Effect of breed, finish weight and sex on pork meat and eating quality and fatty acid profile

by

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March 2011

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge joint funding for this research from Pig ReGen Ltd (who funded the production performance aspects of the study) and the British Pig Executive (BPEX) (who funded the investigations into meat and eating quality) and the Department of Agriculture and Rural Development for Northern Ireland (DARDNI). The authors also wish to acknowledge the pig unit staff at AFBI Hillsborough, Food Chemistry staff at AFBI Newforge and AFBI Biometrics, in particular David Kilpatrick and Sally Dawson for statistical analysis.

The Agricultural Research Institute of Northern Ireland was amalgamated with DARD Science Service to become the Agri-Food and Biosciences Institute (AFBI) on 1st April 2006.

1. Executive Summary

By 2007 the terminal sire breed that was commonly used in Northern Ireland had changed from Landrace to Pietrain or Tempo due to the onset of Post Weaning Multi Systemic Wasting Syndrome (PMWS). A study was instigated which aimed to examine the production and carcass performance of pigs representative of these breeds. In addition, the meat and eating quality of pork from these pigs was investigated. In total 960 pigs representing genetics from the Landrace, Tempo, Pietrain (Austrian line) and Pietrain (Belgium line) breeds (available in Northern Ireland) were reared under normal commercial conditions. Meat samples from 253 of these pigs (boars and gilts) with finish weights categorised as either light (average 95 kg), medium (average 104 kg) or heavy (average 113 kg) within each breed were taken for meat quality analysis. Ninety six of these samples (12 boars and 12 gilts per breed representing an even spectrum of finish weights between 95 and 115 kg) were also used to test for effects of sex, breed and finish weight on eating quality. A total of 39 meat samples from pigs with heavy finish weights were also analysed to test for effects of breed on the fatty acid profile of the pork. The highest growth rate during finish was attained from Tempo pigs. However, the carcass performance of Pietrain pigs (both Austrian and Belgium lines) was superior to that of the Landrace or Tempo pigs. Financially, a similar margin over feed was attained using Tempo and Pietrain (Austrian) pigs when growth and carcass performance were considered. Sex had little effect on the meat or eating quality of the pork. Finish weight had no effect on eating quality although meat from heavy pigs (which were also fatter and faster growing) had lower Warner-Bratzler Shear Force (WBSF) and cooking loss than meat from light weight pigs. Overall, breed had a more prominent effect on meat and eating quality than sex or finish weight. Meat from Pietrain pigs had a lower WBSF and higher drip loss than meat from Landrace or Tempo pigs. There was a three way interaction between sex, breed and finish weight on the colour measurements of a* and hue angle but overall, meat from Landrace pigs had the lowest a*, b* and Chroma and highest Hue angle. Meat from the Landrace and Pietrain (Belgium) pigs had a higher score (were less acceptable) for flavour ($P < 0.05$) and aftertaste ($P < 0.001$) than meat from the Pietrain (Austrian) or Tempo pigs.

Therefore, optimum production performance was attained using the Tempo and Pietrain (Austrian) pigs, and it appears that the meat and eating quality of pork from the Pietrain

(Austrian), and in particular the Tempo bred pigs was better than that from the Landrace bred pigs. It is suggested that breed had a larger influence on meat and eating quality than sex or finish weight. It also appears that the fast growth rate of the Tempo bred pigs was not detrimental to the meat or eating quality of the pork. However, overall the eating quality of the pork was considered only satisfactory (average score of 3.5 on an 8 point scale) which indicates that further improvement is required.

2. Introduction

A large number of studies focusing on the meat and eating quality of pork in relation to breed have looked at the effect of the Halothane (Hal) gene, commonly found in the Pietrain breed (Ngapo and Gariepy, 2008). While the growth rate of pigs carrying the Hal gene is often superior to those not carrying the gene, pigs carrying the Hal gene are susceptible to stress ('Porcine Stress Syndrome') which results in a hypersensitivity to various stressors e.g. transport and pre slaughter. In Hal positive pigs, this hypersensitivity causes a rapid rate of pH decline post-slaughter while muscle temperature is still high which results in Pale, Soft and Excuditive (PSE) pork. However, dedicated breeding programmes have aimed to eliminate the Hal gene from the Pietrain breed whilst maintaining the ability for fast lean growth.

Processors are also encouraging producers to take pigs to carcass weights up to 90 kg which equates to a live weight of approximately 118 kg. However a number of studies tend to suggest that eating quality (juiciness, tenderness and flavour) is better from pigs slaughtered at lighter weights (41-60 kg vs 91-100 kg, Ramaswami *et al*., 1993; 80 kg vs 120 kg Ellis *et al*., 1996; 100 vs 130 kg Candek-Potokar *et al.*, 1998). Lighter weight animals are normally younger or slower growing. Meinert *et al*. (2007) noted that meat from older animals is normally tougher than meat from young animals due to a higher degree of collagen cross-linking (Ellis and McKeith, 1995). However, with major genetic advances which have significantly increased the growth rate of pigs, heavier slaughter weights can now be achieved within shorter time frames i.e. with younger pigs.

The main reason for conducting the current study was due to the fact that the breed of terminal sire used in Northern Ireland changed dramatically during 2004/2005. Historically, the terminal sire breed of slaughter generation pigs in Northern Ireland was Landrace or Large White. However, during 2003-2005, Post Weaning Multi Systemic Wasting Syndrome (PMWS) afflicted many herds. At that time anecdotal evidence suggested that the Tempo (a synthetic breed containing ~ ¼ Pietrain genetics and ¾ Large White genetics) and Pietrain breeds were 'resistant' to PMWS. Terminal sires within the Tempo and Pietrain breeds therefore became commonly used. A production study by Magowan and McCann (2009) indicated that the performance (daily gain and feed conversion ratio during finish) of pigs representing the Tempo and Pietrain breeds was superior compared with that of pigs representing the traditional Landrace breed. Furthermore the carcass performance (kill out percentage and lean meat percentage) of Pietrain pigs was superior to that of Landrace or Tempo pigs. The work by Magowan and McCann (2009) also took a representative sample of pigs from each breed to various finish weights (95, 105 and 115 kg live weight) and found that the back fat depth of Pietrain and Tempo pigs remained within code 1 (=/<14mm back fat depth at P_2) whereas that of Landrace pigs was over 14mm when finish weights were 105 kg or over. Overall, considering production and carcass performance characteristics, Pietrain (Austrian Line) and Tempo pigs were found to provide the highest margin over feed costs. However, little was known about the meat and eating quality of pork from the different breeds, in particular the Tempo bred pigs, and when these pigs were taken to different finish weights.

Therefore, the main aim of this study was to compare the meat and eating quality of pork representing either Tempo, Pietrain (Austrian), Pietrain (Belgium) or Landrace breeds. In addition, the effect of increasing the finish weight (from 95 to 115 kg) on the meat and eating quality of pork from each breed was investigated. Kim *et al.* (2008) reported that the breed of pig can have an effect on the fatty acid composition of pork. The opportunity was therefore taken to compare the fatty acid profiles of the pork from the different breeds.

3. Materials and methods

3.1 Production management

3.1.1 General health status of herd

The herd (AFBI Hillsborough) operated a three-week batch farrowing system and over the course of the three weeks, an ‘all in/all out’ policy. The breeding herd was vaccinated against Parvo virus, Erysipelas and was routinely wormed. All progeny were also vaccinated against pneumonia. The herd showed signs of having PMWS for a time during 2004 and the mortality of the finishing pigs rose to approximately 7%. The pigs used in the experiment were born between January and July 2007. No signs of PMWS were evident in the herd during 2006 (average mortality 1.6%) and during the experiment the mortality of the post weaned pigs (to 10 weeks of age) was 1% and that of the finishing pigs was 1.5%.

3.1.2 Genetic background

Dams were $^{1}/_{2}$ Landrace x $^{1}/_{2}$ Large White F1. The sire line breeds included Landrace, Tempo, Pietrain (Austrian line) and Pietrain (Belgium line). The sire line breeds were sourced from the 3 main breeders in Northern Ireland (Deerpark Pedigree Pigs, Glenmarshall Pedigree Pigs and Elite Sires). Each breeder provided semen from a specific line within their herd which they considered ‘the best’ i.e. all Landrace semen came from the same breeder and line of genetics over the course of the experiment. Dams were artificially inseminated within a 3-week batch farrowing system. All progeny were weighed and individually identified at birth. All progeny were weighed again at weaning (28 days of age) and the performance of a representative proportion of pigs within each breed was monitored from weaning to finish.

3.1.3 Reproductive and growth performance

Over 12 time replicates a total of 192 sows were inseminated with semen from one of the above sire line breeds. Dam parity was balanced for each sire line breed. Pre-weaning pigs were offered starter 1 diet from 18 days of age. In total 960 pigs (240 per sire line breed) were used to determine effects of breed on lifetime pig performance. Pigs were weighed at weaning (28 day +/- 2 days of age) and for each breed 20 pigs per replicate were selected on the basis of weight and sex to represent the average pigs weaned respective of sire line breed. Pigs of the same sire line breed were penned together (groups of 20 balanced for sex (boars and gilts)) from weaning to finish. Pigs were transferred at 10 weeks of age from combined stage 1/stage 2 accommodation to finishing accommodation. All pigs were offered the same diets from weaning to finish (Table 2) in the same accommodation using the same feeder types. Pigs were weighed and feed intakes were recorded at 7, 10, 12, 15 and 20 weeks of age. Pigs were weighed weekly thereafter and sent for slaughter at a target finish weight of 105 kg. Their growth performance on an individual basis and feed intake and feed conversion ratio, on a pen basis, was recorded from weaning to finish. Their carcass quality (cold weight, back fat depth at P_2, Kill out % and lean meat %) was also recorded on an individual pig basis. Reproductive, lifetime (birth to finish) and carcass performance respective of the four sire line breeds are reported by Magowan and McCann (2009). The dietary ingredients and nutrient composition of the diets offered throughout the trial are presented in Table 1.

3.1.4 Slaughter protocol

Pigs were weighed and slap marked on the day prior to slaughter. Pigs were offered feed *ad libitum* up to the point when they were removed from the pen. Pigs were removed from their pens and loaded onto a lorry at 8.00 am. Pigs from different pens would have been mixed at this stage. The journey to the abattoir took 1 hr and pigs were held in lairage for 1 hr. Water was sprayed over the pigs while they were in lairage. Pigs were stunned using CO_2 gas before exsanguination. After slaughter, pigs were subjected to standard factory procedures. The hot weight and back fat depth of the empty pig carcasses were measured 45 minutes post slaughter. The back fat depth was measured 65 mm from the top line at the level of the last rib (P_2) using the Ulster Grading probe. Carcasses were then chilled rapidly and were held at 2-4°C for 24 hr after which they were de boned and split into primal cuts.

Table 1 The ingredients and chemical composition of the diets used from weaning to finish

	Diet			
	Starter 1	**Starter 2**	**Grower**	**Normal Finisher**
Ingredient (g/kg)				
Wheat	✓	✓	**700**	**360**
Barley				**394**
Maize	✓	✓		
Cooked cereal	✓	✓		
Soya	✓ **(Toasted)**	✓ **(Toasted)**	**217**	**188**
Rice Protein	✓	✓		
Sugar		✓		
Whey	✓	✓		
Molaferm			**30**	**20**
Vegetable Oil Blend				**10**
Soya Oil	✓	✓	**20**	
Limestone	✓	✓	**11**	**11.5**
Mono DCP	✓	✓	**7.5**	**6.1**
Salt	✓	✓	**1.5**	**2.8**
Lysine	✓	✓	**4.6**	**2.3**
Methionine	✓	✓	**1.4**	**0.4**
Devicare (Mins and vits)	✓	✓	**5**	**5**
Emulsifier		✓		
Lignosulphate binder	✓	✓		
Chemical analysis as formulated				
Dry matter (g/kg)	**904**	**888**	**867**	**870**
Digestible energy (MJ/kg)	**15.8**	**15.5**	**14.0**	**13.5**
Crude protein (g/kg)	**200**	**200**	**186**	**167**
Oil A (g/kg)	**9.7**	**8.4**	**32**	**25**
Fibre (g/kg)	**18**	**22**	**24**	**34**
Ash (g/kg)	**65**	**55**	**48**	**48**
Total lysine (g/kg)	**16**	**15**	**12**	**9.5**

[1] The diets were commercially manufactured by Devenish Nutrition Ltd (Belfast) (Starter Diets 1 & 2) and John Thompson and Sons Ltd (Grower, Normal and Special Finisher). The exact amount of each ingredient cannot therefore be disclosed, however a 'tick' represents the presence of the raw material in the diet.

3.2 Meat quality

Whilst the majority of pigs were taken to live weights of 105 kg, a sub-section of pigs from those described above were identified and sent for slaughter at target weights of either 95 (Light), 105 (Medium) or 115 kg (Heavy). The number of pigs, and therefore meat samples analysed representative of sex, breed and finish weight is outlined in Table 2. These pigs were selected from groups spanning the 12 replications and as such were slaughtered across 12 days. After the 24 hr chilling period and dissection into the primal cuts, representative chops from the *longisimus dorsi* of each pig carcass were removed and meat quality analysis was performed on the fresh pork chops. Warner-Bratzler Shear Force (WBSF) (tenderness), colour, drip loss, cooking loss and ultimate pH were determined as described by Beattie *et al*. (1999). REML analysis (Genstat Version 12) was used to test for effects of sex, breed and finish weight on the meat quality parameters and the production parameters (ADG between weaning and finish, back fat depth at P_2 and cold weight) of the pigs from which the meat samples were taken. No covariates were applied.

Table 2 The average age of pigs and number of meat samples analysed respective of sex, breed and finish weight

		Light		Medium		Heavy	
		Av. Age (days)	**No. samples**	**Av. Age (days)**	**No. samples**	**Av. Age (days)**	**No. samples**
Boars	**Landrace**	153	8	156	17	161	11
	Pietrain (Austrian)	154	8	156	11	157	10
	Pietrain (Belgium)	153	10	156	9	163	6
	Tempo	142	7	149	12	154	14
Gilts	**Landrace**	152	9	156	9	166	8
	Pietrain (Austrian)	152	13	156	12	157	9
	Pietrain (Belgium)	153	10	158	14	164	10
	Tempo	146	9	152	13	151	14

3.3 Eating quality

In total, 96 samples were selected from those above (Section 3.2) to evaluate the effect of breed, sex and finish weight on eating quality. Pork samples from twenty four pigs (12 boars and 12 gilts representing a range of finish weights between 95 and 115 kg) were selected within each sire line breed. In general, within each breed and sex, samples represented pigs with finish weights differing by 2 kg e.g. one sample represented a finish weight of 95 kg, the next 97 kg, the next 99 kg etc. until 117 kg. At 7 days post slaughter the *longisimus dorsi* (LD) was dissected from the pork loin of the pigs selected for eating quality analsysis. The LD was trimmed free of external fat and connective tissue. The LD was sliced into 25 mm steaks, packed into vacuum pack bags (5 steaks to a bag) and after vacuum packing the steaks were blast frozen at -18^{o}C and stored frozen (-20 to -25^{o}C) until required for sensory analysis. After defrosting, steaks were cooked on a clam type grill (Silesia) at a plate temperature of 200^{o}C for 6 minutes, to a final end point temperature of 75^{o}C to 80^{o}C. The acceptability of the pork chops was assessed by an untrained panel for the acceptability of aroma, cooked appearance, texture, juiciness, flavour, aftertaste and overall acceptability. Attributes were scored on an 8 point Hedonic scale from Extremely acceptable to Extremely unacceptable. A score of 1 being awarded for Extremely acceptable and a score of 8 being Extremely unacceptable. Each sample was evaluated by 10 consumers and the average used for statistical analysis. A total of 67 individual consumers were involved in the trial (a number of consumers were used a number of times across the panels). The effect of sex and breed on sensory attributes and meat quality parameters was statistically analysed using REML. In addition the production performance (ADG between weaning and finish, back fat depth at P_2 and cold weight) of the pigs from which the meat was taken was also analysed by REML analysis. Initially a regression analysis within the REML analysis was used to test for interactions between finish weight and sex and breed. No interactive effects were found and so further regression analysis, which ignored interactive effects, was used to test for the effect of finish weight on all the aforementioned parameters.

3.4 Fatty acid profile

In total 39 samples (Tempo 11 (5 boars + 6 gilts), Pietrain (Austrian) 12 (6 boars + 6 gilts), Pietrain (Belgium) 9 (5 boars + 4 gilts), Landrace 7 (4 boars + 3 gilts)) were used to test for breed effects on the fatty acid profile of the pork. These pork chops were derived from pigs with a finish weight of 115 (+/-2) kg. Representative fresh chops were taken from the rump end of the loin from each pig after slaughter and were frozen at -21°C until analysis. After defrosting, the skin was removed from each chop and the adipose tissue was separated from the lean muscle tissue. Representative sub samples of lean (1.0 g) and adipose (0.1 g) tissue were taken for fatty acid analysis by gas chromatography (GC). Fatty acid methyl esters were prepared by the rapid direct method of O'Fallon *et al.* (2007). Internal standards and external methyl ester standards were used for identification and recovery efficiency purposes on the GC. Results were statistically analysed using REML analysis (Genstat Version 12) taking sex effects into consideration.

4. Results

4.1 Summary of pig and carcass performance from Magowan and McCann (2009)

There were no significant differences in growth rate, feed intake, feed use efficiency or variable weight or variable growth rate between wean and 10 weeks of age due to sire line breed. However, sire line breed had a significant effect on the performance of pigs during finishing (Table 3). The growth rate and feed intake of Tempo pigs between 10 weeks of age and finish (105 kg) was 84 g/day and 80 g/day, respectively, higher than that of any other pigs. However, the feed use efficiency of Tempo pigs (2.23) was similar to that of Pietrain (Austrian) pigs (2.29) whereas the feed use efficiency of Pietrain (Belgium) pigs and Landrace pigs was poorer (2.35 and 2.42 respectively). Variability in weight (at 20 weeks of age) and growth rate (between 10 and 20 weeks of age) was greater with Landrace pigs compared with the other terminal sire line breeds which were all similar. Landrace pigs were significantly fatter (P_2 13.9 mm) than the other pigs (average P_2 12.8 mm) (Table 3). However, the kill out percentage (KO%) and lean meat percentage of Pietrain pigs (77.2% and 61.0% respectively) were higher than that of the Tempo and Landrace pigs (average KO% 76.0% and lean meat % 60.1%) (Table 3). When finish weights were taken to 115 kg, the backfat depth at P_2 (Figure 1) and cold weight of all pigs increased significantly although kill out percentage remained constant. Furthermore, the growth rate of pigs taken to finish weights of 115 kg remained high and no 'plateau' effect was observed. Economically, Tempo and Pietrain (Austrian) pigs had a similar margin over feed which was approximately £4.40 more than Landrace pigs and £1.40 more than Pietrain (Belgium) pigs. Overall, Tempo pigs grew faster and were more efficient than Pietrain or Landrace pigs. However, the carcass performance of Pietrain pigs was superior to Tempo and Landrace pigs. There was a lower financial cost associated with the rearing of Tempo pigs but when carcass value was taken into consideration it was found that Tempo and Pietrain (Austrian) pigs had a similar margin over feed. Due to their high growth rate, more efficient use of housing could be achieved using Tempo pigs as they reached 105 kg approximately one week earlier than Pietrain (Austrian) pigs which were the next fastest growing sire line breed.

Table 3 Effect of sire line breed on pig performance from weaning to finish and carcass performance

		Norwegian Landrace	Pietrain Austrian	Pietrain Belgium	Tempo	SED	Sig.
Weight (kg)	Wean	9.1	9.4	9.1	9.2	0.13	NS
	10 wks	29.0	29.8	28.9	29.3	0.58	NS
	15 wks	52.4[ab]	54.2[b]	52.0[a]	57.5[c]	1.08	***
	20 wks	82.6[ab]	84.6[b]	81.2[a]	92.8[c]	1.47	***
	Finish weight	99.7	100.7	98.1	104.7	1.28	***
ADG (g/day)	Wean - 10 wks	485	498	483	491	13.0	NS
	10 – Finish[1]	804[a]	815[a]	794[a]	888[b]	11.6	***
	Wean – Finish[1]	704[a]	713[a]	698[a]	751[b]	7.0	***
ADFI (g/day)	Wean - 10 wks	724	730	715	717	21.7	NS
	10 – Finish[1]	2083	2027	2006	2119	35.6	*
	Wean – Finish[1]	1639	1611	1601	1639	24.1	NS
FCR	Wean - 10 wks	1.53	1.46	1.49	1.49	0.026	NS
	10 – Finish[1]	2.68[c]	2.52[ab]	2.59[bc]	2.44[a]	0.047	***
	Wean – Finish[1]	2.42[c]	2.29[ab]	2.35[bc]	2.23[a]	0.039	***
	P_2 (mm)[1]	13.9[b]	12.8[a]	12.6[a]	12.9[a]	0.23	***
	Lean meat %[1]	59.9[a]	60.8[b]	61.1[b]	60.3[a]	0.21	***
	Cold wt (kg)[1]	77.7[a]	79.4[b]	79.0[b]	78.2[a]	0.30	***
	Kill out %[1]	75.8[a]	77.4[b]	77.0[b]	76.1[a]	0.28	***

[1] Finish weight applied as covariate
NS = Not significant, * = <0.05, ** = <0.01, *** = <0.001

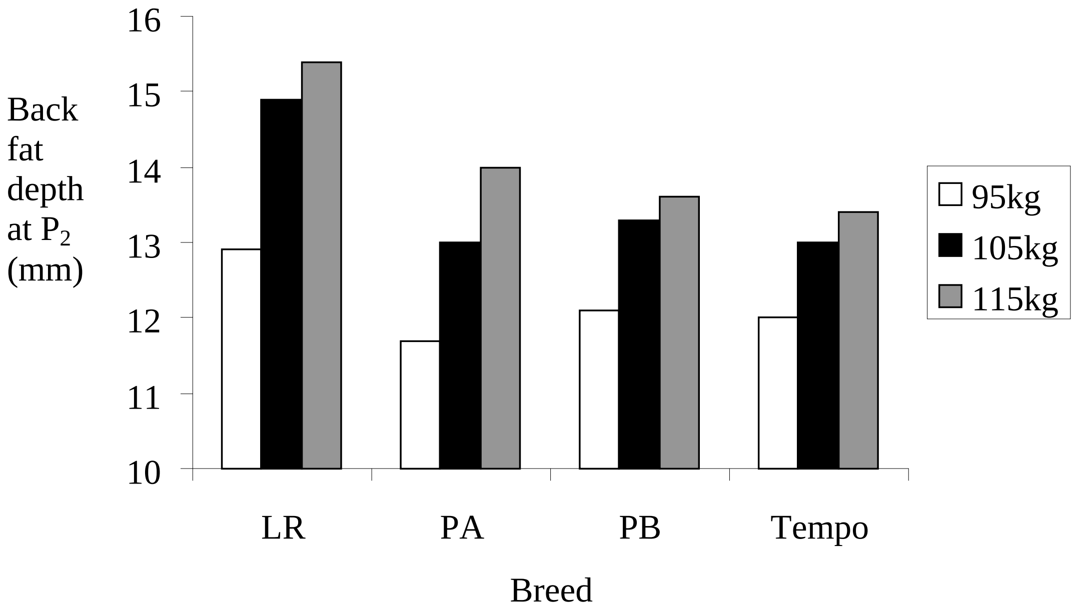

Figure 1 Effect of breed and finish weight on back fat depth at P_2.

4.2 Effect of sex, breed and finish weight on meat quality

4.2.1 Performance of pigs within the dataset respective of sex, breed and finish weight

The back fat depth at P_2 and cold weight of boars within this dataset was statistically similar (12.7 mm and 78.1 kg) to that of gilts (13.2 mm 79.8 kg) but the average daily gain (ADG) of the boars between weaning and finish was greater (752 g/day; $P < 0.01$) than that of gilts (743 g/day).

The cold weight of pigs from all breeds was similar (79.1, 78.8, 79.7 and 78.3 kg for Landrace, Pietrain (Austrian), Pietrain (Belgium) and Tempo respectively, $P > 0.05$, SED 1.17). However, the ADG between weaning and finish and back fat depth at P_2 of the pigs from the different breeds were different and followed a similar pattern to that found in the full production study i.e. the ADG of Tempo pigs was significantly greater (786 g/day, $P < 0.001$, SED 6.9) than that of Landrace (736 g/day), Pietrain (Austrian) (739 g/day) or Pietrain (Belgium) (727 g/day) pigs. In addition Landrace pigs had the greatest back fat depth at P_2 (13.7 mm, $P < 0.01$, SED 0.44) whereas Pietrain (Austrian) and Pietrain (Belgium) pigs had the lowest (12.6 and 12.2mm respectively) with that of Tempo pigs being intermediate (13.3 mm).

Light, medium and heavy weight pigs had an average finish weight of 95.3 kg (SD 2.29), 104.3 kg (SD 2.62) and 113.2 kg (SD 2.40) respectively. As expected, the cold weight and back fat depth at P_2 of pigs from the three weight categories differed significantly (both $P < 0.001$). The cold weight of the light, medium and heavy weight pigs was 71.2, 79.0 and 86.8 kg respectively (SED 1.01) and the back fat depth at P_2 was 12.2, 12.6 and 14.1 mm respectively (SED 0.38). The ADG between weaning and finish was greatest ($P < 0.001$, SED 6.0) for heavy weight pigs (786 g/day) and lowest for light weight pigs (705 g/day) with that of medium weight pigs being intermediate (750 g/day).

4.2.2 Effect of sex, breed and finish weight on meat quality

There was no significant effect of sex on Warner-Bratzler Shear Force (WBSF), colour parameters, pH_u or drip loss but meat from boars had a higher cooking loss percentage ($P < 0.05$) than gilts (Table 4). There was a statistically significant effect of breed on all colour parameters except L* (Table 5). Landrace pigs had a significantly lower ($P < 0.01$) a* value and significantly higher ($P < 0.001$) hue angle than Pietrain (Belgium) and Tempo pigs (Table 5). Landrace pigs had significantly lower b* and chroma values (both $P < 0.05$) than Pietrain pigs (both Belgium and Austrian). Drip loss was significantly lower ($P < 0.01$) in Tempo pigs than all other breeds (Table 4). Warner-Bratzler Shear Force (WBSF) was significantly lower ($P < 0.01$) for pigs slaughtered at heavy weights compared with that from those slaughtered at light and medium weights (Table 4). Cooking loss was also significantly lower ($P < 0.05$) for heavy weight pigs compared with light weight pigs (Table 4).

Breed had a significant effect on pHu but differences were not of practical significance. There were statistically significant 3 way interactions between sex, breed and finish weight for a* values and hue angle (Table 5). The 3 way interaction (sex, breed and finish weight) shows that there was no clear pattern in a* values in relation to finish weight in either boars or gilts (Table 6). There were no statistically significant differences in a* values between boars and gilts when slaughtered at a light finish weight. The a* values of Tempo and Pietrain (Austrian) boars when slaughtered at a medium finish weight were significantly higher than the other 2 breeds (Table 6). However, there were no statistically significant breed differences in the a* values of gilts slaughtered at a medium finish weight. When pigs were slaughtered at a heavy finish weight Tempo and Pietrain (Belgium) boars had significantly higher a* values than Landrace boars, whilst Pietrain (Austrian) boars had intermediate a* values and were not significantly different from the other 3 breeds (Table 6).

The 3 way interaction (sex, breed and finish weight) for hue angle shows a similar but inverse pattern to a* values since hue angles are an inverse function of a* values (hue angle = $\tan^{-1}$ [b/a]). There were no significant breed differences between boars when slaughtered at a light finish weight or between gilts when they were slaughtered at a heavy finish weight (Table 7). The significantly lower hue angle in Tempo pigs compared to Landrace and Pietrain (Austrian) pigs (Table 5) is mainly due to the lower hue angle in Tempo boars slaughtered at medium and heavy finish weights (Table 7).

Table 4 Effect of sex, breed and finish weight on meat quality

	pHu	**WBSF (kg)**	**Cooking loss (%)**	**Drip loss (%)**
Effect of sex:				
Boar	5.48	4.18	28.7	6.2
Gilt	5.50	4.21	27.8	6.1
SED	0.011	0.101	0.41	0.30
Significance	NS	NS	<0.05	NS
Effect of breed:				
Landrace	5.50	4.43^{b}	28.6	6.0^{b}
Pietrain (Austrian)	5.47	4.07^{a}	28.1	6.9^{b}
Pietrain (Belgium)	5.47	4.10^{a}	28.8	6.6^{b}
Tempo	5.53	4.18^{ab}	27.7	5.1^{a}
SED	0.02	0.148	0.59	0.44
Significance	<0.001	<0.05	NS	<0.01
Effect of finish weight:				
Light	5.49	4.37^{b}	29.0^{b}	5.6^{a}
Medium	5.50	4.25^{b}	28.3^{ab}	6.2^{ab}
Heavy	5.48	3.96^{a}	27.5^{a}	6.6^{b}
SED	0.014	0.128	0.51	0.38
Significance	NS	<0.01	<0.05	0.053
Interactions (P Value):				
Sex x Breed	NS	NS	NS	NS
Sex x Finish weight	NS	NS	NS	NS
Breed x Finish weight	NS	NS	NS	NS
Sex x Breed x Finish weight	NS	NS	NS	NS

[a,b,c] Numbers with common superscripts are not significantly different.
NS Not significant, ($P > 0.05$)

Table 5 Effect of sex, breed and finish weight on colour parameters

	L*	a*	b*	Chroma	Hue
Effect of sex:					
Boar	53.4	2.19	7.76	8.17	75.6
Gilt	52.9	2.05	7.74	8.08	75.9
SED	0.53	0.221	0.180	0.240	1.02
Significance	NS	NS	NS	NS	NS
Effect of breed:					
Landrace	52.4	1.63[a]	7.41[a]	7.63[a]	78.2[c]
Pietrain (Austrian)	54.4	2.10[ab]	8.11[c]	8.50[b]	76.6[bc]
Pietrain (Belgium)	53.3	2.28[b]	7.96[bc]	8.35[b]	75.1[ab]
Tempo	52.4	2.48[b]	7.53[ab]	8.03[ab]	73.1[a]
SED	0.77	0.321	0.259	0.346	1.48
Significance	0.062	<0.01	<0.05	<0.05	<0.001
Effect of finish weight:					
Light	53.0	1.84	7.62	7.89	76.8
Medium	52.9	2.29	7.77	8.25	75.4
Heavy	53.4	2.23	7.86	8.25	75.2
SED	0.67	0.279	0.226	0.30	1.29
Significance	NS	NS	NS	NS	NS
Interactions (P Value):					
Sex x Breed	NS	NS	NS	NS	NS
Sex x Finish weight	NS	NS	NS	NS	NS
Breed x Finish weight	NS	NS	NS	NS	NS
Sex x Breed x Finish weight	NS	<0.05	NS	NS	<0.01

[a,b,c] Numbers with common superscripts are not significantly different.
NS Not significant, (*P > 0.05)*

Table 6 Interaction (P < 0.05) between sex, breed and finish weight for a* values

		Finish weight		
Sex	**Breed**	**Light**	**Medium**	**Heavy**
Boars	**Landrace**	2.11	1.2	1.13
	Pietrain (Austrain)	1.7	3.19	1.72
	Pietrain (Belgium)	2.26	1.59	2.82
	Tempo	1.74	3.78	3.08
Gilts	**Landrace**	1.17	1.95	2.21
	Pietrain (Austrain)	1.74	1.51	2.74
	Pietrain (Belgium)	2.35	1.51	2.15
	Tempo	1.66	2.63	1.98
	SED	0.765		

Table 7 Interaction (P < 0.01) between sex, breed and finish weight for hue angle

		Finish weight		
Sex	**Breed**	**Light**	**Medium**	**Heavy**
Boars	**Landrace**	75.4	81.2	81.2
	Pietrain (Austrain)	78.4	71.7	77.8
	Pietrain (Belgium)	74.2	78.8	73.2
	Tempo	76.1	69.5	69.6
Gilts	**Landrace**	81.5	76	74
	Pietrain (Austrain)	78.3	80.1	73.3
	Pietrain (Belgium)	74.4	73.5	76.7
	Tempo	75.8	72.2	75.6
	SED	3.52		

4.3 Effect of sex, breed and finish weight on eating quality

4.3.1 Performance of pigs within the dataset respective of sex, breed and finish weight

The samples taken for sensory analysis represented a sub sample of those analysed for meat quality. The meat quality and pig performance respective of this sub sample was analysed to ensure these samples were reflective of previous findings. The ADG between weaning and finish, cold weight and back fat depth at P_2 of the boars and gilts within this sub sample was similar to that of pigs in the data set used for meat quality analysis (ADG : 753 and 750 g/day; Cold weight : 79.3 and 80.4 kg; Back fat depth : 13.2 and 13.4 mm for boars and gilts respectively). Likewise the ADG between weaning and finish, cold weight and back fat depth at P_2 for the various breeds was reflective of the pigs used in the data set of meat quality analysis (ADG : 742, 741, 736 and 787 g/day; Cold weight : 80.1, 80.7, 80.4, 78.3 kg; Back fat depth : 14.2, 13.3, 12.3 and 13.5 mm for Landrace, Pietrain (Austrian), Pietrain (Belgium) and Tempo pigs respectively). Regarding finish weight, pigs were selected within each breed and sex to represent a spectrum of weights at intervals of approximately 2 kg from 95 to 115 kg and therefore regression analysis was used to test for effects of finish weight on the various sensory and meat quality parameters and pig performance measurements. Similar to the pattern found within the samples used for meat quality analysis, as finish weight increased, ADG between weaning and finish also increased significantly ($P < 0.001$, for every kg increase in finish weight ADG increased by 3.4 g/day), cold weight increased significantly ($P < 0.001$, for every kg increase in finish weight cold weight increased by 0.77 kg) and back fat depth at P_2 increased significantly ($P < 0.01$, for every kg increase in finish weight back fat depth increased by 0.11 mm).

Regarding the meat quality of the sub set of samples, again a three way interaction was observed for hue angle. In addition, effect of sex was similar within this analysis except for no effect was noted on cooking loss and it was found that meat from gilts had a higher WBSF ($P < 0.05$, 4.39) compared with meat from boars (3.82). The pattern of effects of breed on meat quality attributes were also in line with those observed from the analysis of all samples i.e. meat from Landrace pigs having the highest WBSF (4.45) and meat from Pietrain Austrian and Belgium pigs having a higher chroma value and drip loss than meat from Tempo or Landrace pigs. Effect of finish weight was also similar with cooking loss decreasing significantly ($P < 0.05$) as finish weight increased although there was no effect on drip loss.

4.3.2 Effects of sex, breed and finish weight on eating quality

There were no significant interactions between sex, breed or finish weight on the sensory attributes of the pork. Overall the mean scores for acceptability ranged from 2.8 to 3.5 indicating that samples were reasonably acceptable (8 point scale). There was no statistically significant effect of sex on the acceptability of any of the attributes assessed (Table 8). Breed had a statistically significant effect on the acceptability of flavour ($P < 0.05$) and aftertaste ($P < 0.001$). The mean score for acceptability of flavour was significantly higher (less acceptable) for pork from Pietrain (Belgium) pigs than for pork from Pietrain (Austrian) or Tempo bred pigs with the acceptability of pork from Landrace pigs being intermediate (Table 8). The mean acceptability scores for aftertaste of pork from the Pietrain (Belgium) and Landrace pigs were significantly higher (less acceptable) than pork from the Pietrain (Austrian) and Tempo pigs. The regression analysis showed some indication of a possible negative relationship ($P = 0.058$) between finish weight on the acceptability of aroma (Table 9). However, the gradient of the slope was very low (-0.0096). Therefore very large weight changes (approximately 100 kg) would be required to alter the acceptability score by 1 scale point.

Table 8 Effect of sex and breed on the acceptability of eating quality attributes of the *longissimus dorsi* muscle at 7 days post slaughter

	Acceptability[1]						
	Aroma	**Appearance**	**Flavour**	**Texture**	**Juiciness**	**Aftertaste**	**Overall Acceptability**
Effect of sex							
Boars	2.86	3.24	3.43	3.37	3.37	2.95	3.42
Gilts	2.83	3.34	3.47	3.53	3.51	2.82	3.46
SED	0.078	0.094	0.112	0.09	0.098	0.07	0.089
P Value	NS	NS	NS	0.064	NS	NS	NS
Effect of breed							
Landrace	2.92	3.37	3.49[ab]	3.55	3.53	3.02[b]	3.5
Pietrain (Austrian)	2.81	3.13	3.33[a]	3.36	3.32	2.80[a]	3.3
Pietrain (Belgium)	2.9	3.34	3.71[b]	3.56	3.58	3.00[b]	3.56
Tempo	2.78	3.34	3.27[a]	3.32	3.33	2.71[a]	3.39
SED	0.101	0.119	0.15	0.108	0.121	0.086	0.11
P Value	NS	NS	<0.05	0.051	0.058	<0.001	NS
Interaction							
Sex x Breed	NS	NS	NS	NS	NS	NS	NS

[1] Acceptability of all attributes scored using an 8 point category scale where low values indicate greater acceptability of the Attribute.
[a,b,c] Numbers with common superscripts are not significantly different.
NS Not significant, (*P > 0.05)*

Table 9 Regression coefficients showing effect of finish weight on eating quality of pork *longissimus dorsi* muscle

	Aroma	Appearance	Flavour	Texture	Juiceness	Aftertaste	Overall Acceptability
Slope	-0.0096	0.0029	-0.0061	-0.0022	-0.0157	-0.0068	-0.0064
Se	0.00499	0.00615	0.00747	0.00578	0.01743	0.00486	0.00578
P	0.058	NS	NS	NS	NS	NS	NS

Se Standard error, P probability

[1] Acceptability of all attributes scored using an 8 point category scale where low values indicate greater acceptability of the attribute.

[a,b,c] Numbers with common superscripts are not significantly different.

NS Not significant (*P > 0.0.)*

4.4 Effect of breed on fatty acid profile

The finish weight of pigs, from which pork chops for this analysis were taken, averaged 114.4 kg. The adipose tissue from Pietrain (Belgium) pigs had the lowest percentage of total saturated fatty acids and the highest percentage of total unsaturated fatty acids, total omega 3 and total omega 6 fatty acids, polyunsaturated fatty acids (PUFA) and omega 6 long chain polyunsaturated fatty acids (LCPUFA n6 respectively) (Table 10). Similarly the lean tissue of Pietrain (Belgium) pigs had the lowest percentage of total saturated fatty acids and the highest percentage of total unsaturated fatty acids, total omega 6 fatty acids and omega 3 long chain polyunsaturated fatty acids (LCPUFA n3) (Table 11). Breed had no significant effect on the percentage of monounsaturated fatty acids (MUFA). There was a higher percentage of omega 3 and 6 long chain polyunsaturated fatty acids in the lean tissue compared with the adipose tissue.

Table 10 The effect of terminal sire breed on the fatty acid profile (g of FA/100 g of total fatty acids) of adipose tissue of pork from the loin of heavy weight pigs

Fatty acids:	Landrace	Pietrain (Austrian)	Pietrain (Belgium)	Tempo	SED	P. Value
C16:0	24.5[b]	24.3[ab]	23.0[a]	23.6[ab]	0.55	<0.05
C18:0	13.8[ab]	14.5[b]	12.3[a]	15.2[b]	0.79	<0.05
C18:1c9	35.1	34.6	33.9	36.0	0.92	NS
C18:2c9,12	16.4[a]	16.8[a]	20.0[b]	17.3[a]	1.07	<0.01
C18:3 n3	1.65[a]	1.69[a]	1.93[b]	1.68[a]	0.10	<0.05
Total Unsaturated	60.1[ab]	59.7[a]	63.1[c]	62.3[bc]	1.14	<0.01
Total Saturated	40.0[bc]	40.3[c]	36.9[a]	37.8[ab]	1.14	<0.01
Total omega 3	1.78[a]	1.78[a]	2.07[b]	1.79[a]	0.107	<0.05
Total omega 6	17.0[a]	17.3[a]	20.7[b]	17.9[a]	1.10	<0.01
MUFA	40.7	39.9	39.6	41.9	1.14	NS
PUFA	19.4[a]	19.8[a]	23.5[b]	20.4[a]	1.22	<0.01
LCPUFA n3[†]	0.12	0.09	0.14	0.11	0.021	NS
LCPUFA n6[†]	1.17[a]	1.23[a]	1.38[b]	1.28[ab]	0.060	<0.05

[a,b,c] Numbers with common superscripts are not significantly different. NS Not significant, (*P* > 0.05) MUFA Monounsaturated fatty acids, PUFA Polyunsaturated fatty acids, LCPUFA Long chain PUFA

[†] LCPUFA n3 (C20:5, C22:5, C22:6), LCPUFA n6 (C20:2, C20:3, C20:4)

Table 11 The effect of terminal sire breed on the fatty acid profile (g of FA/100 g of total fatty acids) of lean tissue of pork from the loin of heavy weight pigs

Fatty acids:	Landrace	Pietrain (Austrian)	Pietrain (Belgium)	Tempo	SED	P. Value
C16:0	25.2	24.9	24.5	24.4	0.32	0.089
C18:0	14.1^{b}	14.4^{b}	12.7^{a}	13.4^{a}	0.48	<0.001
C18:1c9	35.5^{bc}	35.1^{ab}	34.4^{a}	37.1^{c}	0.95	<0.05
C18:2c9,12	13.2	14.0	15.7	13.1	1.03	0.075
C18:3 n3	1.15	1.18	1.26	1.14	0.09	NS
Total Unsaturated	58.9^{a}	59.0^{a}	61.0^{b}	60.5^{b}	0.62	<0.001
Total Saturated	41.2^{b}	41.0^{b}	39.0^{a}	39.5^{a}	0.62	<0.001
Total omega 3	1.47	1.48	1.68	1.43	0.10	0.094
Total omega 6	15.0^{a}	15.7^{a}	17.7^{b}	14.7^{a}	1.12	<0.05
MUFA	41.9	41.2	41.1	43.8	1.22	0.050
PUFA	17.0	17.7	19.9	16.7	1.24	0.053
LCPUFA n3†	0.29^{a}	0.31^{a}	0.41^{b}	0.30^{a}	0.042	<0.05
LCPUFA n6†	2.12	2.24	2.54	2.08	0.183	0.065

[a,b,c] Numbers with common superscripts are not significantly different.
NS Not significant, ($P > 0.05$)
MUFA Monounsaturated fatty acids, PUFA Polyunsaturated fatty acids, LCPUFA Long chain PUFA
† LCPUFA n3 (C20:5, C22:5, C22:6), LCPUFA n6 (C20:2, C20:3, C20:4)

5. Discussion

The production and carcass performance of pigs, respective of sex, breed and finish weight, from which the meat samples were taken for meat and eating quality analysis was similar to that observed in the full scale production trial. Therefore, the meat samples used in the analysis were derived from pigs reflecting the production performance characteristics of boars and gilts within each breed at each finish weight.

In the current study, sex had little effect on the meat or eating quality of the pork except that pork from gilts had a lower cooking loss and tended to be less acceptable regards texture than pork from boars. These attributes could be related to the fact that the gilts were fatter (had a higher back fat depth at P_2) than the boars. Meinert *et al.* (2008) noted that across studies the effect of gender is not consistent and they suggested that the differences found were more a factor of production systems than gender. However, within those studies which found differences, the eating quality of pork from gilts tended to be better than that from boars e.g. Channon *et al*. (2004). In the current study, samples were not specifically analysed for 'boar taint, but it was noted that there were no interactions between sex and finish weight on the overall acceptability and aroma scores of pork indicating that these characteristics were similar for heavy weight boars and light weight gilts. It could therefore be suggested that 'boar taint' was not prevalent. The levels of both androstenone and skatole, which are the main chemicals produced by boars which contribute to 'boar taint' increase during sexual maturation (Claus *et al*., 1994). In the current study, it should also be noted that, due to the faster growth rate of the heavy weight pigs, the average age of the heavy weight pigs was at most only 10 days more than that of light weight pigs. As such there was little difference in the maturity of the heavy and light weight pigs which may have been a key reason why differences in aroma and acceptability were not found. On the other hand it has also been suggested that although both androstenone and skatole are positively correlated with carcass weight and age, the correlations are not very high and slaughtering pigs at a low weight, with the intention to reduce boar taint, is not always effective (Aldal *et al*., 2005).

In the current study, the finish weight of the pigs had little effect on meat quality and no effect on eating quality. Light weight pigs at finish were on average 95 kg which equated to a carcass weight of 71 kg and average back fat depth at P_2 of 12.2 mm, medium weight pigs were on average 104 kg at slaughter which equated to a carcass weight of 79 kg and average back fat depth at P_2 of 12.6 mm and heavy weight pigs were on average 113 kg which equated to a carcass weight of 87 kg and average back fat depth at P_2 of 14.1 mm. Heavier animals normally means an older animal and meat from older animals is normally tougher than meat from young animals due to a higher degree of collagen cross-linking (Ellis and McKeith, 1995). However, in the current study, as already mentioned, the age difference between the heavy and light weight pigs differed by only 10 days at the most. Using restricted fed pigs to control finish weight, Candek-Potokar *et al*. (1998) found no effect of age (difference of 30 days) on the eating quality of pork pigs slaughtered at 110 kg. However, some studies tend to suggest that eating quality (juiciness, tenderness and flavour) is better from pigs slaughtered at lighter weights (41-60 kg vs 91-100 kg, Ramaswami *et al.* (1993); 80 kg vs 120 kg Ellis *et al.* (1996); 100 vs 130 kg Candek-Potokar *et al*. (1998)). On the contrary, Bejerholm and Aaslyng (2003) found that the *L dorsi* muscle of pigs slaughtered > 90 kg was more tender than the *L dorsi* muscle from pigs slaughtered < 65 kg and they found no differences in odour or flavour. In agreement with Bejerholm and Aaslyng (2003), although weight ranges were different, WBSF of meat samples from the *L dorsi* muscle of pigs slaughtered at heavy weights (113 kg) was lower than that for pigs with finish weights of either 104 or 95 kg, indicating that the meat from the heavier pigs was more tender. However, drip loss increased as finish weight increased. A reason for this may be related to the fact that the back fat depth of heavy pigs was greater than that of light and medium weight pigs. Assuming that the fall in pH post slaughter was similar for the light, medium and heavy pigs, it is possible that the rate of chilling was slower for heavier carcasses due to a higher degree of insulation both from the bulk of meat and the higher back fat depth of the heavier carcass. A slower rate of chilling would have contributed to a more tender meat but more drip loss. In contrast to the effect of finish weight on drip loss, as finish weight increased, cooking loss decreased. This may have been related to the fatness of the pigs and although intramuscular fat content was not determined, it may be possible that the heavier pigs tended to have a higher degree of intramuscular fat due to having a higher back fat depth. A high degree of intramuscular fat has been found to decrease cooking loss Cannata *et al.* (2010).

The breed of pig was found to have the greatest influence on meat and eating quality attributes. Much of the work focusing on the breed of pigs compares the Pietrain breed or traditional breeds e.g. Tamworth and Duroc with commercial breeds. There are no known studies which have compared the meat and eating quality of pork from the 'Tempo' breed. The Tempo breed is a synthetic breed composed of Large White and Pietrain genetics. In the current study the production performance of the Tempo breed was superior and when consideration was given to carcass quality it was concluded that financially the use of the Tempo breed and Pietrain (Austrian) breed resulted in a better margin over feed cost compared with the Landrace or Pietrain (Belgium) breeds. In addition, the eating quality of pork from the Pietrain (Austrian) and in particular the Tempo pigs was more acceptable regards flavour and aftertaste. However in agreement with previous workers (Rosenvald and Anderson, 2003), the drip loss from the Pietrain breeds (both Austrian and Belgium lines) was high and although the Tempo breed contained Pietrain genetics, the drip loss from pork originating from Tempo pigs was significantly lower.

The statistically significant 3 way interaction between sex, breed and weight for a* and hue angle is difficult to explain as no clear patterns could be seen. The colour of meat depends on a number of factors including light scattering properties (PSE, DFD), myoglobin content, myoglobin proportion, ultimate pH and rate of chilling (MacDougall, 1983). The higher a* values and lower hue angles in the Tempo boars at medium and heavy weights may be due to increased pigment content since Lindahl *et al.* (2001) showed that a* increased with pigment content. However pigment content had little effect on b* values. Pigment content of muscles generally increases with finish weight (Latorre *et al.*, 2004). Intramuscular fat content in the pigs studied by Lindahl *et al.* (2001) was low (~1.5%) and had no effect on meat colour.

Kim *et al.* (2008) found that breed can have a significant influence on the fatty acid profile of pork which is in agreement with the findings in the current study. The fatty acid profile of the lean tissue of Pietrain (Belgium) pigs had the highest percentage of total unsaturated fatty acids and omega 3 long chain polyunsaturated fatty acids, even though all pigs were offered the same diet. There are two possible explanations. Firstly different breeds of pig may vary in their ability to elongate and desaturate dietary 18:2 omega 6 and 18:3 omega 3 to long chain polyunsaturated fatty acids. Secondly, although not measured the different breeds of pig may have had different levels of IMF thereby altering the polyunsaturated fatty acid proportions in the IMF.

The growth rate of the Tempo pigs from 10 weeks to finish was superior to that of the other breeds and this study found that the meat and eating quality of pork from the Tempo bred pigs had a more acceptable flavour than pork from the Pietrain (Belgium) bred pigs which had the slowest growth rate (Table3). This suggests that a high lean growth rate from modern genetics is not detrimental to meat quality. However the differences in eating quality were small. This study is in agreement with previous work by Magowan *et al*. (2010) who found little correlation between meat quality and growth rate of Landrace bred pigs. Overall, breed per se had a greater effect on meat and eating quality of pork than production and carcass characteristics individually, which is in agreement with Ngapo and Gariepy (2008).

Platter *et al.* (2003) suggested that for beef WBSF values less than 3.0 kg would be 80% acceptable to consumers and values of 4.5 around 55% acceptable. A large proportion of the pork tested in this project had WBSF values (mean WBSF ~ 4.1 kg) above the 3.0 kg cut off, however, the panellists rated the pork between moderately and slightly acceptable for both texture (mean ~3.5kg) and for overall acceptability since the midpoint panel score between acceptable/unacceptable would be 4.5. This may be comparable to the 55% acceptability obtained by Platter *et al*. (2003) for beef with WBSF values of around 4.5. Comparing the WBSF values from pork samples collected from pigs at AFBI Hillsborough by McCann *et al*. (2008) with these current samples indicates that the current pork is less tender. It would be of interest to initially compare the quality of this pork from the AFBI Hillsborough pigs with that of pigs from other farms in Northern Ireland and also with pork samples from Great Britain and Ireland. Further work to develop a model to relate WBSF values to consumer acceptability using a large number of consumers would also be extremely beneficial.

6. Conclusion

Meat and eating quality was optimised using the Tempo and Pietrain (Austrian) breeds compared with the Landrace and Pietrain (Belgium) breeds. The production performance of Tempo bred pigs was also superior to that of Landrace bred pigs which indicates that a fast growth rate using modern genetics is not detrimental to the overall meat and eating quality of pork. Overall, breed had a greater influence on meat and eating quality than the sex or finish weight of the pigs. Finally the WBSF values for overall acceptability of the pork samples were only just acceptable. This suggests further work is required to improve the eating quality of pork.

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