010	0.163	**0.289**	-0.095
Hue	-0.097	**-0.902**	**-0.487**	**-0.658**		-0.026	-0.104	0.040	-0.169	0.161
pH_u	**-0.246**	-0.116	**-0.320**	-0.261	-0.026		0.093	**-0.346**	**-0.394**	-0.146
Shear force (kg/cm^2)	0.053	0.053	-0.041	-0.010	-0.104	0.093		0.023	0.024	-0.037
% cooking loss	0.052	0.111	0.178	0.163	0.040	**-0.346**	0.023		**0.355**	0.174
% drip loss	0.167	**0.243**	**0.295**	**0.289**	-0.169	**-0.394**	0.024	**0.355**		**0.240**
% Intramuscular fat	0.101	0.140	0.160	-0.095	0.161	-0.146	-0.037	0.174	**0.240**	

Correlation values ≥ 0.194, 0.254, 0.321 are significant (P < 0.05, 0.01 and 0.001 respectively). Significant correlations are highlighted in bold.

Table 21 Correlation between carcass and meat quality evaluation parameters

	L*	***a****	***b****	**Chroma**	**Hue**	**pH$_u$**	**Shear force (kg/cm^2)**	**% cooking loss**	**% drip loss**	**% Intra-muscular fat**
Eye muscle area (cm^2)	0.073	-0.097	0.014	-0.020	0.142	0.075	0.115	-0.068	**-0.325**	-0.045
Eye muscle depth (mm)	-0.033	0.154	0.147	0.160	-0.124	0.121	-0.174	-0.015	-0.101	0.045
% Fat in chop	0.080	-0.005	0.160	0.108	0.076	-0.188	-0.050	0.169	-0.075	-0.024
% Fat in tail	**0.286**	0.148	**0.219**	**0.204**	-0.100	-0.176	-0.029	0.087	0.048	0.105
V measurement (mm)	0.192	-0.075	0.092	0.032	0.122	-0.157	-0.035	0.122	-0.084	-0.081
P_{2ARINI} (mm)	0.103	0.045	-0.068	-0.062	0.043	-0.056	0.093	-0.002	-0.025	-0.151
$P_{2FACTORY}$ (mm)	-0.142	-0.109	-0.136	-0.141	0.033	0.186	0.098	-0.052	-0.155	-0.106
KO%	0.061	0.095	-0.070	-0.014	-0.182	0.128	0.057	-0.037	-0.102	0.067
% Lean	**0.210**	0.186	0.185	**0.200**	-0.119	**-0.221**	-0.089	0.001	**-0.228**	0.168

Correlation values ≥ 0.194, 0.254, 0.321 are significant ($P < 0.05$, 0.01 and 0.001 respectively). Significant correlations are highlighted in bold.

5.8 *Relationship between production performance and carcass quality*

The correlations between production performance (11 weeks – finish) and carcass evaluation parameters are presented in Table 22. Although some relationships were significant the r values obtained were generally weak (i.e. r<0.5). Daily feed intake was positively correlated with % fat in the tail (r = 0.163, P<0.01) and with $P_{2\ ARINI}$ (r = 0.223, P<0.001). Daily liveweight gain was significantly related to eye muscle depth (r = 0.136, P<0.01) % fat in tail (r = 0.232, P<0.001), V measurement (r = 0.298, P<0.001), $P_{2\ ARINI}$ (r = 0.338, P<0.001) and $P_{2\ FACTORY}$ (r = 0.476, P<0.001). In line with this, FCR was inversely related to eye muscle area (r = -0.123, P<0.05), V measurement (r = -0.210, P<0.01) and $P_{2\ FACTORY}$ (r = -0.291, P<0.001).

Table 22 Correlation between production performance (11 weeks – finish) and carcass quality

	Daily feed intake (g)	**Daily liveweight gain (g)**	**FCR**
Eye muscle area (cm^2)	-0.038	0.095	-0.101
Eye muscle depth (mm)	-0.041	**0.136**	**-0.125**
% fat in chop	0.016	0.011	0.010
% fat in tail	**0.163**	**0.232**	-0.082
V measurement (mm)	0.052	**0.298**	**-0.210**
$P_{2\ ARINI}$ (mm)	**0.223**	**0.338**	-0.118
$P_{2\ FACTORY}$ (mm)	0.114	**0.476**	**-0.291**
KO%	-0.028	0.001	-0.044
% lean	-0.001	**-0.128**	0.095

Correlation values ≥ 0.123, 0.136, 0.210 are significant (P<0.05, 0.01 and 0.001 respectively). Significant correlations are highlighted in bold.

5.9 *Relationship between production performance and meat quality*

Daily feed intake between the 11 week to finish period was significantly correlated with *L** (r = 0.202), *a** (r = 0.310), *b** (r = 0.232), chroma (r = 0.277), E (r = 0.219) (P<0.001) and shear force (r = 0.172) (P<0.01). A negative relationship was observed between daily feed intake and hue (r = 0.269, P<0.001) and % cooking loss (r = 0.158, P<0.01). There was a weak positive relationship between daily liveweight gain and *b** (r = 0.120, P<0.05) but no other significant correlations between daily liveweight gain and meat quality parameters. FCR was positively correlated with *a** (r = 0.178, P<0.01), chroma (r = 0.139, P<0.05) and shear force (r = 0.123, P<0.05). There was a significant inverse relationship between FCR and the parameter hue (r = -0.85, P<0.01) (Table 23).

Table 23 Correlation between production performance (11 weeks – finish) and meat quality

	Daily feed intake (g)	**Daily liveweight gain (g)**	**FCR**
*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**
E	**0.219**	0.110	0.101
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

Correlation values ≥ 0.120, 0.158, 0.202 are significant (P<0.05, 0.01 and 0.001 respectively). Significant correlations are highlighted in bold.

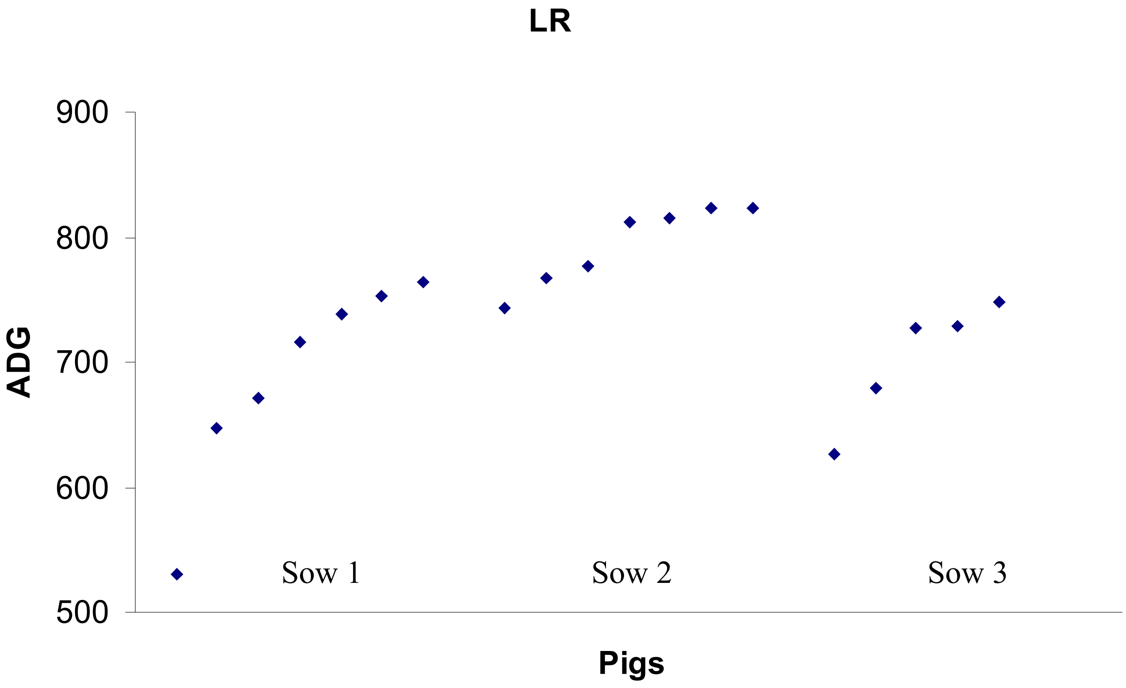
5.10 The effect of dam on production performance of progeny

From the performance data set (5.2) individual sires from each sire type were ranked according to the daily liveweight gain of progeny. The “top” performing sire from each sire type was selected and the performance of their progeny from three different sows was examined (Table 24). There were significant differences in daily liveweight gain between the three litters for Landrace, Large White and Landrace x Duroc sired pigs, with the largest difference occurring between sow 1 (842 g/d) and sow 3 (675 g/d) sired by Large White sires. The variation in daily liveweight gain within and between the progeny from the three sows is displayed graphically in Figure 11. Average P_2 varied significantly between litters for Landrace x Large White and Landrace x Large White x Pietrain sired pigs. Sow 1, sired by Landrace x Large White sire, produced progeny which had a high level of backfat (14 mm) compared to those produced by sows 2 and 3 (10.4 x 9.7 mm respectively). KO% was significantly different between litters sired by Landrace x Duroc sires.

Table 24 Variation in daily liveweight gain, P_2 and KO% in progeny from 3 sows served with the same sire (with litter size as covariate)

	Sow 1	Sow 2	Sow 3	s.e.m.	P
Landrace					
Daily liveweight gain (g wean – finish)	689	795	702	24.4	<0.01
P_2 (mm)	9.7	10.3	11.0	0.34	NS
KO%	73.5	74.6	76.2	0.89	NS
Large White					
Daily liveweight gain	842	732	675	31.0	<0.01
P_2	12.8	10.5	10.4	1.41	NS
KO%	71.5	76.2	78.8	2.39	NS
Duroc					
Daily liveweight gain	786	768	781	17.21	NS
P_2	*	*	*	*	*
KO%	*	*	*	*	*
Landrace x Large White					
Daily liveweight gain	759	723	707	20.8	NS
P_2	14.0	10.4	9.7	0.60	<0.01
KO%	74.6	73.2	75.3	0.69	NS
Landrace x Duroc					
Daily liveweight gain	774	730	708	18.6	<0.05
P_2	12.4	14.7	12.8	0.92	NS
KO%	74.8	76.6	77.2	0.62	<0.05
Large White x Duroc					
Daily liveweight gain	683	722	736	16.26	NS
P_2	9.9	11.0	11.0	0.71	NS
KO%	76.5	75.0	76.5	0.83	NS
Landrace x Large White x Duroc					
Daily liveweight gain	751	746	772	28.9	NS
P_2	11.0	9.3	11.9	0.71	NS
KO%	74.8	75.2	73.8	1.01	NS
Landrace x Large White x Pietrain					
Daily liveweight gain	731	720	652	32.3	NS
P_2	9.3	11.6	9.5	0.60	<0.05
KO%	74.8	75.6	78.6	1.89	NS

* No carcass data obtained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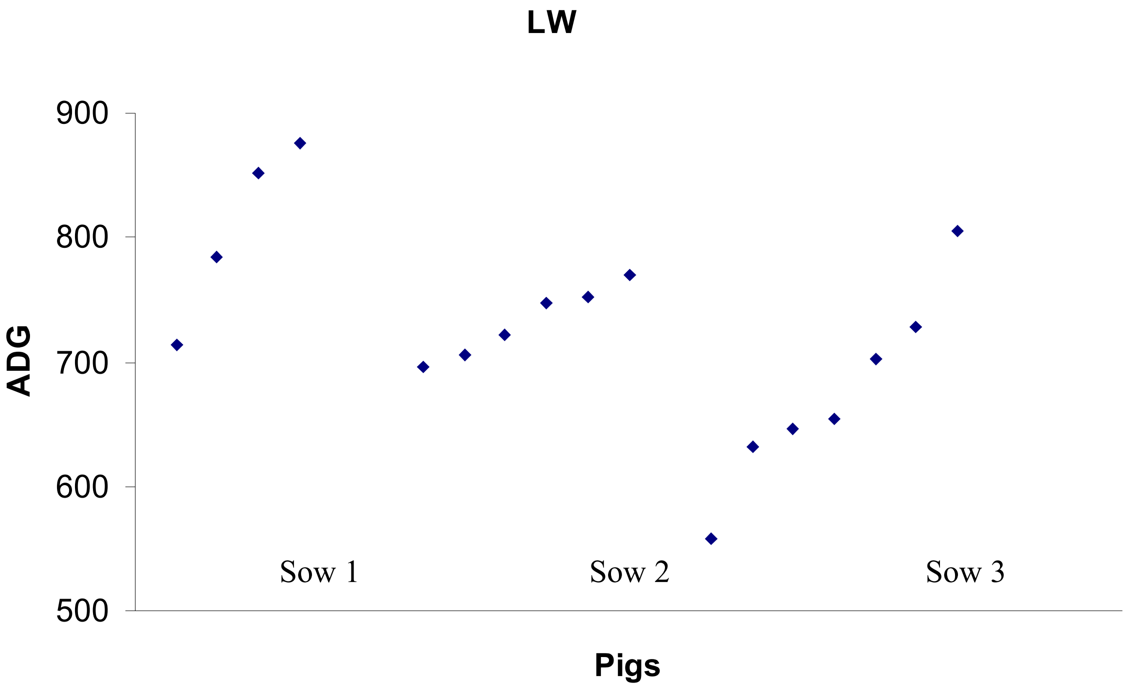
Pigs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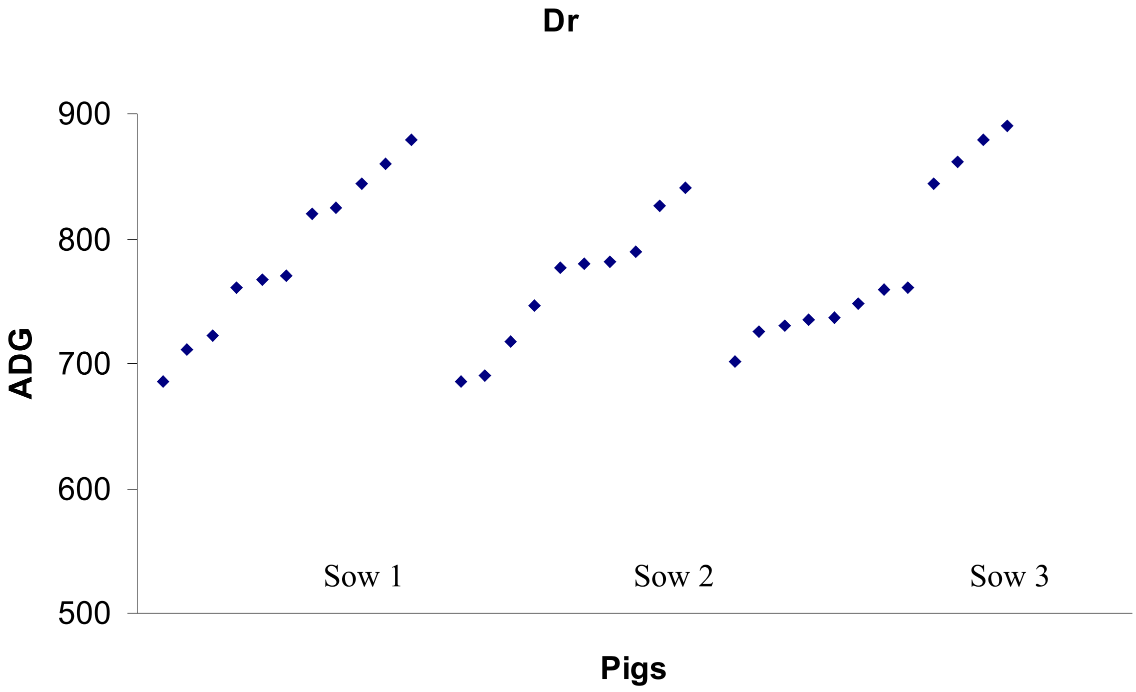
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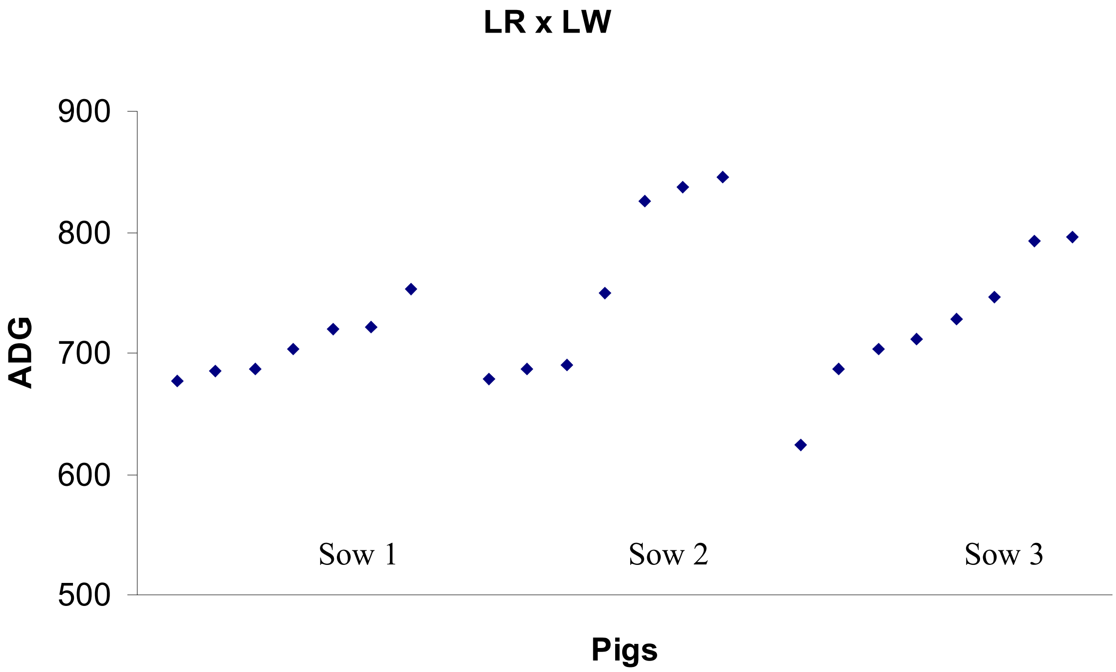
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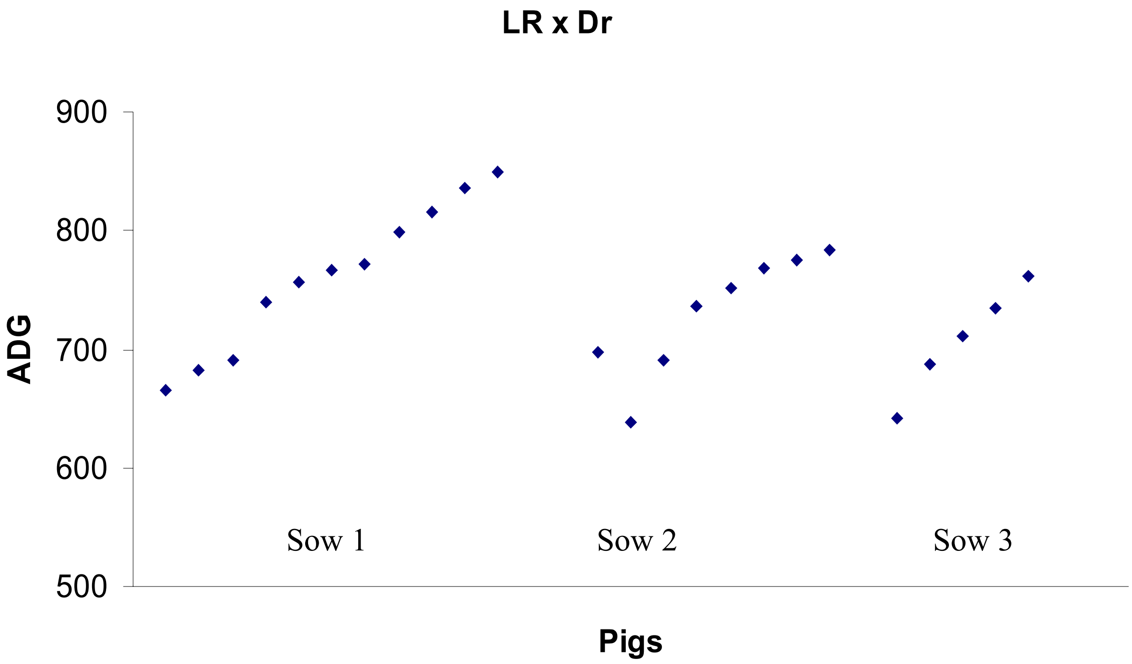
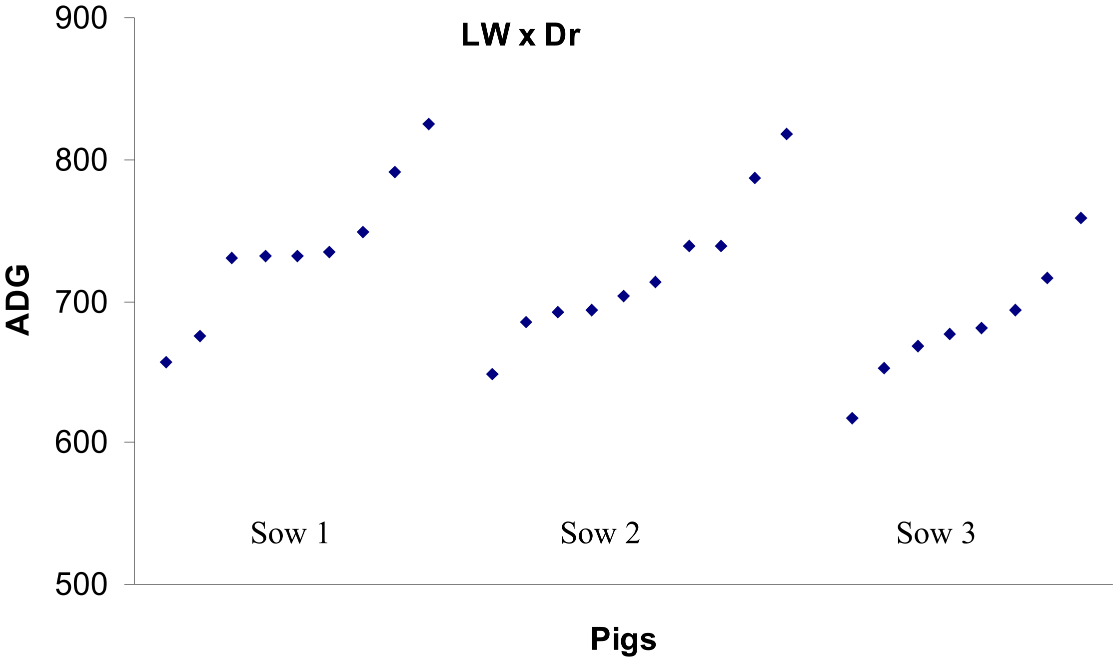
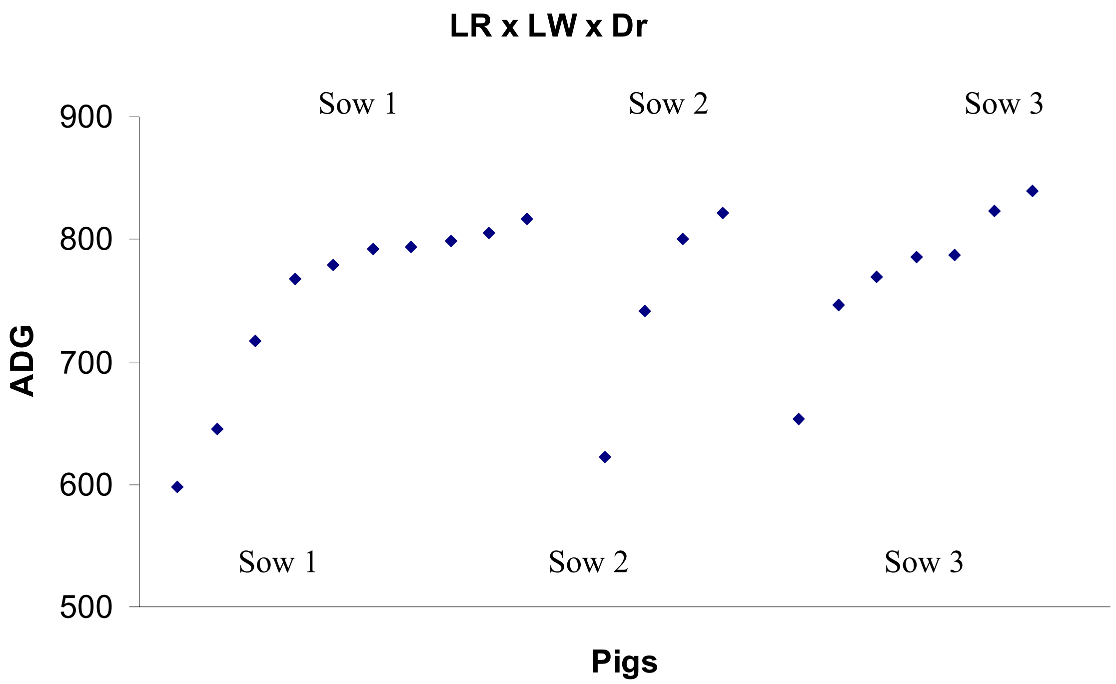




Sow 1 Sow 2 Sow 3



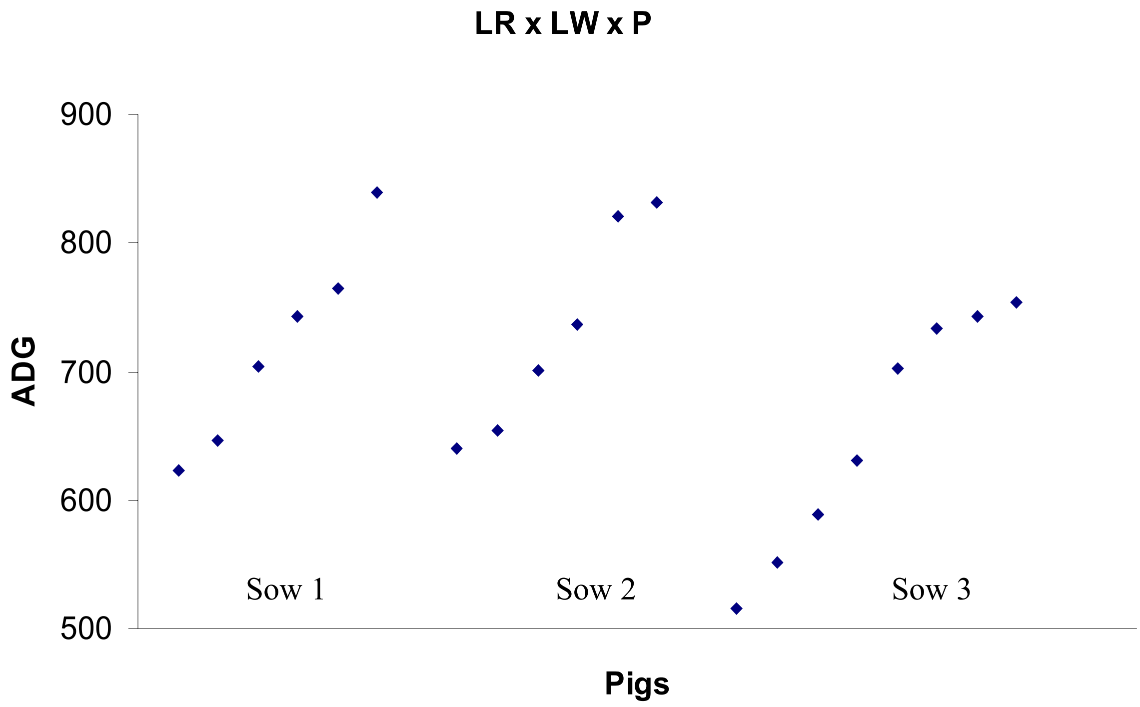


Figure 11 Variation in ADG (weaning to slaughter) within and between progeny of three sows sired by the top sire in each sire type

6. DISCUSSION

6.1 Reproductive performance

There was no difference in the reproductive performance of sows served by either pure or crossbred boars. It has been reported that the use of crossbred sires may improve conception rates between 6 and 20% resulting in greater numbers of piglets per litter (McLaren *et al*., 1987). It has also been suggested that hybrid vigour in the boar can produce between 0.25 to 0.75 piglets more 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 sired by pure or crossbred boars. These workers suggested that parity, season and dam breed had a greater effect on reproductive performance than the sire breed.

When individual sire types were compared, sows mated with Duroc and Large White x Duroc boars produced greater numbers of live pigs than the other sire types. This supports previous work which has shown that Duroc sired litters are larger (Smith *et al.,* 1990; Edwards *et al*., 1992). Edwards *et al*. (1992) compared the progeny from 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. It should also be noted that the Landrace x Duroc cross sires and the three-way Landrace x Large White x Duroc cross sires had the smallest numbers born alive, hence the greater number born alive is not consistent across all Duroc crosses.

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 sire type observed in the present study supports this finding.

6.2 Production performance

It has been reported (Rempel *et al*., 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 that found by other researchers. For example Lichman *et al*. (1975) reported no significant difference between average daily gain and FCR for pigs sired by Large White compared to those sired by Large White x Landrace boars. Similarly, McLaren *et al*. (1987) detected no significant difference between the growth rate of purebred and crossbred sired pigs.

When the production performance of individual sire types were compared, there was a lack of consistent response for any of the production parameters. This suggests that variation between sire types is limited and that sire type does not have a major influence on feed intake, growth rate or FCR. However, the large variation within the progeny of the different sire types would indicate that individual sires would be economically important in terms of production performance.

6.3 Carcass quality

The progeny of crossbred sires had higher backfat levels at the end of the eye muscle (V measurement) than those from purebred sires. However, the actual numerical difference was small (2 mm) with significance attributable to the low s.e.m. (0.510). The fact that there were no significant differences in P_2, KO% and % lean between the progeny of pure and crossbred sires is in keeping with literature. Kennedy and Conlon (1978) reported that the progeny of crossbred boars will provide carcass quality at a level equal to the average carcass quality of progeny sired by both their parent breeds.

In this study, progeny from Duroc and Duroc crossed boars had higher P_2 than Landrace. This is in keeping with that reported by Wood (1993). As the measurement of lean is determined by a formula based on fat depth, there are corresponding differences in this parameter. Whittemore (1993) reported that Pietrain pig types show benefits over White types by up to 4% more lean and 3% better KO%. However, in the present study the progeny of Landrace x Large White x Pietrain boars contained the lowest percentage lean (55.3%) and a high overall fat percentage (28.2%). Consistent with previous work, KO% was 1% higher than the average of the other sire types. The present results indicate that there were no consistent differences between the sire types for carcass quality, even though the means differ for some parameters by up to 30%. Such differences between sire types are not significant because the variation within a sire type is greater than the variation between sire types. The lack of consistent differences between sire types observed for carcass parameters indicate that the variation within sire types is extremely large, i.e. there are individual sires within breeds whose progeny may have large eye muscles or low subcutaneous fat and there are individual sires within the same sire type whose progeny may have small eye muscles and high subcutaneous fat.

6.4 Meat quality

Progeny of purebred sires contained a higher level of intramuscular fat (2.65 vs 2.11%). This is an important difference as fat is a key component in flavour and therefore meat with a low intramuscular fat is stated 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 differences between the individual sire types for the amount of intramuscular fat, although progeny of the Duroc sire contained the highest level (3.01%) of intramuscular fat. Several researchers have reported that Duroc sired pigs have a higher level of intramuscular fat than progeny from other sire types (e.g. Simpson *et al*., 1987). Blanchard *et al*. (1999) compared graded levels of Duroc inclusion with Landrace x Large White crosses and reported that intramuscular fat increased with increasing levels of Duroc (1.04, 1.12 and 1.82% for 0, 0.25 and 0.50 Duroc respectively). These workers also stated that Duroc meat was more tender (i.e. had a lower shear force) than Landrace x Large White meat. In this study there was no difference in shear force for progeny of any of the sire types.

There is controversy 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 level to be between 2.5 and 3% and Wood (1993) hypothesized that intramuscular fat levels of 1% and greater were adequate. The levels of intramuscular fat determined in this study fall within these reported values and it is therefore proposed that intramuscular fat levels for the progeny of all sire types were adequate for satisfactory meat quality in terms of juiciness.

Jeremiah and Weiss (1984) stated that measurement of pH 24 hours 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 all the mean pH_u values were below this value and therefore the significant differences between the sire types are of little practical significance.

Intramuscular fat was correlated with percentage drip loss but not with shear force. This is in line with Eikelenboom *et al.* (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). Beattie *et al*. (1999) observed an inverse relationship between intramuscular fat and shear force, when the means of different slaughter weights were compared. The mean intramuscular fat was much lower (0.8%) than in the current studies (mean 2.5%) and their shear force values slightly higher.

6.5 Relationship between carcass and meat quality parameters

Examination of the correlation matrix presented in Table 18 revealed some interesting points. For example, there was a lack of relationship between P_2 values and eye muscle area and depth (r = -0.03 and –0.01 respectively). Demo (1994) also reported a poor relationship between P_2 and eye muscle area (r = 0.09-0.19). 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 the amount of backfat there is no indication that other parameters have been improved. Currently the market requires low backfat, minimal inter-muscular fat and large eye muscle. If these objectives are to be met it is essential that selective breeding schemes take all these factors into account. This will only be achieved if the method of carcass grading in NI is altered. Grading on fat depth alone erroneously discriminates against 'blocky', meat type pigs. Measurements such as eye muscle depth could be included in carcass grading i.e. eye muscle depth and P_2 can be simultaneously determined by use of a Hennesy probe, to provide an incentive for producers to improve the quality of their carcasses. If the introduction of a selective breeding scheme is to be successful in NI, it requires the full support of both local producers and processors.

The CIELAB parameters *L*, b** and chroma were negatively correlated with pH_u. This is in keeping with Garrido *et al.* (1994) and Hermesch *et al.* (2000). The negative relationship (r = -0.39) between pH_u and % drip loss is also in agreement with Hermesch *et al.* (2000) (r = -0.71). Intramuscular fat was correlated with % drip loss (r = 0.24) but not with shear force (r = -0.037). This is in line with Eikelenboom *et al.* (1996) who reported a poor relationship between shear force and intramuscular fat (r = 0.01). However, this finding is in contrast to the theory that increased intramuscular fat content in meat increases tenderness (e.g. Blanchard *et al*. 1999).

The correlations between carcass and meat quality evaluation parameters were weak. Demo *et al.* (1993) reported that there was a negative correlation between eye muscle area and colour (r = -0.82). No such relationship was determined in this study (r = 0.07). However the lack of relationship between P_2 values and meat quality parameters 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 proteins (proteolysis). The latter is influenced by the temperature pH profile post mortem, which also has an influence on PSE, water holding capacity and cooking loss. Thus in a study where several of these factors may be changed by genetic parameters, poor correlations between any one carcass parameter and meat quality are to be expected and are in keeping with those reported by Ellis *et al*. (1996).

6.6 Relationship between production performance and carcass and meat quality parameters

There was a lack of any consistent relationships between performance and carcass quality parameters (Table 22). 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 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 x Landrace and Large White x Landrace pigs had higher daily feed intakes and greater levels of subcutaneous fat 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, i.e. 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 liveweight gains and produced more tender meat. However, as presented in Table 23, no such relationship was observed in the present study. These findings 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 of three pig genotypes (n = 411) and determined that there was a lack of relationship between ADG and pHu, L and a (r<0.1). Hermesch *et al*. (2000) stated that there were no clear genetic relationships between growth rate and meat quality parameters. However, a negative relationship with intramuscular fat (r = -0.21) was reported which suggested that rapid growth rate may reduce eating quality. 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 parameters be included in selection indices for pigs. Without such an inclusion the meat quality of NI pig products will not improve. The relationships between feed intake and meat quality presented in Table 23 are interesting and 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.

6.7 The effect of dam on production performance of progeny

As displayed in Table 24, there were significant variations in performance and carcass quality parameters between the progeny of three sows served with the same sire. There are two possible explanations for these findings; the variation is either as a result of variation between the sows or as a result of variation within the sire. Considering the small number of pigs involved in determining the parameters for the three sows, and the fact that the experiment was designed to examine the effect of sire type, it is impossible to categorically state which of these explanations are correct. Indeed, in reality it is likely to be a combination of sire and dam variation. More research is required to quantify the effects of dam versus variation within sires on the performance of progeny.

7. CONCLUSIONS

- There are no consistent differences in reproduction, production, carcass or meat quality characteristics between the main sire types commonly used in NI.
- The variation within sire type is greater than the variation between sire types. Consequently, genetic selection should be focused on identifying the best sires within each sire type.
- P_2 was poorly related to eye muscle area indicating that P_2 may not be the most suitable method of grading. The method of carcass grading currently used in NI should be expanded to include both eye muscle depth and P_2.
- The correlations between carcass and meat quality parameters were weak suggesting that meat quality could not be improved by selecting on carcass measurements.
- The results indicated that there was a lack of consistent relationships between performance and carcass quality parameters.
- Variation in progeny performance occurred between sows served with the same sire indicating that sow genotype may also influence production parameters.

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APPENDIX I

Table 1.1 Means and standard deviation of eye muscle area for the eight different sire types

Breed	No.	Minimum (cm^2)	Mean (cm^2)	Maximum (cm^2)	SD
LR	35	26.67	38.61	50.68	5.84
LW	57	32.08	40.37	48.77	3.93
Dr	41	29.76	39.60	49.49	5.37
LR x LW	50	29.92	39.16	51.52	4.77
LR x Dr	44	31.38	40.60	55.99	5.97
LW x Dr	45	27.48	39.75	50.43	5.64
LR x LW x Dr	37	30.27	40.55	53.21	5.57
LR x LW x P	53	29.65	39.32	48.48	4.91

Table 1.2 Means and standard deviations of eye muscle depth for the eight different sire types

Breed	No.	Minimum (mm^2)	Mean (mm^2)	Maximum (mm^2)	SD
LR	33	34.64	47.12	56.96	5.45
LW	55	34.05	48.20	58.16	6.21
Dr	36	34.38	47.63	63.36	6.42
LR x LW	39	39.84	48.40	60.96	5.18
LR x Dr	38	33.28	45.37	55.52	4.44
LW x Dr	37	36.24	48.59	56.88	4.77
LR x LW x Dr	36	33.28	48.31	58.24	6.39
LR x LW x P	49	35.04	48.07	60.24	5.37

Table 1.3 Means and standard deviations of % fat in chop for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	35	16.70	26.71	36.16	5.49
LW	57	10.52	28.40	47.07	7.61
Dr	41	7.39	25.89	43.54	7.68
LR x LW	50	5.68	23.81	47.65	8.08
LR x Dr	44	9.74	25.68	38.53	5.58
LW x Dr	45	12.68	26.46	43.65	7.26
LR x LW x Dr	37	11.52	26.64	37.91	6.55
LR x LW x P	53	10.01	28.04	46.43	7.44

Table 1.4 Means and standard deviations of % fat in tail for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	38	14.58	41.08	62.11	11.59
LW	53	24.96	47.31	82.72	13.72
Dr	36	16.63	23.71	78.55	29.16
LR x LW	49	10.90	44.61	84.28	11.89
LR x Dr	41	22.11	44.78	84.95	12.21
LW x Dr	42	18.59	39.46	78.08	11.43
LR x LW x Dr	36	22.81	44.73	85.23	11.94
LR x LW x P	48	24.50	44.39	84.74	11.70

Table 1.5 Means and standard deviations of V measurement for the eight different sire types

Breed	No.	Minimum (mm)	Mean (mm)	Maximum (mm)	SD
LR	38	8.10	16.53	47.90	7.73
LW	53	9.00	21.74	61.70	10.84
Dr	36	10.00	20.31	46.00	6.94
LR x LW	49	9.10	23.10	59.10	9.94
LR x Dr	41	9.00	23.57	55.20	10.56
LW x Dr	43	8.00	20.46	69.50	10.01
LR x LW x Dr	41	9.00	23.57	55.20	10.56
LR x LW x P	49	8.00	20.81	53.90	8.93

Table 1.6 Means and standard deviations of KO% for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	31	71.14	76.39	82.43	2.29
LW	52	72.00	75.77	80.22	1.82
Dr	38	70.00	76.59	83.33	3.05
LR x LW	45	72.63	77.38	83.21	2.26
LR x Dr	36	70.22	75.91	82.67	2.86
LW x Dr	35	72.08	76.75	80.54	2.15
LR x LW x Dr	34	72.28	75.96	81.02	2.15
LR x LW x P	47	71.64	77.09	84.94	2.67

Table 1.7 Means and standard deviations of $P_{2FACTORY}$ for the eight different sire types

Breed	No.	Minimum (mm)	Mean (mm)	Maximum (mm)	SD
LR	31	6.0	9.9	15.0	2.28
LW	52	7.0	11.9	21.0	2.90
Dr	37	7.0	12.2	20.0	2.97
LR x LW	44	8.0	12.0	21.0	3.04
LR x Dr	38	6.0	11.9	21.0	3.19
LW x Dr	35	6.0	11.3	16.0	2.33
LR x LW x Dr	34	6.0	10.9	16.0	2.48
LR x LW x P	48	7.0	12.1	21.0	2.99

Table 1.8 Means and standard deviations of P_{2ARINI} for the eight different sire types

Breed	No.	Minimum (mm)	Mean (mm)	Maximum (mm)	SD
LR	26	6.0	9.9	17.0	3.07
LW	43	6.0	11.8	20.0	3.66
Dr	35	6.0	11.6	17.0	2.92
LR x LW	36	6.8	11.7	20.0	2.85
LR x Dr	30	7.0	11.6	20.0	3.37
LW x Dr	25	6.3	10.5	18.0	2.77
LR x LW x Dr	25	6.0	9.3	12.0	1.81
LR x LW x P	36	6.0	10.5	21.0	3.46

Table 1.9 Means and standard deviations of % lean for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	24	54.19	57.71	61.58	1.92
LW	52	46.54	56.16	61.57	2.83
Dr	31	48.58	56.06	62.09	3.23
LR x LW	44	49.53	56.25	61.65	2.97
LR x Dr	38	47.48	55.91	60.38	3.12
LW x Dr	22	53.16	56.37	60.28	1.78
LR x LW x Dr	33	50.75	56.63	61.68	2.88
LR x LW x P	48	47.37	55.38	60.64	2.76

APPENDIX 2

Table 2.1 Means and standard deviations of *L** for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	42.34	53.76	61.33	4.95
LW	54	42.40	54.61	65.74	4.34
Dr	34	43.97	55.78	64.23	3.74
LR x LW	52	44.02	55.69	63.55	4.33
LR x Dr	43	46.62	55.22	65.58	4.80
LW x Dr	33	41.63	54.31	64.91	5.17
LR x LW x Dr	35	43.58	55.00	68.87	5.17
LR x LW x P	53	44.87	53.85	65.96	4.43

Table 2.2 Means and standard deviations of *a** for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	0.27	3.55	6.57	1.52
LW	54	0.50	4.63	8.06	1.87
Dr	34	2.05	4.78	10.77	2.00
LR x LW	52	0.14	7.02	12.70	2.45
LR x Dr	43	0.18	4.14	8.61	2.17
LW x Dr	33	0.38	4.36	9.36	2.28
LR x LW x Dr	35	1.05	3.97	8.99	1.74
LR x LW x P	53	0.52	4.17	9.48	2.01

Table 2.3 Means and standard deviations of *b** for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	3.66	8.25	12.03	1.84
LW	54	4.33	9.02	11.31	1.50
Dr	34	5.23	9.21	12.01	1.71
LR x LW	52	4.23	8.98	12.70	2.08
LR x Dr	43	4.60	8.89	13.51	1.94
LW x Dr	33	4.81	8.70	13.29	2.21
LR x LW x Dr	35	5.55	8.52	13.01	1.70
LR x LW x P	53	4.35	8.66	12.59	1.84

Table 2.4 Means and standard deviations of Chroma for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	4.75	9.06	13.71	2.05
LW	54	4.57	10.22	13.65	2.00
Dr	34	5.90	10.46	15.27	2.25
LR x LW	52	4.75	10.40	15.37	2.66
LR x Dr	43	4.94	9.90	16.02	2.56
LW x Dr	33	5.63	9.86	16.26	2.73
LR x LW x Dr	35	6.47	9.47	15.81	2.15
LR x LW x P	53	4.42	9.70	15.01	2.41

Table 2.5 Means and standard deviations of Hue for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	43.70	67.23	86.76	8.83
LW	54	52.39	63.70	86.25	7.74
Dr	34	45.16	63.28	75.47	7.43
LR x LW	52	42.37	61.71	88.32	8.51
LR x Dr	43	54.31	66.60	88.46	8.59
LW x Dr	33	32.26	64.78	86.55	10.20
LR x LW x Dr	35	53.90	65.73	82.97	7.00
LR x LW x P	53	50.64	65.53	84.66	7.76

Table 2.6 Means and standard deviations of E for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	29	43.10	54.55	62.33	5.00
LW	54	43.25	55.59	66.77	4.40
Dr	34	44.63	56.80	64.50	3.80
LR x LW	52	45.00	56.71	65.10	4.50
LR x Dr	43	47.37	56.15	66.27	4.91
LW x Dr	33	42.29	55.25	65.63	5.30
LR x LW x Dr	35	44.11	55.84	69.63	5.27
LR x LW x P	53	45.09	54.75	66.50	4.61

Table 2.7 Means and standard deviations of pH_u for the eight different sire types

Breed	No.	Minimum	Mean	Maximum	SD
LR	30	5.32	5.57	6.35	0.22
LW	56	5.02	5.52	5.91	0.12
Dr	34	5.30	5.48	5.78	0.12
LR x LW	52	5.32	5.52	5.90	0.12
LR x Dr	44	5.32	5.51	5.83	0.13
LW x Dr	33	5.36	5.50	5.84	0.12
LR x LW x Dr	37	5.38	5.56	6.10	0.15
LR x LW x P	53	5.33	5.57	6.40	0.21

Table 2.8 Means and standard deviations of shear force for the eight different sire types

Breed	No.	Minimum (kg/cm^2)	Mean (kg/cm^2)	Maximum (kg/cm^2)	SD
LR	30	1.70	2.85	4.40	0.74
LW	56	2.03	2.97	4.70	0.59
Dr	34	1.91	2.80	3.99	0.61
LR x LW	52	1.88	2.94	4.66	0.64
LR x Dr	44	1.88	2.83	4.03	0.54
LW x Dr	33	1.88	2.96	5.11	0.67
LR x LW x Dr	37	2.07	2.89	4.50	0.46
LR x LW x P	53	1.83	2.78	4.99	0.61

Table 2.9 Means and standard deviations of cooking loss for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	30	13.87	22.83	30.36	4.17
LW	56	15.79	24.76	29.23	2.92
Dr	34	16.58	23.54	31.47	3.43
LR x LW	52	15.88	23.35	30.04	3.21
LR x Dr	44	15.29	23.45	28.61	3.29
LW x Dr	33	17.39	24.52	31.14	3.21
LR x LW x Dr	37	19.93	24.95	30.00	2.70
LR x LW x P	53	16.02	25.09	31.59	3.78

Table 2.10 Means and standard deviations of drip loss for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	30	0.74	5.62	10.39	2.05
LW	56	1.96	6.05	10.34	2.12
Dr	34	1.08	6.65	15.03	2.87
LR x LW	52	2.22	5.48	12.34	2.47
LR x Dr	44	1.48	5.67	9.85	1.95
LW x Dr	33	1.63	5.72	12.68	2.30
LR x LW x Dr	37	1.54	5.78	10.24	2.02
LR x LW x P	53	1.45	5.88	13.15	2.45

Table 2.11 Means and standard deviations of intramuscular fat for the eight different sire types

Breed	No.	Minimum (%)	Mean (%)	Maximum (%)	SD
LR	15	1.39	2.30	3.86	0.76
LW	25	1.12	2.69	7.32	1.26
Dr	10	1.60	3.01	6.84	1.71
LR x LW	13	1.42	1.94	2.87	0.50
LR x Dr	17	1.12	2.22	3.82	0.77
LW x Dr	14	1.15	2.19	4.04	0.78
LR x LW x Dr	13	1.39	2.08	2.90	0.48
LR x LW x P	30	1.39	2.39	5.78	1.05