MASSEY UNIVERSITY

GROWTH POTENTIAL AND MEAT QUALITY OF DIFFERENT PIG GENOTYPES

PART I

Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

Project 2H-10

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Introduction

The genetic merit of pigs is one of the major, if not the foremost factor affecting farm profitability. It is therefore important, at regular intervals, to compare and benchmark the pig genotypes currently used commercially. It is of interest to the pig industry both in New Zealand and Australia to find out how good the current genotypes are and what the potential is for further performance improvement if pigs are fed to their full genetic potential. Moreover, being able to quantify the growth potential of commercially used pig genotypes is required when establishing their nutrient requirements and thus to design feeding strategies which will maximize farm profitability. The challenge here is tailoring the right diet for the right pig.

The underlying micro-traits for the economically important traits of higher average daily gain, lower feed conversion ratio and higher leanness (lower back fat thickness in NZ) are the maximum protein deposition potential (PdMax), and the minimum lipid to protein ratio in the whole body (Target L/P). PdMax represents the maximum daily protein deposition rate (g/d) that can be achieved for a certain type of pig, and Target L/P represents the energy partitioning between lipid and protein deposition when energy intake, but not protein intake is limiting. Target L/P is a function of energy intake only and is independent of live weight (de Lange *et al.*, 2008). Both PdMax and Target L/P are used in growth models to characterise pig genotypes and are usually determined in slaughter or nitrogen balance studies (Moughan *et al*., 2006, Weiss *et al.*, 2004). An alternative to these methods is to record live weight and feed intake in a growth trial, in which pigs are fed specially formulated diets. Feed intake curves are then used as input parameters in the pig growth model and simulations are conducted to determine the combination of PdMax and Target L/P which best fit the observed growth and intake curves. This is the approach that has been followed in the current study.

Pork quality is determined by a number of factors along from the breeding of the pigs through the cooking of the meat by the consumer. Pork quality characteristics can be assessed subjectively by a taste panel made up of trained or untrained people, or by objective measurements of related physico-chemical properties. In this study, we have investigated the following objective parameters that affect both the processing and eating quality of pork: meat colour, amount of intramuscular fat, water holding capacity, shear force, and pH.

The aim of the present study was to evaluate the growth performance and pork quality of two genotypes commonly used in New Zealand.

Material and Methods

All procedures involving animals were approved by the Massey University Animal Ethics Committee (MUAEC 10/60).

Animal and Housing

Pooled boar semen of PIC genotypes (i.e., 337 and 356) was used to inseminate females of the PIC line C46 on a commercial pig farm located in the North Island, New Zealand. The day after birth a total of 133 pigs were individually tagged. At 5-6 weeks of age 16 females and 16 males pigs from each boar genotype were selected (15.4 ± 2.6 kg; live weight ± standard deviation) and transported at the Massey University Pig Biology Unit. The pigs were kept in pens of either eight males or eight females (4 animals from each genotype per pen) and individually fed the diets as slurry twice daily. Water was available at all times. After a one week adaptation period, the recording of daily feed offered and refused and weekly live weight started.

Diet and Feeding

The pigs were fed two diets (Table 1). The first diet (MinLP) was limiting in energy but not limiting in amino acids, thus in this experimental phase the capacity of the pigs to partition energy between body fat and body protein (minimum lipid to protein ratio, MinLP) was driving growth (Weis et al. 2004). This diet was fed restricted and the amount of feed offered per day (kg) was calculated as (LW × 0.26 + 9.1) / 13.85. Once the pigs' LW was ≥ 49.5 kg their diet was changed to the second diet (PdMax), which was limiting in neither energy nor amino acids and was fed twice daily *up to appetite*. In this phase of the study, the pig maximum protein deposition potential (PdMax) was limiting growth. The pigs remained on the PdMax diet until being slaughtered.

Slaughter

Once the pigs reached LW ~90 kg, (92.9 ± 4.81 kg they were transported (± 1 hour) to a commercial slaughterhouse (Landmeats Ltd, Wanganui) and rested for at least one hour before being slaughtered. At slaughter P2 back fat thickness and carcass weight were measured. The pH of the *longissimus dorsi* (LD) was measured 45 minutes after slaughter (pH Spear, Eutech Instruments, OAKLON®). The day after slaughter the head was separated from the carcass (C1) and the carcass split into along the spine. The left carcass was then cut between the 3rd and 4th rib, and between the 2nd to last and last lumbar vertebrae, resulting in three primal cuts namely: the shoulder, middle and leg. These cuts were weighed. A short loin was prepared as the caudal part resulting from a cut through the middle between 2nd to last rib and the last. Pictures were taken of the cranial face of the short loin. The *longissimus* muscle plus the overlapping fat and skin from the short loin was then boned out, vacuum

packed, taken back to Massey University, stored first for 7 days in a chiller (2 ± 1ºC) and then transferred to a freezer (-30 ± 2ºC) until required for further meat quality assessments.

Table 1. Diet composition of the two experimental diets

Ingredient Liveweight range (kg)	MinLP diet, % 18-53	PdMax diet, % 53-93
Barley	66.6	62.55
Soybean meal	24	28
Fish meal	4	0
Soybean oil	1	5
Lysine	0.3	0.35
Methionine	0.3	0.3
Threonine	0.2	0.2
Tryptophan	0.05	0.05
Vitamin+mineral premix[1]	0.3	0.3
Dicalcium phosphate	3	3
Disodium phosphate	0.15	0.15
Salt	0.1	0.1
Nutrient composition[2]		
DE (MJ/kg)	13.85	14.81
True digestible lysine, g/kg	12.6	12.0
Lysine/DE ratio	0.91	0.81

[1] Vitalean; Vitec Nutrition, 2/20 Kerwyn Avenue, East Tamaki, Auckland, NZ
[2]Calculated composition from Morel *et al.*, 1999.

Chemical analyses

The diets were analysed in duplicate at the nutrition laboratory at IFNHH, Massey University for dry matter (DM), GE, protein and amino acid content, fat, ash and neutral detergent fibre (NDF). The methods used are given in Table 2.

Table 2. Laboratory methods used for diet analysis (AOAC, 2005)

Dietary constituent tested	Method and Particulars	AOAC Standard Reference
Dry Matter	Convection oven 105°C	AOAC 930.15, 925
Gross Energy	Bomb calorimetry	n/a
Protein	Leco total combustion method	AOAC 968.06, N-P=6.25
Fat	Soxtec extraction	AOAC 991.36
Ash	Furnace 550°C	AOAC 991.36
Neutral Detergent Fibre	Tecator Fibretec System	AOAC 2002.04
Amino Acids	HCl acid hydrolysis followed by HPLC separation	AOAC 994.12
Cysteine and Methionine	From performic acid oxidation	n/a

Loin measurements

Measurements on pictures of loin were taken using a Placom KP-90N digital planimeter and a milli-metric ruler. The loin width and depth, back fat depth, lean surface area (LSA) and back fat surface area (BFSA) were measured and ratio LSA/BFSA was calculated.

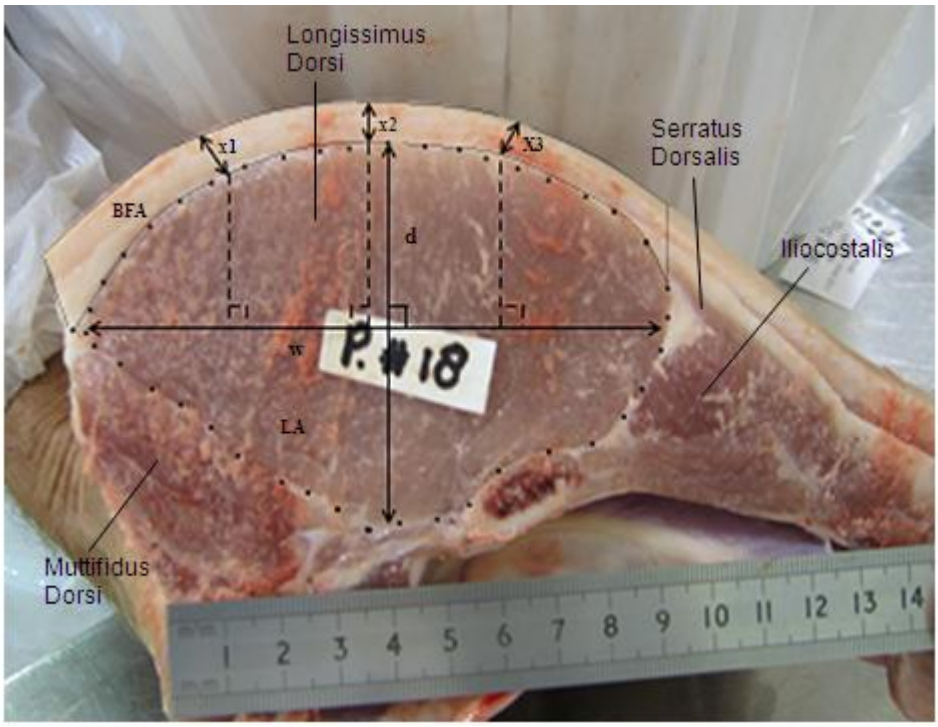

Figure 1 Location of the measurements taken on the loin pictures: d = depth(cm); w = width (cm); LFA = longissimus muscle surface area (cm^2) (inside ••• area); BFSA = back fat surface area (cm^2) (inside - - - area); x1-x3 = back fat depth (mm).

Meat quality analyses

The back fat and skin were removed from the loin and different parts of the loin were used for measuring colour, shear force, drip losses, intramuscular fat (IMF), ultimate pH, sarcomere length, and water holding capacity (WHC) (Figure 2.).

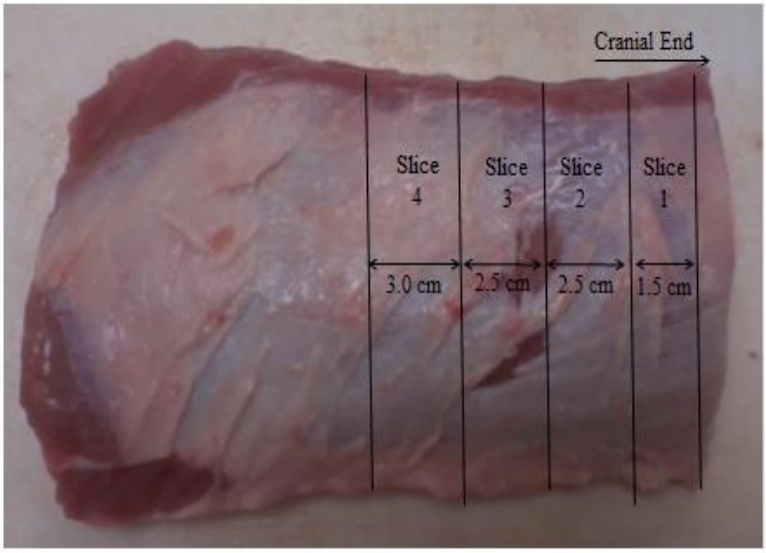

Figure 2. The first cut was to square off the cranial end. Slice 1 was used for colour, sarcomere length, pH and expressed juice loss assessments. Slices 2 and 3 were to measure cooking loss and shear force . Slice 4 was used for drip loss and IMF assessments.

Colour

A sample was cut from the pale end of slice 1, placed in a sealed bag and stored frozen. When required for testing the samples were thawed in the chiller (whilst still remaining in their sealed bags), then pulled out of the bag and cut in half with a knife to expose the internal surface to the air at room (18-20°C) temperature for ~30minutes. Then a petri dish was placed and lightly squashed on the upper surface of the sample. This was to keep the chromometer clean. Then each sample was measured twice (once each half) with a chromometer. The chromometer model used was the Minolta CR-200 which had a 10mm diameter aperture and was calibrated against a white standard for values: lightness (L^*) = 97.55, redness (a^*) = −0.52 and yellowness (b^*) = 2.60 The petri dish was cleaned after every fifth sample with distilled water and dried with a paper towel.

Ultimate pH

The pH was measured with a digital pH meter with temperature compensation. The pH meter was calibrated for pH7 and pH4 with standard solutions which were 2 ± 1ºC first prior to the sample being measured. An internal (core) sample of 2.0-2.5 g of pork was taken from slice 1 and homogenised with 10 ml 150 mM potassium chloride (KCl) as described by Purchas and Zou (2008). Once the sample was homogenised the pH was recorded.

Expressed juice loss

An internal single sample of 500 ± 20 mg was taken from slice 1 and placed on a piece of Whatman number one filter paper (11 cm diameter). The filter paper was pressed between two Perspex plates and a 10 kg weight was placed on the top for 5 min. Once 5 minutes was reached the weight was removed, the area of the squashed pork was drawn with a pen and the area of the moisture on the paper was measured by a Placom Digital Planimeter KP-90N as described by Purchas (1990). The expressed juice loss was then calculated by the following formula:

Expressed juice (cm^2 / g) =[Outside wetted area(cm^2)] / [Sample wt (g)]

Sarcomere Length

A sliver of the dark part of the pork sample was cut 8-10 mm along the length of the muscle fibres and 1×1mm cross section with a scalpel blade. The sliver was then teased-out with a scalpel blade to increase the surface area of the sample and then transferred to a microscope slide. About 2-3 droplets of distilled water was added to the sample and a second microscope slide was pressed on top; squashing the sample between the two microscope slides. The microscope slide was then placed on a holder, so that the sample was 100 mm from the white surface. A He-Ne laser was passes through the sample. The sample in the holder was rotated until 3 bands were clearly visible. The distance between the first order diffraction bands was measured, and 12 measurements per sample were used to calculate the mean distance (mm). The following formula was used to calculate the sarcomere length (SL) in micrometres (µm):

$$SL(\mu m) = 0.6328 \times \left[\sqrt{\left(\left(\frac{x}{10 \times 2}\right)^2 + 100\right)}\right] / \left(\frac{x}{10 \times 2}\right)$$

x = The calculated mean distance between the first-order diffraction bands (mm)

Cooking losses and shearforce measurement

Slices 2 and 3 (2.5 cm thick) were placed into a 150 × 250 ml plastic bag and weighed prior to cooking. The sample was then suspended in a water bath at 70ºC for 90 min. Each sample was then drained for 5 minutes, and placed in the chiller (2ºC) overnight (~20 hours). The following morning the sample was dried on a paper towel and reweighed as described by Purchas, Burnham and Morris

(2002). The following equation was used to calculate the cooking losses:

$$Cooking\ Loss\ (\%) = \frac{Raw\ weight\ (g) - cooked\ weight\ (g)}{Raw\ weight\ (g)} \times 100$$

These cooked samples were then subjected to a meat toughness test using the Warner-Bratzler Shear Force machine (WSFM). Six cores were prepared that run parallel to the muscle fibres in length with a 13 × 13 mm cross section. Each of the 6 cores were sheared twice (approx. 1/3 and 2/3 along the length of each core) yielding a total of 12 shear values per sample as described by Purchas (1990).

Drip loss

Slice 4 was trimmed (intermuscular fat removed) and cut into a cube measuring approximatively (3 x 3 x 3 cm). The sample was weighed, put on a metal hook, placed in a 150 × 250 mm plastic bag and hung in the chiller at 2 ± 1ºC. Each sample was reweighed after 24 and 48 hours as described by Edens, Lyons and Jacques (1996). Drip loss was calculated by the following equation:

$$Drip\ loss\ (\%) = \frac{Original\ weight\ (g) - end\ weight\ (g)}{Orignal\ weight\ (g)} \times 100$$

End weight (g) = drip loss weight (g) after either 24 or 48 hours.

Intramuscular fat

A trimmed ~40 g sample was taken from slice 4 of the loin and placed in a sealed plastic bag and stored in the freezer. The frozen sample was minced with a knife, placed in a new sealed plastic bag and weighed before being freeze dried. The freeze dried sample was weighed, ground and the fat content quantified by solvent extraction (petroleum ether, BP 40-60 ^{o}C using a Soxtec apparatus (AOAC 911.36).

Calculation of Target L/P and Pdmax.

According to de Lange *et al.* (2008) Target L/P is a linear function of daily digestible energy intake (DEi):

Target L/P = $\alpha \times$ DEi

where the slope α is specific to a genotype

Between 20 and 50 kg LW, the pigs were restricted fed so that energy was the limiting factor and growth was driven by Target L/P. Then, between 50 and 95 kg LW, the pigs were fed to appetite a diet which was not limiting in either energy of amino acids, and growth was driven by Pdmax.

In each period the total digestible energy intake (TDEi) and the change in empty body weight (δEBW = EBWe − EBWs) were measured. The growth model equations were used to derive two equations with two unknown variables, namely the increase in whole body protein mass (δP) and the increase in whole body lipid mass (δL)

1) TDEi (MJ) = DEM + DEPM + DEG

Where:
Digestible energy for maintenance:
DEM (MJ) = $\int_{lws}^{Lwe}$ 0.5 x $LW^{0.75}$ / average daily gain (ADG, kg/d)
with *Lws*= liveweight at the start and *Lwe*= liveweight at the end

Digestible energy content of maintenance protein:
DEPM (MJ) = (Basal + integument losses) × 24 /1000

Basal (g) = 11.8 × total dry matter intake
Integument losses (g) = $\int_{lws}^{Lwe}$ 0.093 x $LW^{0.75}$ / ADG

Digestible energy for growth: DEG (MJ) = δP × 43.9 + δL × 52.8

2) TDEi (MJ) = DEM + DEPM + δP × 43.9 + δL × 52.8

3) δEBW (kg) = EBWe − EBWs

Where:
Empty body weight (EBW) = Live weight – gut fill = LW − 0.277 × $LW^{0.612}$

EBW = Body Protein +Body Lipid + Body Water + Body Ash

δEBW (kg) = $P_e + L_e + W_e + A_e - P_s - L_s - W_s - A_s$ = δP + δL + δA + δW

Water $W = 5.202 \times P^{0.855} \Rightarrow \delta W = a \times \delta P$; the factor a is estimated by the slope of the first derivative of the water function at an average P over each experimental phase.

$Ash = 0.189 \times P \Rightarrow \delta A = 0.189 \times \delta P$

4) **$\delta EBW\ (kg) = \delta P \times (1 + 0.189 + a) + \delta L$**

Equations **2** and **4** are solved for δP and δL

Daily protein deposition (Pd) is δP divided by number of days in the period, and lipid deposition (Ld) is δL divided by number of days in the period.

The target LP slope α is $\delta L / \delta P$ per unit of daily digestible energy intake in the first phase of the experiment and Pdmax is Pd in the second phase of the experiment

Statistical analysis

A linear model with boar genotype and sex as fixed effects and their interaction was fitted to the data. Difference between genotype × sex groups were tested with LSD where appropriate.

Results

One male pig from genotype 356 had a pinched nerve in the back and was removed from the trial during the second phase of the experiment.

The chemical analysis of the experimental diets is presented in Table 3.

Table 3. Chemical composition of the experimental diets.

	Diet	
On a as received basis	Minlp	PdMax
DM, g/kg	895	885
GE, MJ/kg	16.22	17.03
Protein, g/kg	236	207
Fat, g/kg	25	65
Ash, g/kg	77	65
Neutral detergent fibre, g/kg	134	136
Aspartic acid, g/kg	19.8	18.7
Threonine, g/kg	9.8	8.6
Serine, g/kg	8.7	8.4
Glutamic acid, g/kg	39.1	37.2
Proline, g/kg	16.3	13.7
Glycine, g/kg	9.8	7.8
Alanine, g/kg	9.1	7.8
Valine, g/kg	11.4	10.5
Isoleucine, g/kg	9.2	8.6
Leucine, g/kg	15.4	14.4
Tyrosine, g/kg	6.6	6.2
Phenylalanine, g/kg	10.5	10.1
Histidine, g/kg	5.7	5.1
Lysine, g/kg	14.0	13.3
Arginine, g/kg	13.2	11.9
Cysteine, g/kg	3.5	4.0
Methionine, g/kg	6.1	6.0

The growth performance data as well as Target LP slope and PdMax values are presented in Table 4. In each phase of the experiment pigs from genotype 337 grew faster ($P < 0.0001$) and had better feed conversion ratio ($P < 0.0001$) than those from genotype 356. Similarly, entire male pigs grew faster ($P < 0.0001$) and had better feed conversion ratio than female pigs ($P < 0.0001$). Significant interactions between sex and genotype were observed for ADG and FCR and Target LP slope in the first phase of the experiment, such that female pigs of genotype 356 had lower performance that the other three genotype x sex combinations.

The results for the carcass measurements are presented in Table 5. Pigs from genotype 337 had less backfat, a lower percentage of the carcass as leg and more as shoulder than those from genotype 356. Shoulder represented a higher percentage of the carcass in male pigs than female pigs.

Loin measurements are presented in Table 6. Pigs from genotype 337 had wider longissimus muscles , less backfat depth and a greater longissimus muscle lean surface area than pigs from genotype 356.

The ultimate pH was lower for genotype 356 than 337, but no other differences in meat quality parameters were observed between genotypes or sexes (Table 6).

Table 4. Least-squares means for growth performance data.

Growth Data	Genotype (G)		Sex (S)		337	337	356	356	*P* values				
	337	356	F	M	F	M	F	M	G	S	G*S	RSD[1]	R^2 %[2]
MinLP evaluation													
n	32	32	32	32	16	16	16	16					
LW start, kg	18.54	18.15	18.54	18.15	18.98	18.09	18.1	18.21	0.600	0.590	0.500	2.91	1.7
ADG, g/d	750	710	710	760	750^{b}	760^{b}	680^{a}	750^{b}	0.000	0.000	0.020	0.04	40.6
Daily feed intake, g/d	1230	1240	1240	1230	1240	1220	1240	1230	0.330	0.110	0.480	0.03	6.5
FCR	1.63	1.74	1.75	1.62	1.67^{a}	1.60^{a}	1.83^{b}	1.65^{a}	0.000	0.000	0.040	0.11	40.5
LW diet change, kg	52.69	52.29	52.27	52.72	52.56	52.83	51.97	52.61	0.410	0.350	0.710	1.91	2.8
Target LP slope	0.025	0.033	0.033	0.025	0.027	0.023	0.039	0.026	0.000	0.000	0.020	0.007	46.3
PdMax evaluation													
n	32	31	32	31	16	16	16	15					
ADG, g/d	1200	1130	1088	1240	1135	1263	1041	1220	0.000	0.000	0.250	0.09	49.6
Feed intake, g/d	2190	2210	2220	2190	2200^{b}	2180	2230	2190	0.150	0.040	0.460	0.05	10.8
FCR	1.85	1.98	2.06	1.77	1.96	1.74	2.16	1.81	0.000	0.000	0.110	0.16	52.0
LW slaughter, kg	93.27	91.57	91.68	93.16	92.98	93.56	90.38	92.76	0.100	0.150	0.380	4.09	8.6
PdMax, g/d	226	203	193	237	208	245	178	229	0.001	0.000	0.303	25.7	50.4
Overall Performance													
ADG, g/d	940	890	880	960	920^{b}	970^{c}	830^{a}	$940^{b,c}$	0.000	0.000	0.040	0.05	49.3
Daily feed intake, g/d	1640	1650	1660	1630	1670	1620	1660	1640	0.600	0.010	0.530	0.05	10.7
FCR	1.75	1.87	1.91	1.71	1.82^{b}	1.67^{a}	2.00^{c}	$1.74^{a,b}$	0.000	0.000	0.050	0.12	54.5

[1] Residual standard deviation (RSD); [2] coefficient of determination (R^2). *P* values for differences between genotypes or sexes are in the Table
[a,b,c] Genotype x sex interactions values within row with different superscripts are statistically different from each other ($P < 0.05$).

Table 5. Least-squares means for slaughter and carcass measurements.

	Genotype (G)		Sex (S)		337	337	356	356	*P* values				
	337	**356**	**F**	**M**	**F**	**M**	**F**	**M**	**G**	**S**	**G*S**	**RSD[1]**	**R^2 %[2]**
n	32	31	32	31	16	16	16	15					
Carcass weight, kg	71.1	69.4	69.7	70.8	71.2	71.1	69.1	70.5	0.130	0.450	0.410	3.85	9.4
P2 BF depth, mm	9	10	9	9	8^{a}	9^{b}	10^{c}	9^{b}	0.010	0.880	0.010	1.34	21.0
Dressing %	76.2	75.4	76.0	75.7	76.5	76.0	75.5	75.4	0.151	0.576	0.719	2.23	4.2
pH, 45 min	6.31	6.35	6.38	6.28	6.35	6.26	6.40	6.31	0.450	0.120	0.980	0.77	5.0
Left side carcass cuts													
Shoulder, kg	10.18	9.66	9.71	10.13	10.06	10.30	9.35	9.96	0.001	0.004	0.192	0.56	29.7
Middle, kg	10.54	10.35	10.50	10.39	10.67	10.42	10.34	1.04	0.213	0.466	0.400	0.61	4.6
Leg, kg	10.69	10.86	10.74	10.82	1.74	10.64	10.73	11.00	0.361	0.672	0.331	0.75	3.2
Shoulder, %	32.4	31.3	31.4	32.3	32.0	32.9	30.8	31.8	0.000	0.000	0.735	0.95	40.1
Middle, %	33.6	33.6	34.0	33.2	33.9	33.2	34.0	33.1	0.957	0.012	0.714	1.24	10.5
Leg, %	34.0	35.2	34.7	34.5	34.1	33.9	35.2	35.1	0.000	0.604	0.912	1.21	19.6

[1] Residual standard deviation (RSD); [2] coefficient of determination (R^2). *P* values for differences between genotypes or sexes are in the Table
[a,b,c] Genotype x sex interactions values within row with different superscripts are statistically different from each other ($P < 0.05$).

Table 6. Least-squares means for loin-picture analysis.

	Genotype (G)		Sex (S)		337	337	356	356	*P* values				
	337	**356**	**F**	**M**	**F**	**M**	**F**	**M**	**G**	**S**	**G*S**	**RSD[1]**	**R^2 %[2]**
n	32	31	32	31	16	16	16	15					
LM[3] width, cm	10.0	9.7	10.0	9.7	10.2	9.8	9.8	9.6	0.013	0.016	0.463	0.52	18.3
LM depth, cm	6.2	6.0	6.2	6.0	6.3	6.0	6.1	5.9	0.189	0.058	0.579	0.48	9.0
BF depth, mm	6.6	8.2	7.8	7.0	6.5^{a}	6.6^{a}	9.0^{c}	7.3^{b}	0.000	0.059	0.023	1.58	31.0
LM Lean surface area (LSA), cm^2	44.3	41.2	43.9	41.6	46.2	42.4	41.6	40.8	0.01	0.056	0.21	4.71	17.3
Backfat surface area, (BFSA, cm^2	9.9	9.7	10.8	8.8	10.3	9.4	11.3	8.1	0.89	0.021	0.17	3.40	11.1
LSA:BFSA (log10)	0.682	0.648	0.630	0.700	0.684	0.681	0.576	0.720	0.40	0.09	0.07	0.16	10.6
Back-transformed	4.81	4.45	4.27	5.01	4.83	4.80	3.77	5.25					

[1] Residual standard deviation (RSD); [2] coefficient of determination (R^2). [3] LM= Longissimus muscle

P values for differences between genotypes or sexes are in the Table

[a,b,c] Genotype x sex interactions values within row with different superscripts are statistically different from each other ($P < 0.05$).

Table 7. Least-squares means for meat quality characteristics.

	Genotype (G)		Sex (S)		337	337	356	356	P value				
	337	**356**	**F**	**M**	**F**	**M**	**F**	**M**	**G**	**S**	**G*S**	**RSD[1]**	**R^2 %[2]**
n	32	31	32	31	16	16	16	15					
Ultimate pH	5.37	5.29	5.33	5.33	5.39	5.35	5.28	5.31	0.005	0.984	0.199	0.34	12.3
Thaw loss, %	1.88	2.40	2.14	2.14	1.80	1.97	2.48	2.32	0.027	0.982	0.481	0.91	7.3
Driploss 24h, %	13.20	13.53	13.79	12.94	12.47	13.92	13.40	13.66	0.657	0.251	0.426	2.99	3.9
Driploss 48h, %	16.77	16.09	16.80	16.06	16.25	17.28	15.87	16.32	0.310	0.260	0.660	2.61	3.8
Cooking losses %	28.93	28.49	29.13	28.29	28.33	29.52	28.24	28.73	0.612	0.337	0.689	3.51	2.2
Expressed Juice Loss (cm^2/g)	34.91	34.43	35.39	33.96	33.84	35.99	34.08	34.79	0.508	0.055	0.331	2.95	8.0
Sarcomere length, µm	1.60	1.62	1.61	1.61	1.60	1.60	1.62	1.62	0.21	0.89	0.975	0.07	3.4
Shear Force Test													
Mean, N	23.72	23.51	23.45	23.78	24.7	22.75	22.86	24.15	0.866	0.797	0.214	5.12	3.4
Peak F, N	74.24	70.27	71.51	73	76.86	71.62	69.15	71.4	0.278	0.682	0.305	14.44	4.8
Colour Test													
L^*(lightness)	48.93	47.96	48.68	48.20	48.50	49.35	47.90	48.01	0.882	0.080	0.429	1.76	10.1
a^*(redness)	6.70	7.14	6.85	6.99	6.80	43.21	7.18	7.11	0.094	0.598	0.797	2.07	1.1
b^*,(yellowness)	3.09	3.22	3.13	3.19	3.18	3.19	3.19	3.25	0.504	0.754	0.551	0.78	2.1
IMF, %	0.80	0.89	0.90	0.79	0.78^a	0.82^a	1.02^b	0.76^a	0.159	0.080	0.017	0.24	16.1

[1] Residual standard deviation (RSD); [2] coefficient of determination (R^2). *P* values for differences between genotypes or sexes are in the Table
[a,b,c] Genotype x sex interactions values within row with different superscripts are statistically different from each other ($P < 0.05$).

Discussion

Growth performance and carcass composition

There are many ways to describe the partitioning of energy retained between Pd and Ld for grower-finisher pigs. In the review written by de Lange *et al*. (2008), it was concluded that a simple positive linear relationship existed between DEI and Target L/P: Target L/P = $\alpha \times$ DEI. This was sufficient to predict the effect of energy intake on body composition provided the diet is limiting in energy, but not limiting in protein/amino acids during the energy-dependant phase. The slope (α) value is unique to a specific pig genotype. This conclusion was made after re-analysing data from 13 different trials where the slopes ranged between 0.020 and 0.048.

The slopes of the genotypes investigated in the current study, 0.025 for 337 and 0.033 for 356, were found to be between the fattest (0.048) and leanest (0.020) of the 13 genotypes reported by de Lange *et al.* (2008) (Figure 1). The slope would be expected to be lowest for entire males compared to females within the same genotype because entire males are the leanest (or least fat) compared to females and castrated males. The findings of the current trial support this with males having lower slope values than females (0.025 vs 0.033).

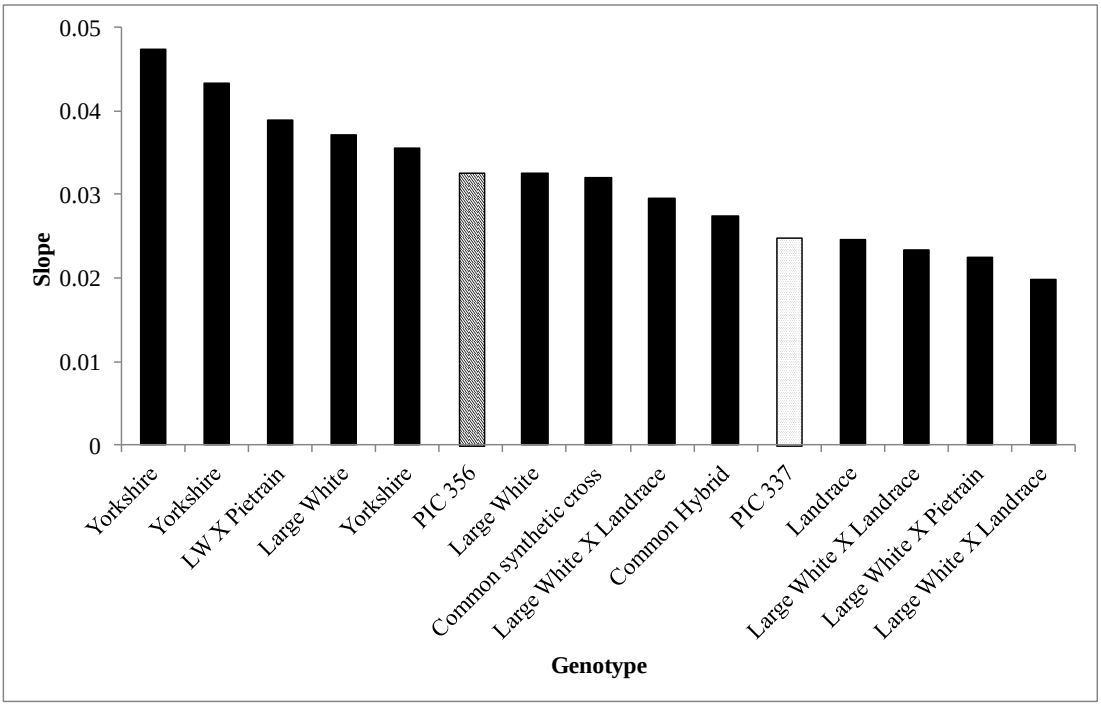

Figure 1. Comparison of the Target MinLP slopes for the two genotypes evaluated in this study (PIC 356 and PIC 337), with values published by de Lange *et al.* (2008, data from Tables 14.2 and 14.5).

PdMax is unique to genotype and constant between LW of 20 kg until the pigs start to mature after which PdMax starts to decline (de Lange *et al*,. 2008). In Figure 2, the PdMax and ADG values observed in the current trial are compared with values reported for eight other trials. The PdMax

values from the current trial are greater than the other trials shown in Figure 2. This is consistent with the trend that the more recent genotypes are leaner and have better growth performance traits compared to older genotypes. Knap and Rauw (2008) reported that PdMax increased from 110 g/d in 1970 to 230 g/d in 2004.

Previous trials which have evaluated PdMax have done so using diets with lysine as the first limiting amino acid over several different levels in nitrogen balance, serial slaughter and growth trials. In the current trial, PdMax was calculated (using the calculation rules of the Massey Pig Growth Model www.porkmaster.org) from a growth trial in which all the pigs were offered the same diet, not limiting in either energy or protein/amino acids which and offered *to appetite* at each scheduled meal time

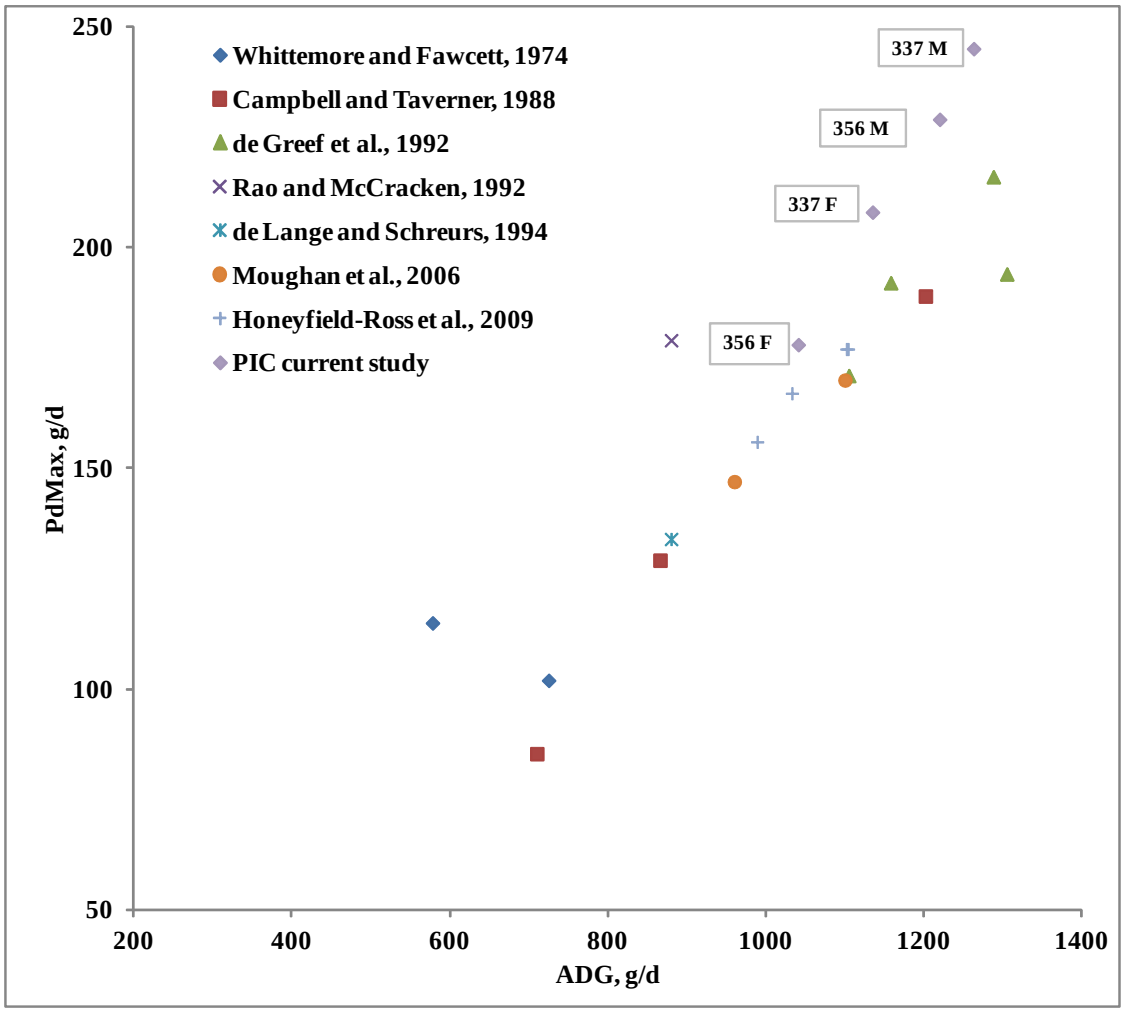

Figure 2. Comparison of the PdMax value of males and females from the two genotypes evaluated in this study with values published in the literature.

Overall, pigs of genotype 337 had a higher average daily gain, better feed conversion ratio, lower Target LP slopes, higher PdMax, lower backfat thickness and larger loin muscle surface area than pigs of genotype 356. This is consistent with the information provided by PIC (PIC, 2011) stating that 337 have been primarily selected for fast lean growth. The genotype 356 is a cross between 337 and Hampshire, thus providing a more robust type of pig with slightly lower growth performance.

The percentage of shoulder, middle and leg varied between genotype and sex, where the genotype 337 pigs and entire males both had the greatest shoulder mass as a percentage; the females had the greatest middle percentage and genotype 356 pigs had the greatest leg percentage. Our findings and the data reported by Cisneros (1996) and (Berard *et al.,* 2010) suggest that the distribution of body mass amongst wholesale cuts differs between genotypes and sex, thus representing an opportunity to tailor genotype to certain markets. The Hampshire breed in the study of Cisneros (1996) and the Hampshire cross (genotype 356) in this study yielded lower shoulder percentages.

Pork quality

PSE pork was not an issue in the current trial as the pH measured in the longissimus muscle 45 minutes post slaughter were all < 6.0 (Sellier and Monin, 1994). The ultimate pH of both genotypes was lower than the value of 5.5-5.6 normally observed for pork. Moreover, pigs of the Hampshire cross genotype (356) had a lower ultimate pH than those of genotype 337 (5.29 vs 5.37). The longissimus muscle of the Hampshire genotype is well documented to have low ultimate pH values which may result in acid meat quality (Sellier and Monin, 1994). This effect was reported (Heuven *et al.*, 2003; Moeller *et al.*, 2003) to be due to the RN-gene which may be present in Hampshire pigs. However, this is unlikely to be the case in the present study as the PIC has removed the RN-gene from its Hampshire lines.

Both genotypes had similar Warner-Bratzler shear force (WBSF) values to those reported for other studies recently conducted in New Zealand with Duroc cross-bred gilts (60 to 80 N; Janz *et al*., 2008) and PIC hybrid gilts (59.55 to 70.12 N; Nuijten, 2010). In a survey of pork tenderness, using the MIRINZ method, conducted in NZ by Rosenvold and Stuart in 2009, it was found that 93% of the 400 samples were very tender or tender, 7% were acceptable and < 1% were tough. Using the data of Purchas *et al.* (2002) who measured shear force by both methods in beef samples, it can be calculated precisely (R^2 = 99.1%) that MIRINZ (kg) = 0.679 × WBSF (kg) – 0.4752, where 1 N = 9.81 kgf. Based on this equation the mean MIRINZ shear force values for 337 and 356 were 4.66 and 4.39 kgf, respectively. Applying the cutting point of Bickerstaffe *et al.* (2001) to data from the current trial, 73% of the pork would be classified as very tender and 27% as tender.

The percentage of IMF in a muscle will influence meat appearance (marbling) and also have an effect on meat tenderness, juiciness and flavour. An optimum level of 2% IMF in the *longissimus* muscle has been proposed (Bejherholm and Barton Gate, 1986). The IMF for 337 and 356, of 0.8 and 0.9%, respectively, were on the low side of values (1.0 to 1.4 %) recently reported for modern genotypes in New Zealand (Morel *et al.*, 2010). The lower than optimal level of IMF in the loin could limit the level of acceptability of sensory characteristics that can be achieved.

Summary

- PIC genotype 337 had better growth performance and higher PdMax values than genotype 356
- Over the entire experimental period (18 to 94 kg live weight) the amount of digestible energy required per kg live weight gain ranged from 24.1 for male pigs of the genotype 337 to 28.9 MJ DE for female pigs of the genotype 356.
- The PdMax values measured in this study ranged from 178 for females of the genotype 356 to 245 g/d for males of the genotype 337.
- No differences in pork meat quality characteristics were observed between the genotypes.

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MASSEY UNIVERSITY

GROWTH POTENTIAL AND MEAT QUALITY OF DIFFERENT PIG GENOTYPES

PART II

Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

Project 2H-10

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Introduction

The genetic merit of pigs is one of the major, if not the foremost factor affecting farm profitability. It is therefore important, at regular intervals, to compare and benchmark the pig genotypes currently used commercially. It is of interest to the pig industry both in New Zealand and Australia to find out how good the current genotypes are and what the potential is for further performance improvement if pigs are fed to their full genetic potential. Moreover, being able to quantify the growth potential of commercially used pig genotypes is required when establishing their nutrient requirements and thus to design feeding strategies which will maximize farm profitability. The challenge here is tailoring the right diet for the right pig.

The underlying micro-traits for the economically important traits of higher average daily gain, lower feed conversion ratio and higher leanness (lower back fat thickness in NZ) are the maximum protein deposition potential (PdMax), and the minimum lipid to protein ratio in the whole body (Target L/P). PdMax represents the maximum daily protein deposition rate (g/d) that can be achieved for a certain type of pig, and Target L/P represents the energy partitioning between lipid and protein deposition when energy intake, but not protein intake is limiting. Target L/P is a function of energy intake only and is independent of live weight (de Lange *et al.*, 2008). Both PdMax and Target L/P are used in growth models to characterise pig genotypes and are usually determined in slaughter or nitrogen balance studies (Moughan *et al*., 2006, Weiss *et al.*, 2004). An alternative to these methods is to record live weight and feed intake in a growth trial, in which pigs are fed specially formulated diets. Feed intake curves are then used as input parameters in the pig growth model and simulations are conducted to determine the combination of PdMax and Target L/P which best fit the observed growth and intake curves. This is the approach that has been followed in the current study.

Pork quality is determined by a number of factors along from the breeding of the pigs through the cooking of the meat by the consumer. Pork quality characteristics can be assessed subjectively by a taste panel made up of trained or untrained people, or by objective measurements of related physico-chemical properties. In this study, we have investigated the following objective parameters that affect both the processing and eating quality of pork: meat colour, amount of intramuscular fat, water holding capacity, shear force, and pH.

The aim of the present study was to evaluate the growth performance and pork quality of a genotype commonly used in New Zealand.

Material and Methods

All procedures involving animals were approved by the Massey University Animal Ethics Committee (MUAEC 10/60).

Animal and Housing

A total of 32 entire males and females from a New Zealand's crossbred genotype (Waratah Farms, Ltd) were included in this trial. The pigs were not specially bred for this trial and were obtained from a commercial farm at 21.9 ± 0.9 kg (live weight ± standard deviation) and transported at the Massey University Pig Biology Unit. The pigs were kept in pens of either eight males or eight females and individually fed the diets as slurry twice daily. Water was available at all times. After a one week adaptation period, the recording of daily feed offered and refused and weekly live weight started.

Diet and Feeding

The pigs were fed two diets (Table 1). The first diet (MinLP) was limiting in energy but not limiting in amino acids, thus in this experimental phase the capacity of the pigs to partition energy between body fat and body protein (minimum lipid to protein ratio, MinLP) was driving growth (Weis *et al*., 2004). This diet was fed restricted and the amount of feed offered per day (kg) was calculated as (11.5 + 0.21 x LW)/13.85. After 6 weeks, their diet was changed to the second diet (PdMax), which was limiting in neither energy nor amino acids and was fed *to appetite*. In this phase of the study, the pig maximum protein deposition potential (PdMax) was limiting growth. The pigs remained on the PdMax diet until being slaughtered.

Slaughter

Once the pigs reached LW ~90 kg, (93.3 ± 3.3 kg they were transported (± 1 hour) to a commercial slaughterhouse (Landmeats Ltd, Wanganui) and rested for at least one hour before being slaughtered. At slaughter P2 back fat thickness and carcass weight were measured. The pH of the *longissimus dorsi* (LD) was measured 45 minutes after slaughter (pH Spear, Eutech Instruments, OAKLON®). The day after slaughter the shoulder, middle and leg from the left part of the pig were weighed. The middle was cut from the cranial end between the 2nd -3rd and between the last and 2nd to last lumbar vertebrae. A short loin was prepared as the caudal part resulting from a cut through the middle between the last and 2nd to last rib. Pictures were taken of the cranial face of the short loin. The *longissimus* muscle plus the overlapping fat and skin from the short loin was then boned out, vacuum packed, taken back to Massey University, stored first for 7 days in a chiller (2 ± 1ºC) and then transferred to a freezer (-30 ± 2ºC) until required for further meat quality assessments.

Table 1. Diet composition of the two experimental diets

Ingredient Liveweight range (kg)	MinLP diet, % 24-52	PdMax diet, % 52-93
Barley	66.6	62.55
Soybean meal	24	28
Fish meal	4	0
Soybean oil	1	5
Lysine	0.3	0.35
Methionine	0.3	0.3
Threonine	0.2	0.2
Tryptophan	0.05	0.05
Vitamin+mineral premix[1]	0.3	0.3
Dicalcium phosphate	3	3
Disodium phosphate	0.15	0.15
Salt	0.1	0.1
Nutrient composition[2]		
DE (MJ/kg)	13.85	14.81
True digestible lysine, g/kg	12.6	12.0
Lysine/DE ratio	0.91	0.81

[1] Vitalean; Vitec Nutrition, 2/20 Kerwyn Avenue, East Tamaki, Auckland, NZ
[2]Calculated composition from Morel *et al.*, 1999.

Chemical analyses

The diets were analysed in duplicate at the nutrition laboratory at IFNHH, Massey University for dry matter (DM), GE, protein and amino acid content, fat, ash and neutral detergent fibre (NDF). The methods used are given in Table 2.

Table 2. Laboratory methods used for diet analysis (AOAC, 2005).

Dietary constituent tested	Method and Particulars	AOAC Standard Reference
Dry Matter	Convection oven 105°C	AOAC 930.15, 925
Gross Energy	Bomb calorimetry	n/a
Protein	Leco total combustion method	AOAC 968.06, N-P=6.25
Fat	Soxtec extraction	AOAC 991.36
Ash	Furnace 550°C	AOAC 991.36
Neutral Detergent Fibre	Tecator Fibretec System	AOAC 2002.04
Amino Acids	HCl acid hydrolysis followed by HPLC separation	AOAC 994.12
Cysteine and Methionine	From performic acid oxidation	n/a

Loin measurements

Measurements on pictures of loin were taken using a Placom KP-90N digital planimeter and a milli-metric ruler. The loin width and depth, back fat depth, lean surface area (LSA) and back fat surface area (BFSA) were measured and ratio LSA/BFSA was calculated.

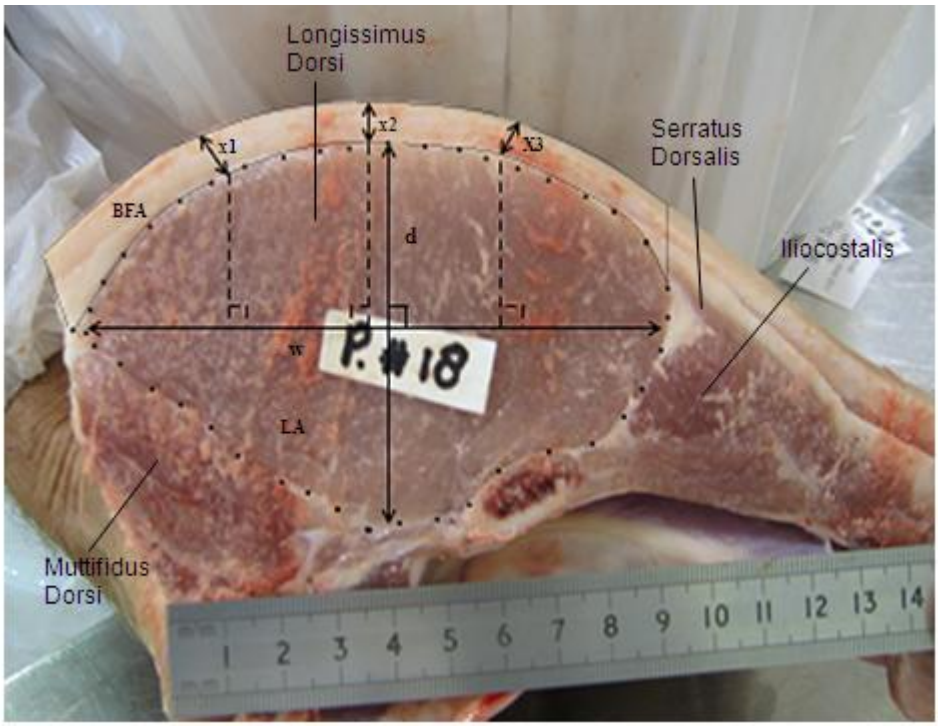

Figure 1 Location of the measurements taken on the loin pictures: d = depth(cm); w = width (cm); LSA = longissimus muscle surface area (cm^2) (inside ••• area); BFSA = back fat surface area (cm^2) (inside - - - area); x1-x3 = back fat depth (mm).

Meat quality analyses

The back fat and skin were removed from the loin and different parts of the loin were used for measuring colour, shear force, drip losses, intramuscular fat (IMF), ultimate pH, sarcomere length, and water holding capacity (WHC) (Figure 2.).

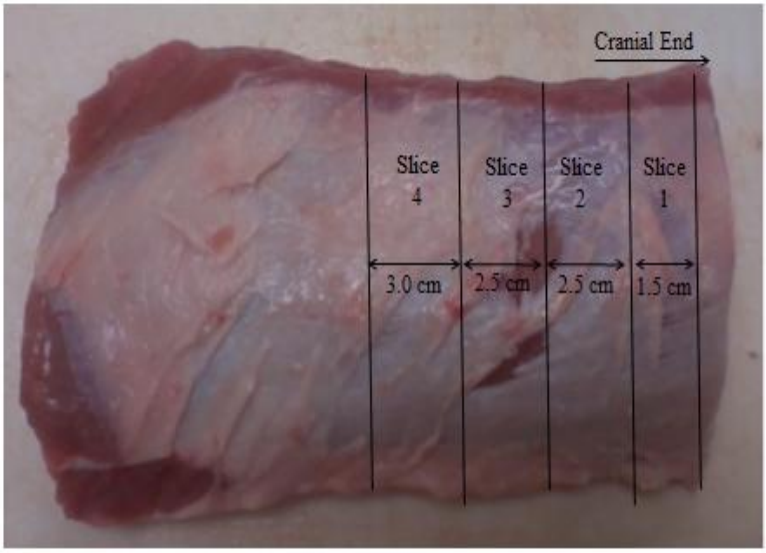

Figure 2. The first cut was to square off the cranial end. Slice 1 was used for colour, sarcomere length, pH and expressed juice loss assessments. Slices 2 and 3 were to measure cooking loss and shear force . Slice 4 was used for drip loss and IMF assessments.

Colour

A sample was cut from the pale end of slice 1, placed in a sealed bag and stored frozen. When required for testing the samples were thawed in the chiller (whilst still remaining in their sealed bags), then pulled out of the bag and cut in half with a knife to expose the internal surface to the air at room (18-20°C) temperature for ~30minutes. Then a petri dish was placed and lightly squashed on the upper surface of the sample. This was to keep the chromometer clean. Then each sample was measured twice (once each half) with a chromometer. The chromometer model used was the Minolta CR-200 which had a 10mm diameter aperture and was calibrated against a white standard for values: lightness (L^*) = 97.55, redness (a^*) = −0.52 and yellowness (b^*) = 2.60 The petri dish was cleaned after every fifth sample with distilled water and dried with a paper towel.

Ultimate pH

The pH was measured with a digital pH meter with temperature compensation. The pH meter was calibrated for pH7 and pH4 with standard solutions which were 2 ± 1ºC first prior to the sample being measured. An internal (core) sample of 2.0-2.5 g of pork was taken from slice 1 and homogenised with 10 ml 150 mM potassium chloride (KCl) as described by Purchas and Zou (2008). Once the sample was homogenised the pH was recorded.

Expressed juice loss

An internal single sample of 500 ± 20 mg was taken from slice 1 and placed on a piece of Whatman number one filter paper (11 cm diameter). The filter paper was pressed between two Perspex plates and a 10 kg weight was placed on the top for 5 min. Once 5 minutes was reached the weight was removed, the area of the squashed pork was drawn with a pen and the area of the moisture on the paper was measured by a Placom Digital Planimeter KP-90N as described by Purchas (1990). The expressed juice loss was then calculated by the following formula:

Expressed juice (cm^2 / g) = [Outside wetted area (cm^2)] / [Sample wt (g)]

Sarcomere Length

A sliver of the dark part of the pork sample was cut 8-10 mm along the length of the muscle fibres and 1×1mm cross section with a scalpel blade. The sliver was then teased-out with a scalpel blade to increase the surface area of the sample and then transferred to a microscope slide. About 2-3 droplets of distilled water was added to the sample and a second microscope slide was pressed on top; squashing the sample between the two microscope slides. The microscope slide was then placed on a holder, so that the sample was 100 mm from the white surface. A He-Ne laser was passes through the sample. The sample in the holder was rotated until 3 bands were clearly visible. The distance between the first order diffraction bands was measured, and 12 measurements per sample were used to calculate the mean distance (mm). The following formula was used to calculate the sarcomere length (SL) in micrometres (µm):

$$SL(\mu m) = 0.6328 \times \left[\sqrt{\left(\left(\frac{x}{10 \times 2}\right)^2 + 100\right)}\right] / \left(\frac{x}{10 \times 2}\right)$$

x = The calculated mean distance between the first-order diffraction bands (mm)

Cooking losses and shearforce measurement

Slices 2 and 3 (2.5 cm thick) were placed into a 150 × 250 ml plastic bag and weighed prior to cooking. The sample was then suspended in a water bath at 70ºC for 90 min. Each sample was then drained for 5 minutes, and placed in the chiller (2ºC) overnight (~20 hours). The following morning the sample was dried on a paper towel and reweighed as described by Purchas, Burnham and Morris

(2002). The following equation was used to calculate the cooking losses:

$$Cooking\ Loss\ (\%) = \frac{Raw\ weight\ (g) - cooked\ weight\ (g)}{Raw\ weight\ (g)} \times 100$$

These cooked samples were then subjected to a meat toughness test using the Warner-Bratzler Shear Force machine (WSFM). Six cores were prepared that run parallel to the muscle fibres in length with a 13 × 13 mm cross section. Each of the 6 cores were sheared twice (approx. 1/3 and 2/3 along the length of each core) yielding a total of 12 shear values per sample as described by Purchas (1990).

Drip loss

Slice 4 was trimmed (intermuscular fat removed) and cut into a cube measuring approximatively 3 cm^3. The sample was weighed, put on a metal hook, placed in a 150 × 250 mm plastic bag and hung in the chiller at 2 ± 1ºC. Each sample was reweighed after 24 and 48 hours as described by Edens, Lyons and Jacques (1996). Drip loss was calculated by the following equation:

$$Drip\ loss\ (\%) = \frac{Original\ weight\ (g) - end\ weight\ (g)}{Orignal\ weight\ (g)} \times 100$$

End weight (g) = drip loss weight (g) after either 24 or 48 hours.

Intramuscular fat

A trimmed ~40 g sample was taken from slice 4 of the loin and placed in a sealed plastic bag and stored in the freezer. The frozen sample was minced with a knife, placed in a new sealed plastic bag and weighed before being freeze dried. The freeze dried sample was weighed, ground and the fat content quantified by solvent extraction (petroleum ether, BP 40-60 ^{o}C using a Soxtec apparatus (AOAC 911.36).

Calculation of Target L/P and Pdmax.

According to de Lange *et al.* (2008) Target L/P is a linear function of daily digestible energy intake (DEi):

Target L/P = α × DEi

where the slope α is specific to a genotype

Between 20 and 50 kg LW, the pigs were restricted fed so that energy was the limiting factor and growth was driven by Target L/P. Then, between 50 and 95 kg LW, the pigs were fed to appetite a diet which was not limiting in either energy of amino acids, and growth was driven by Pdmax.

In each period the total digestible energy intake (TDEi) and the change in empty body weight (δEBW = EBWe − EBWs) were measured. The growth model equations were used to derive two equations with two unknown variables, namely the increase in whole body protein mass (δP) and the increase in whole body lipid mass (δL)

1) TDEi (MJ) = DEM + DEPM + DEG

Where:
Digestible energy for maintenance:
DEM (MJ) = $\int_{lws}^{Lwe}$ 0.5 x $LW^{0.75}$ / average daily gain (ADG, kg/d)
with *Lws*= liveweight at the start and *Lwe*= liveweight at the end

Digestible energy content of maintenance protein:
DEPM (MJ) = (Basal + integument losses) × 24 /1000

Basal (g) = 11.8 × total dry matter intake
Integument losses (g) = $\int_{lws}^{Lwe}$ 0.093 x $LW^{0.75}$ / ADG

Digestible energy for growth: DEG (MJ) = δP × 43.9 + δL × 52.8

2) TDEi (MJ) = DEM + DEPM + δP × 43.9 + δL × 52.8

3) δEBW (kg) = EBWe − EBWs

Where:
Empty body weight (EBW) = Live weight – gut fill = LW − 0.277 × $LW^{0.612}$

EBW = Body Protein +Body Lipid + Body Water + Body Ash

δEBW (kg) = $P_e + L_e + W_e + A_e - P_s - L_s - W_s - A_s$ = δP + δL + δA + δW

Water $W = 5.202 \times P^{0.855} \Rightarrow \delta W = a \times \delta P$; the factor a is estimated by the slope of the first derivative of the water function at an average P over each experimental phase.

$Ash = 0.189 \times P \Rightarrow \delta A = 0.189 \times \delta P$

4) **$\delta EBW\ (kg) = \delta P \times (1 + 0.189 + a) + \delta L$**

Equations **2** and **4** are solved for δP and δL

Daily protein deposition (Pd) is δP divided by number of days in the period, and lipid deposition (Ld) is δL divided by number of days in the period.

The target LP slope α is $\delta L / \delta P$ per unit of daily digestible energy intake in the first phase of the experiment and Pdmax is Pd in the second phase of the experiment

Statistical analysis

A linear model with sex as fixed effect was fitted to the data.

Results

The chemical analysis of the experimental diets is presented in Table 3.

Table 3. Chemical composition of the experimental diets.

	Diet	
On a as received basis	Minlp	PdMax
DM, g/kg	895	885
GE, MJ/kg	16.22	17.03
Protein, g/kg	236	207
Fat, g/kg	25	65
Ash, g/kg	77	65
Neutral detergent fibre, g/kg	134	136
Aspartic acid, g/kg	19.8	18.7
Threonine, g/kg	9.8	8.6
Serine, g/kg	8.7	8.4
Glutamic acid, g/kg	39.1	37.2
Proline, g/kg	16.3	13.7
Glycine, g/kg	9.8	7.8
Alanine, g/kg	9.1	7.8
Valine, g/kg	11.4	10.5
Isoleucine, g/kg	9.2	8.6
Leucine, g/kg	15.4	14.4
Tyrosine, g/kg	6.6	6.2
Phenylalanine, g/kg	10.5	10.1
Histidine, g/kg	5.7	5.1
Lysine, g/kg	14.0	13.3
Arginine, g/kg	13.2	11.9
Cysteine, g/kg	3.5	4.0
Methionine, g/kg	6.1	6.0

The growth performance data as well as Target LP slope and PdMax values are presented in Table 4. In each phase of the experiment male pigs grew faster ($P < 0.01$), had better feed conversion ratio ($P < 0.01$), a lower Target LP slope ($P<0.001$) and a higher PdMax than females pigs ($P<0.01$).

The results for the carcass measurements are presented in Table 5. Male Pigs had less backfat ($P<0.01$), a lower percentage of the carcass as middle ($P<0.001$) and a higher percentage of the carcass as shoulder ($P<0.001$) than female pigs.

No statistically significant differences between sexes were observed for the loin pictures measurements (Table 6).

Male pigs has more cooking losses ($P<0.05$) and a redder meat than female pigs ($P<0.01$), but no other differences in meat quality parameters were observed between sexes (Table 7).

Table 4. Least-squares means for growth performance data.

	Sex			
	Female	Male	SE	P value
MinLP evaluation				
n	15	16		
LW start, kg	24.4	24.8	0.33	0.40
ADG (g/d)	628	678	12	0.008
Daily Feed Intake, (g/d)	1324	1324	13	0.992
FCR	2.11	1.96	0.03	0.002
LW diet change, kg	50.8	53.3	0.58	0.005
Target LP slope	0.056	0.043	0.0023	0.000
PdMax evaluation				
ADG, g/d	1039	1120	20	0.009
Feed Intake, g/d	2473	2522	25	0.175
FCR	2.39	2.26	0.03	0.007
LW slaughter, kg	92.3	94.3	0.81	0.10
PdMax, g/d	159	179	4.6	0.005
Overall				
ADG, g/d	828	883	13	0.006
Daily Feed Intake, g	1884	1882	14	0.928
FCR	2.28	2.14	0.03	0.007

Table 5. Least-squares means for slaughter and carcass measurements.

	Sex			
	Female	**Male**	**SE**	***P value***
n				
Carcass weight, kg	71.2	72.7	0.69	0.14
P2 BF depth(mm)	10.7	9.1	0.35	0.005
Dressing %	77.2	77.1	0.24	0.96
pH, 45 min PS	6.44	6.32	0.53	0.111
Left side carcass cuts				
Shoulder, kg	9.5	10.2	0.15	0.003
Middle,kg	15.6	14.6	0.16	0.000
Leg, kg	10.2	10.9	0.09	0.000
Shoulder, %	30.7	32.7	0.31	0.000
Middle, %	36.0	34.0	0.28	0.000
Leg, %	33.2	33.4	0.31	0.723

Table 6. Least-squares means for loin-picture analysis.

	Sex			
	Female	**Male**	**SE**	***P value***
n				
LM[1] width, cm	9.3	9.3	0.13	0.95
LM depth, cm	5.4	5.4	0.13	0.89
BF depth, mm	8.3	7.5	0.4	0.215
LM Lean surface area (LSA), cm^2	34.9	34.6	1.26	0.878
Backfat surface area, (BFSA), cm^2	9.2	8.2	0.23	0.09
LSA:BFSA (log10)	3.83	4.38	0.22	0.103
Back-transformed				

[1] LM= Longissimus muscle

Table 7. Least-squares means for meat quality characteristics.

	Sex (S)			
	Female	**Male**	**SE**	***P value***
n	15	16		
Ultimate pH	5.39	5.39	0.014	0.775
Driploss 24h, %	12.5	12.6	0.82	0.934
Driploss 48h, %	14.3	14.6	0.81	0.800
Cooking losses, %	29.6	31.3	0.50	0.024
Expressed Juice Loss, (cm^2/g)	37.9	38.0	1.10	0.975
Sarcomere length, µm	1.67	1.69	0.13	0.379
Shear Force Test				
Mean, N	23.3	22.9	0.90	0.775
Peak F, N	77.4	79.1	3.58	0.738
Colour Test				
L^*(lightness)	49.2	50.0	0.35	0.128
a^*(redness)	7.9	7.0	0.22	0.005
b^* (yellowness)	3.5	3.4	0.19	0.714
Intramuscular fat %	1.17	1.01	0.08	0.154

Discussion

Growth performance and carcass composition

There are many ways to describe the partitioning of energy retained between Pd and Ld for grower-finisher pigs. In the review written by de Lange *et al*. (2008), it was concluded that a simple positive linear relationship existed between DEI and Target L/P: Target L/P = $\alpha \times$ DEI. This was sufficient to predict the effect of energy intake on body composition provided the diet is limiting in energy, but not limiting in protein/amino acids during the energy-dependant phase. The slope (α) value is unique to a specific pig genotype. This conclusion was made after re-analysing data from 13 different trials where the slopes ranged between 0.020 and 0.048.

The slope of the genotype investigated in the current study (0.0495) was found to be on the high site of the values reported by de Lange *et al*., (2008) for 13 genotypes (Figure 1). The slope would be expected to be lowest for entire males compared to females within the same genotype because entire males are the leanest (or least fat) compared to females and castrated males. The findings of the current trial support this with males having lower slope values than females (0.043 vs 0.056).

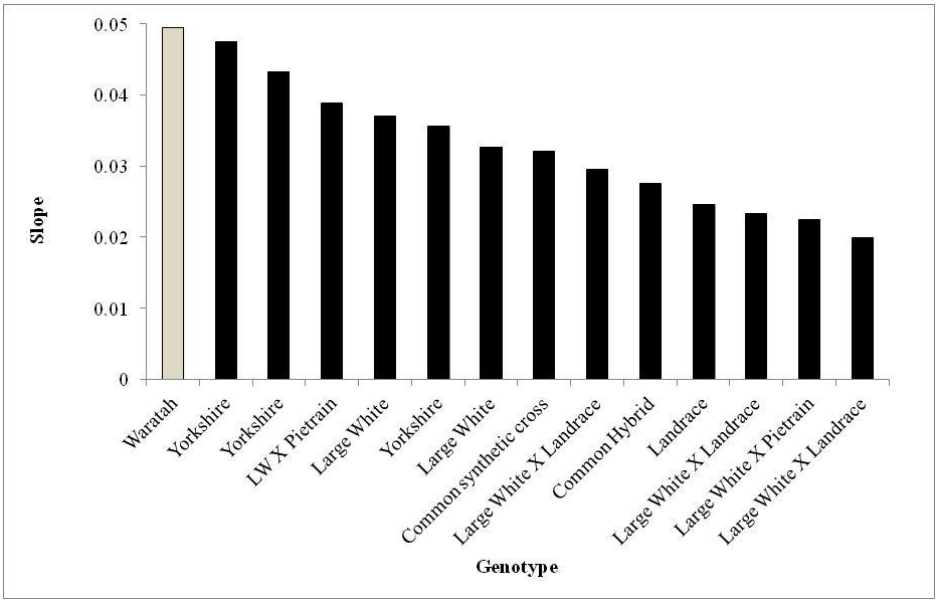

Figure 1. Comparison of the Target MinLP slopes for the genotype evaluated in this study (Waratah) with values published by de Lange *et al.* (2008, data from Tables 14.2 and 14.5).

PdMax is unique to genotype and constant between LW of 20 kg until the pigs start to mature after which PdMax starts to decline (de Lange *et al*,. 2008). In Figure 2, the PdMax and ADG values observed in the current trial are compared with values reported for eight other trials. The PdMax values for male and female pig of the commercial genotype investigated in this study are in the middle to top of the range of the values reported in the other trials shown in Figure 2. This is consistent with the trend that the more recent genotypes are leaner and have better growth performance traits

compared to older genotypes. Knap and Rauw (2008) reported that PdMax increased from 110 g/d in 1970 to 230 g/d in 2004.

Previous trials which have evaluated PdMax have done so using diets with lysine as the first limiting amino acid over several different levels in nitrogen balance, serial slaughter and growth trials. In the current trial, PdMax was calculated (using the calculation rules of the Massey Pig Growth Model www.porkmaster.org) from a growth trial in which all the pigs were offered the same diet, not limiting in either energy or protein/amino acids which and offered to appetite at each scheduled meal time

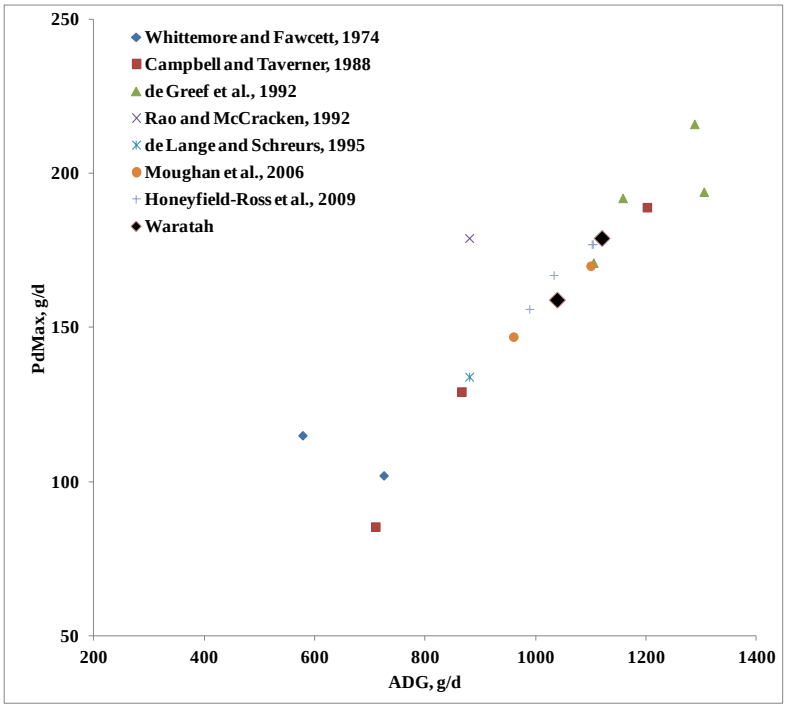

Figure 2. Comparison of the PdMax value of males and females from the genotype evaluated in this study (Waratah) with values published in the literature.

Overall, male pigs had a higher average daily gain, better feed conversion ratio, lower Target LP slopes, higher PdMax and lower backfat thickness than female pigs.

The percentage of shoulder, middle and leg varied between sexes, where entire males had the greatest shoulder mass as a percentage. Our findings and the data reported by Cisneros (1996) and Berard *et al.*, (2010) suggest that the distribution of body mass amongst wholesale cuts differs between genotypes and sex, thus representing an opportunity to tailor genotype to certain markets.

Pork quality

PSE pork was not an issue in the current trial as the pH measured in the longissimus muscle 45 minutes post slaughter were all < 6.0 (Sellier and Monin, 1994). The ultimate pH of both sexes was lower than the value of 5.5-5.6 normally observed for pork.

Both sexes had similar Warner-Bratzler shear force (WBSF) values to those reported for other studies recently conducted in New Zealand with Duroc cross-bred gilts (60 to 80 N; Janz *et al.*, 2008) and hybrid gilts (59.55 to 70.12 N; Nuijten, 2010). In a survey of pork tenderness, using the MIRINZ method, conducted in NZ by Rosenvold and Stuart in 2009, it was found that 93% of the 400 samples were very tender or tender, 7% were acceptable and < 1% were tough. Using the data of Purchas *et al.* (2002) who measured shear force by both methods in beef samples, it can be calculated precisely (R^2 = 99.1%) that MIRINZ (kg) = 0.679 × WBSF (kg) – 0.4752, where 1 N = 9.81 kg. Based on this equation the mean MIRINZ shear force values for males and females were 5.00 and 4.99 kg, respectively. Applying the cutting point of Bickerstaffe *et al.* (2001) to data from the current trial, 62.5 % of the pork would be classified as very tender and 37.5 % as tender.

The percentage of IMF in a muscle will influence meat appearance (marbling) and also have an effect on meat tenderness, juiciness and flavour. An optimum level of 2% IMF in the longissimus muscle has been proposed (Bejherholm and Barton Gate, 1986). The IMF for male and female of 1.0 and 1.2 %, respectively, were within the range of values (1.0 to 1.4 %) recently reported for modern genotypes in New Zealand (Morel *et al.*, 2010). The lower than optimal level of IMF in the loin could limit the level of acceptability of sensory characteristics that can be achieved.

Summary

- Male pigs had better growth performance and higher PdMax values than female pigs
- Over the entire experimental period (25 to 93 kg live weight) the amount of digestible energy required per kg live weight gain were 30.9MJ DE for male pigs and 33.0 MJ DE for female pigs.
- The PdMax values measured in this study were 159 g/d for female pigs and 179 g/d for male pigs.
- No major differences in pork meat quality characteristics were observed between the sexes.

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