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Growth of carcass components and its relation with conformation in pigs of three types

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Abstract

The growth of carcass tissues and developmental changes in tissue distribution were studied in three pig types which were selected to have morphologies that could be described as attenuated, blocky and flabby. These were achieved by incorporating, respectively, Landrace, Pietrain and Meishan genes to give commercial 'types' (designated L, P and M,) exhibiting some of the phenotypic qualities of these breeds. Twenty-five female pigs of each type with an average start weight of 27.2 kg were fed ad libitum and slaughtered over a (nominal) live weight range of 35–115 kg. Relations were quantified using the logarithmic transformation of data in the allometric model. Significant type differences in relative growth rates (the *b* coefficient or slope in the logarithmic plot) were not common, occurring in 14% of the relationships examined, whereas 61% of differences in the constant term (*a* or intercept in the logarithmic plot) were significant. Increase in carcass weight with age was not different between the types but in relation to slaughter live weight (dressing percentage) P had the highest value, M the lowest. Carcass dimensions showed that, relative to body length, P had the widest ham and shoulder over the whole size range whereas M had a deep (ventral–dorsal) shoulder and wide belly, attributes of shape that would be regarded as undesirable by the meat trade. Relative to carcass weight, L was only slightly longer (3 mm) in the body than M at the heavy end of the weight range but markedly longer (29 mm) than P. These differences in carcass conformation were also evident in the shape of pelvic limb muscles which, at a given length, were lightest and narrowest in M and, in some cases, heavier and wider in P than in L. Pelvic limb volume relative to limb length was greatest in P and least in M. Carcass composition (at a given prepared side weight) of P was characterized by low fat and high lean weights, and a high lean to bone ratio. Subcutaneous fat *b* was lowest in P, indicating that P was early maturing, but M carcasses had the most subcutaneous and intermuscular fat, also indicative of early maturing. There was, thus, no simple relation between maturity characteristics and carcass composition. M carcasses also had the greatest weight of skin. P had a light hindloin and heavy pelvic limb, M a heavy shoulder, hindloin and flank but a light pelvic limb; L had a light shoulder but a heavy foreloin. The distribution of individual tissues mirrored these differences in joint weights to a varying extent; in most cases the match (relatively heavy/light) was with a single tissue. These data, thus, indicated some pig type differences in tissue distribution and of particular significance was the relatively light lean mass in the pelvic limb of M. The results showed important differences in carcass quality between commercially available pig types differing in conformation.

Keywords: Pig growth; Carcass composition; Conformation differences

1. Introduction

Differences in the carcass composition of pig genotypes must be understood if pig management and efficiency of feed use are to be optimised, the required carcass specification produced, and environmental impact minimised. Quantification of the growth of the carcass parts and the definition of pig type differences are essential prerequisites of Integrated Management Systems. In this report, three commercially available genotypes are described in that context.

The value of a pig carcass is determined by its weight, fatness level and muscularity but there are differences between genotypes in these characteristics (Kempster &

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Evans, 1981; Kolstadt, 2001; Wood, Dransfield, & Rhodes, 1979). Previous studies have revealed a wide range in these differences. For example, Fortin, Wood, and Whelehan (1987a) compared Pietrain, Large White and 'Iron Age' (European Wild Pig×Tamworth) pigs at the same side weight. The Large White had approximately 13% more fat, but the Iron Age 100% more, than the Pietrain. The large differences between the Iron Age and the other two breeds were attributed to the early maturing characteristics of this type and to a lower mature body size. Stage of maturity is a primary reason for reported genotype-dependent differences in carcass composition, effects being more pronounced when pigs of different mature weights are compared at the same weight than at the same age.

Genotypes also vary in the morphology of the body, or conformation, and in some European countries—for example Belgium, Germany, The Netherlands—where it has shown marked variation, conformation assessment has historically been important in commercial pig classification. In other areas, such as the United Kingdom, conformation has had little weighting and carcass quality has been mainly linked to the P_2 fat thickness measurement. However, attention to carcass conformation is becoming more widespread as its effects on meat yield and the shape of retail cuts are being recognized. There is some evidence that breeds differ in the relative growth rates of tissues in discrete anatomical regions, independently of degree of maturity (Fortin, Wood, & Whelehan, 1987b). Clearly, this would be responsible, at least in part, for breed differences in conformation, but the extent of this cause-and-effect relation is poorly understood.

We studied pig types falling into three broad categories of body shape and associated with different sectors of the industry. First, there are the 'white' pigs, forming the basis of mainstream production, which have been selected for leanness and growth rate and have a relatively attenuated body form. Second, there are the 'meat types', increasingly used as sires in commercial production and typified by a muscular carcass with a morphology that is thick-set and blocky. Finally, there are the female lines, which incorporate genes for prolificacy. The conformation of this type may be described as flabby and has been less influenced by selection for meat production, reflecting more the physiological demands for increased litter size. The extent of this range of conformation in pigs and its implications for carcass composition, physical characteristics and value, merits further investigation.

As part of the project designed to assess the potential of on-farm visual imaging of pig size and shape in an integrated management system, examples of attenuated, blocky and flabby conformation, as outlined above, were provided by using three pig types incorporating, respectively, Landrace, Pietrain and Meishan genes. The objectives of this part of the study were to compare the growth of dissected lean, fat and bone tissues in the three types and to determine how carcass composition relates to conformation-related characteristics of the carcass, particularly in the pelvic limb.

2. Materials and methods

2.1. Animals

Seventy-five female pigs of average start live weight 27.2 kg were obtained by crossing (using AI) JSR Genepacker 90 primiparous females (Large White/Landrace crossbred) with PIC lines, selected to create attenuated, blocky and flabby somatotypes (25 pigs per type). The breed compositions of these progeny were: ('Landrace' type) 0.75 Landrace, 0.25 Large White; ('Pietrain' type) 0.50 Pietrain, 0.25 Landrace, 0.25 Large White; and ('Meishan' type) 0.25 Meishan, 0.375 Landrace, 0.375 Large White. To reduce within-type variation, a single male from each crossing line was used.

All pigs were fed ad libitum. The chemical composition of the diet (g/kg fresh weight), determined from an average of six sub-samples taken throughout the experiment, was as follows: dry matter 883, moisture 117, oil (acid hydrolysis) 47.2, oil (ether extractives) 41.2, protein (6.25 N) 194, sugar 57.4, starch 368, ash 49.6, lysine 11.4, calcium 6.6, phosphorus 5.3, salt 5.9, sodium 1.3, potassium 9.5, vitamin A (iu) 6700, vitamin E (iu) 59, neutral detergent fibre 112, acid detergent fibre 51.3, calculated DE 14.5 (MJ/kg).

Pigs were weighed at the start of the experiment and at the points of slaughter (Table 1). Five serial slaughter

Table 1
Experimental design: weight and temporal distribution of the slaughter groups of the three pig types

	Mean slaughter weight (kg, ±S.D.)	Days to slaughter from 27 kg live weight
'Landrace' type	36.0 (4.51)	17
	35.0 (7.19)	31
	63.0 (4.41)	52
	77.6 (13.1)	73
	115.8 (11.5)	101
'Pietrain' type	31.2 (4.14)	17
	45.4 (5.20)	37
	64.4 (3.85)	58
	84.4 (6.70)	79
	116.2 (4.66)	107
'Meishan' type	29.6 (2.42)	13
	45.4 (6.56)	34
	62.0 (4.52)	48
	84.5 (9.43)	69
	102.7 (9.02)	104

groups were scheduled, with five of the females of each type in each group (with the exception of the fourth group of 'Meishan' type pigs, from which one was lost). Target end points for each group were predetermined by calendar date, with the intention of giving intervals between slaughter points of approximately 20 kg throughout the 35–115 kg (nominal) growth range.

The mean number of days from start of experiment to slaughter was not always the same for the equivalent serial slaughter group from each pig type, but it was similar (Table 1). Moreover, pigs within a type/slaughter group category were variable in weight, the result being that pigs within a type were spaced quite evenly, with respect to weight and age, across the whole growth period.

2.2. Slaughter and carcass measurements

Animals were slaughtered, using conventional electrical stunning and subsequent exsanguination, in the abattoir of the Division of Food Animal Science, University of Bristol. Following chilling at 2±1 °C for 24 h, cold carcass weight was measured and the following measurements were made on the intact hanging carcass:

Width of ham—the maximum width (lateral–lateral) in the pelvic limb region, measured with callipers.
Width of belly—the maximum width (lateral–lateral) in the abdominal region, measured with callipers.
Width of shoulder—the maximum width (lateral–lateral) in the thoracic limb region, measured with callipers.
Depth of shoulder—the maximum depth (dorsal–ventral) in the sternal region, measured with callipers.

Carcasses were split into two sides by sawing through the median plane and two further measurements were recorded:

Length of pelvic limb—from the distal end of the phalanges of the hind foot to the cranial edge of the pubic bone at its symphysis in the median plane, measured with a metal tape.
Length of body—from the cranial edge of the pubic bone at it symphysis in the median plane to the cranial edge of the first rib at its junction with the sternum, measured with a metal tape.

2.3. Carcass jointing

The left side of each carcass was prepared and cut into six joints as described by Brown and Wood (1979). The head was removed by cutting through the joint between the occipital bone of the skull and the first cervical vertebra, the feet by cutting between the carpal/metacarpal bones (fore feet) or tarsal/metatarsal bones (hind feet), and the tail by a cut between the third and fourth caudal vertebrae. The flare fat and kidney were then removed to give a side after preparation, the weight of which was common to both complete and partial dissection methods (see below) and which therefore served as the basic weight for the expression of composition. The prepared side was cut into six joints (shoulder, foreloin, hindloin, belly, flank and pelvic limb). One departure from the method of Brown and Wood (1979) was the removal of the pelvic limb (leg). Because this joint was selected as the sample joint for dissection in a proportion of the carcasses, and because dimensions and weights were required for whole, individual muscles from this region (see below), an anatomically defined and consistently removed joint was achieved by cutting along muscle boundaries rather than by straight line cuts as used for the removal of the other joints using a 'butchery' method. The procedure was as follows.

The subcutaneous fat was removed using a 'butchery' cutting line. This straight line was at a right angle to the line of the back and passed through the junction of the last lumbar and first sacral vertebrae. The subcutaneous fat was peeled back to reveal the underlying musculature and the limb was then removed using 'anatomical' cutting lines (following the boundaries of muscles). The *tensor fasciae latae* (included in the limb) was freed from its attachment in the lumbar/abdominal joint and the *rectus femoris* (included in abdominal joint) was freed of its attachment in the pelvic limb. With the half carcass lying on its lateral surface, *sartorius* and *pectineus* were dissected clear of the ilium to enable *iliopsoas* to be freed from its attachment to the femur. This muscle and *psoas minor* were now dissected clear of their attachments to the *os coxae* and they were included in the lumbar joint. The half carcass was now turned onto its medial surface to enable *gluteus medius* to be dissected clear of its attachment to the fascia of *longissimus lumborum*. The final separation of the pelvic limb from the lumbar and abdominal region was achieved by cutting through *longissimus lumborum* and *multifidi* and continuing the cut through the intervertebral disc between the last lumbar and first sacral vertebrae.

The volume of the pelvic limb joint was measured by the method of weighing in water (Adam & Smith, 1964).

2.4. Dissection

A full side dissection was carried out on 40% of the pigs and for the remaining 60% the pelvic limb (sample joint) was dissected. Each joint was separated into skin, subcutaneous fat, intermuscular fat, lean and bone as described by Brown and Wood (1979). The pelvic limb joint was treated differently in that additional measurements were made on individually separated muscles: weights, lengths (using predetermined reference points) and widths (at 90° to the lengths) were recorded for the *gluteobiceps, semimembranosus, gluteus medius, vastus lateralis, semitendinosus* and *rectus femoris*.

2.5. Statistical analysis

Prediction equations for full side composition were based on the composition of the pelvic limb joint derived from 42 fully dissected carcasses (10 female and four male per pig type). Plots of weight of tissue in the pelvic limb joint against the weight of the same tissue in the side showed only minor evidence of pig type or sex bias, hence more robust prediction equations were obtained by pooling the pigs. The basic model used the weight of (the predicted) tissue in the pelvic limb joint, weight of side after preparation, and the weight of the pelvic limb joint (Williams, 1976) but weights of additional dissected tissues were included as suggested by Fisher (1990) if the residual mean square was found to be reduced in an iterative stepwise procedure. The predicted composition of the partially dissected sides plus the observed composition of the fully dissected sides formed the comprehensive carcass composition data set. The prediction equations used are shown below. All weights are in grams.

$\text{Total SK} = 10.9 + 0.0903(\text{SWAPREP}) + 3.11(\text{SK}_{\text{PL}}) - 0.1914(\text{PL}) - 1.14(\text{IMF}_{\text{PL}})$

$r^2 = 94.8$, RSD = 138 g

$\text{Total SCF} = 5.7 + 0.1951(\text{SWAREM}) + 3.436(\text{SCF}_{\text{PL}}) - 0.833(\text{LEAN}_{\text{PL}})$

$r^2 = 98.8$, RSD = 268 g

$\text{Total IMF} = -49.0 + 0.0761(\text{SWAREM}) + 2.562(\text{IMF}_{\text{PL}}) + 0.5901(\text{SCF}_{\text{PL}}) - 0.2195(\text{PL})$

$r^2 = 98.9$, RSD = 111 g

$\text{Total LEAN} = -164 + 2.728(\text{LEAN}_{\text{PL}}) + 0.5276(\text{SWAREM}) - 1.228(\text{SCF}_{\text{PL}}) - 1.464(\text{PL})$

$r^2 = 99.8$, RSD = 288 g

$\text{Total BONE} = -22.8 + 2.519(\text{BONE}_{\text{PL}}) + 0.0364(\text{SWAREM}) - 0.0016(\text{PL}) - 0.2648(\text{SCF}_{\text{PL}})$

$r^2 = 98.7$, RSD = 118 g

SK = skin weight. SCF = subcutaneous fat weight. IMF = intermuscular fat weight. LEAN = lean weight. BONE = bone weight. SK_{PL}, SCF_{PL}, IMF_{PL}, LEAN_{PL}, BONE_{PL} = respective tissue weight in pelvic limb joint. SWAPREP = side weight after preparation. PL = pelvic limb joint weight. r^2 = proportion of variance accounted for by the regression. RSD = residual standard deviation.

General linear modelling using Genstat (Genstat Version 5, Release 4.1; Numerical Algorithms Group, 1997) was performed on the carcass measurements. Two models were fitted. First, the significance of differences in intercepts between pig types was tested by using pig type as a factor and a related dimension of carcass or carcass component size as a covariate. Second, the significance of differences in the slopes of the covariate between pig types was tested by including the interaction term between pig type and covariate in the model.

The relation between body components is conventionally described by the allometric formula of Huxley (1932) as shown below in its original and logarithmic forms:

$$y = a \cdot x^{\mathrm{b}}$$

$$\log(\mathrm{y}) = a' + b \cdot \log(x) \quad [\text{where } a' = \log(a)]$$

This function has been widely used by others (e.g. Rook, Ellis, Whittemore, & Phillips, 1987). Preliminary analysis showed that the relations between pairs of body components were generally made more linear by converting both scales to logarithms. This is particularly apt where the dimensionality of measurements is different, for example in the case of length and mass measurements. Thus, the logarithmic form of the allometric model was fitted. Logarithms were taken to the base 10 throughout.

Predicted values of carcass and muscle dimensions (at set values for body and muscle lengths) and tissue weights (at set values for side weight after preparation or weights of total tissues in prepared side) were calculated to facilitate comparison between pig types in body form (conformation) and carcass composition, respectively. The two sets of basic size parameters underpinning these predictions were body lengths of 600 and 800 mm and prepared side weights of 11 and 33 kg (approximating to cold carcass weights of 25 and 75 kg, respectively). These were selected as being representative of each end of the range and, although arbitrary, they correspond closely to plus and minus one standard deviation from the means. The corresponding muscle lengths and total tissue weights used for predicting muscle shape and tissue distribution at opposite ends of the size range were pooled pig type means at the two side weights of 11 and 33 kg.

Separate predictions for the pig types were calculated where significant differences between them occurred in the relations. Where there were no significant differences in slopes and intercepts, a pooled estimate was derived.

3. Results

3.1. Carcass weight and dimensions

The relation between carcass weight and live weight (W) at slaughter is shown in Table 2 for both the entire cold carcass and for the prepared side weight. There were significant differences between pig types in the constant estimates from the regressions on live weight. The ‘Pietrain’ type had the heaviest carcass and prepared side, the ‘Meishan’ type the lightest carcass and

Table 2
Estimates of parameters from the regression of $\log_{10}$ cold carcass weight (kg) and side weight after preparation (g) on $\log_{10}$ live weight (kg), and $\log_{10}$ cold carcass weight (kg) on $\log_{10}$ age (days). Significance of differences between pig type growth coefficients (*b*) and constants (*a*)

Weight		'Pietrain' type	'Landrace' type	'Meishan' type	Significance	r^2, %	RSD
On live weight							
Cold	*b*	1.059	1.089	1.062	NS	98.9	0.023
Carcass	*a*	−0.216	−0.288	−0.243	<0.01		
Side after	*b*	1.080	1.103	1.082	NS	98.8	0.025
preparation	*a*	2.395	2.333	2.367	<0.01		
On age							
Cold	*b*		1.806[a]		NS	92.2	0.062
carcass	*a*		−2.072[a]		NS		

[a] Pooled-within-pig type.

side. At a live weight of 100 kg, dressing percentages for the three types were 'Pietrain' 79.8, 'Landrace' 77.6 and 'Meishan' 76.0.

There were no significant differences between the pig types in the regression estimates for $\log_{10}$ cold carcass weight on $\log_{10}$ age. Since there was no difference between pig types in carcass growth rate, subsequent analyses are presented in relation to the carcass itself.

Differences between the pig types in carcass shape were indicated by the parameters from the regressions of $\log_{10}$ width, depth or limb length measurements on $\log_{10}$ body length, a dimension that serves as an index of overall size. Body length varied from 550 mm in the youngest animals to more than 850 mm in the oldest. In relation to carcass weight or age at slaughter, the 'Pietrain' type had the shortest bodies and the 'Landrace' type the longest. The parameter estimates *a* (constant) and *b* (relative growth coefficient) are shown in Table 3, together with those for the regression of $\log_{10}$ cold carcass weight on $\log_{10}$ body length. There were significant ($P<0.001$) differences between pig types in the constants, but not coefficients, for widths of belly and shoulder, and carcass weight. Thus, over the size range studied, the 'Pietrain' type had the greatest width of belly and shoulder relative to body length, the 'Landrace' type the smallest. Likewise, the 'Pietrain' type had the greatest relative carcass weight, the 'Meishan' type the smallest. For width of ham and depth of shoulder, there were significant differences between pig types in the coefficients, *b*. Estimated values have been calculated for body lengths of 600 and 800 mm, equivalent to carcass weights of approximately 25 ('Landrace' type and 'Meishan' type) or 30 kg ('Pietrain' type) and 70 ('Landrace' type and 'Meishan' type) or 79 kg ('Pietrain' type), respectively. These estimates are shown in Table 4. As there were no differences in the case of pelvic limb length, the pooled regression values were used.

Table 3
Estimates of parameters from the regression of $\log_{10}$ carcass dimension (mm) and $\log_{10}$ carcass weight (kg) on $\log_{10}$ length of body (mm), together with significance of differences between pig type growth coefficients (*b*) and constants (*a*)

Dimension		'Pietrain' type	'Landrace' type	'Meishan' type	Significance	r^2, %	RSD
Width of	*b*	0.857	0.910	1.234	<0.001	90.7	0.020
ham	*a*	0.067	−0.105	−1.046	<0.001		
Width of	*b*	0.924	1.064	1.047	NS	93.8	0.016
belly	*a*	−0.179	−0.589	−0.535	<0.05		
Width of	*b*	1.107	1.261	1.159	NS	94.4	0.018
shoulder	*a*	−0.710	−1.194	−0.910	<0.001		
Depth of	*b*	1.128	1.368	1.199	<0.01	95.2	0.017
shoulder	*a*	−0.787	−1.493	−0.987	<0.001		
Length of	*b*	0.825	0.818	0.857	NS	96.3	0.010
pelvic limb	*a*	0.367	0.383	0.277	NS		
Cold	*b*	3.363	3.590	3.694	NS	98.1	0.031
carcass weight	*a*	−7.865	−8.578	−8.875	<0.001		

Table 4
Predicted values ($\hat{y}$) for carcass dimensions (mm) in three pig types at body lengths of 600 and 800 mm

	$\hat{y}$[a]			
	Body length (mm)	'Pietrain' type	$\hat{y}$ 'Landrace' type	'Meishan' type
Width of ham	600	281	265	244
(mm)	800	359	343	342
Width of belly	600	244	232	236
(mm)	800	318	316	319
Width of shoulder	600	231	203	203
(mm)	800	318	292	284
Depth of shoulder	600	222	203	219
(mm)	800	308	301	312
Length of pelvic	600		453[a]	
limb (mm)	800		575[a]	

[a] Pooled-within-pig type.

The relative width of ham, whose increase was greater in the 'Meishan' type than in the other pig types, was actually bigger in the 'Pietrain' type over the entire growth range examined. Only at a body length of 800 mm did the 'Meishan' type value approach that of the 'Landrace' type. Although the relative depth of shoulder increased most in the 'Landrace' type and least in the 'Pietrain' type, it was actually smallest in the 'Landrace' type over the range.

3.2. Carcass composition

Regression of $\log_{10}$ weight of tissue in side on $\log_{10}$ weight of side after preparation showed that for skin, lean and intermuscular fat, there were significant pig type differences in constants but not in coefficients (Table 5). For subcutaneous fat and bone there were significant differences in coefficients: subcutaneous fat relative growth was greatest in the 'Landrace' type and least in the 'Pietrain' type, whereas bone relative growth was greatest in the 'Pietrain' type and least in the 'Meishan' type. Predicted weights and equivalent percentages at the two prepared side weights of 11 and 33 kg are shown in Table 6.

Table 5
Estimates of parameters from the regression of $\log_{10}$ weight of tissue in side (g) on $\log_{10}$ side weight after preparation (g), together with significance of differences between pig type growth coefficients (b) and constants (a)

Tissue		'Pietrain' type	'Landrace' type	'Meishan' type	Significance	r^2, %	RSD
Skin	b	0.848	0.772	0.801	NS	90.8	0.058
	a	−0.645	−0.312	−0.356	<0.001		
Subcutaneous fat	b	1.432	1.694	1.572	<0.05	95.3	0.079
	a	−2.848	−3.898	−3.250	<0.001		
Lean	b	0.971	0.926	0.919	NS	99.1	0.020
	a	−0.082	0.088	0.090	<0.001		
Intermuscular fat	b	1.209	1.234	1.235	NS	97.4	0.045
	a	−2.067	−2.149	−2.128	<0.001		
Bone	b	0.777	0.705	0.661	<0.05	96.8	0.029
	a	−0.020	0.326	0.495	<0.001		

Table 6
Predicted values ($\hat{y}$) for tissue weights (g) in three pig types at side weights (after preparation) of 11 and 33 kg[a]

		$\hat{y}$[a]		
Tissue	Side weight (kg)	'Pietrain' type	$\hat{y}$ 'Landrace' type	'Meishan' type
Skin	11	607 (5.5%)	643 (5.8%)	762 (6.9%)
	33	1540 (4.7%)	1502 (4.6%)	1838 (5.6%)
Subcutaneous fat	11	873 (7.9%)	883 (8.0%)	1262 (11.5%)
	33	4210 (12.8%)	5677 (17.2%)	7093 (21.5%)
Lean	11	6968 (63.3%)	6780 (61.6%)	6335 (57.6%)
	33	20255 (61.4%)	18759 (56.8%)	17376 (52.7%)
Intermuscular fat	11	659 (6.0%)	686 (6.2%)	732 (6.7%)
	33	2488 (7.5%)	2661 (8.1%)	2843 (8.6%)
Bone	11	1314 (11.9%)	1491(13.6%)	1469 (13.4%)
	33	3084 (9.3%)	3234 (9.8%)	3038 (9.2%)

[a] Equivalent percentage values (of prepared side weight) are shown in parentheses.

Skin weight was higher in the 'Meishan' type than in the other two pig types, the difference being approximately one percentage unit over the whole growth range. The 'Meishan' type was also the fattest of the three pig types with over 30% total fat in the 33 kg side whilst the 'Pietrain' type was the leanest with just over 20% total fat. The 'Meishan' type had the lowest weight and proportion of lean, nearly 9 percentage units less than the 'Pietrain' type in the 33 kg side. Bone weight was least in the 'Pietrain' type at 11 kg side weight but there was little between the pig types at a side weight of 33 kg. Consequently, at the heavier weight, the lean to bone ratios were 6.57, 5.80 and 5.72 for the 'Pietrain', 'Landrace' and 'Meishan' types, respectively.

3.3. Joint distribution

In the regression of $\log_{10}$ weight of joint on $\log_{10}$ weight of prepared side weight, estimates of coefficients (Table 7) showed that the joints that included the limbs exhibited relatively low growth rates with values below 1.0. The highest growth rate was in the flank in all three pig types, followed by the belly. In all three pig types the hindloin grew faster than the foreloin. Nowhere was there a significant effect of type on the growth coefficients, but in the foreloin, hindloin, flank, and pelvic limb there were type differences in the constants.

The predicted absolute and relative weights of the joints at 11 and 33 kg prepared side weights are shown in Table 8. The 'Pietrain' type had a relatively light hindloin and a relatively heavy pelvic limb compared with the other two types. In contrast, the 'Meishan' type was characterized by a relatively heavy shoulder, hindloin

Table 7
Estimates of parameters from the regression of $\log_{10}$ weight of joint (g) on $\log_{10}$ prepared side weight (g) and the significance of differences between pig type coefficients (b) and constants (a)

		'Pietrain' type	'Landrace' type	'Meishan' type	Significance	r^2, %	RSD
Shoulder	b	0.943	0.907	0.928	NS	99.6	0.013
	a	−0.266	−0.113	−0.194	NS		
Foreloin	b	1.061	1.077	1.075	NS	99.3	0.022
	a	−1.143	−1.1903	−1.210	<0.001		
Belly	b	1.092	1.158	1.121	NS	98.5	0.028
	a	−1.342	−1.642	−1.476	NS		
Hindloin	b	1.068	1.082	1.134	NS	98.2	0.044
	a	−1.329	−1.363	−1.566	<0.001		
Flank	b	1.133	1.203	1.195	NS	96.5	0.054
	a	−2.027	−2.337	−2.197	<0.001		
Pelvic limb	b	0.961	0.956	0.929	NS	99.7	0.012
	a	−0.327	−0.320	−0.221	<0.001		

Table 8
Predicted values ($\hat{y}$) for joint weights (g) in three pig types at side weights (after preparation) of 11 and 33 kg[a]

		$\hat{y}$[a]		
	Side weight (kg)	'Pietrain' type	$\hat{y}$ 'Landrace' type	'Meishan' type
Shoulder	11		3559 (32.4%)[b]	
	33		9823 (29.8%)[b]	
Foreloin	11	1398 (12.7%)	1457 (13.2%)	1362 (12.4%)
	33	4485 (13.6%)	4759 (14.4%)	4437 (13.4%)
Belly	11		1128 (10.3%)[b]	
	33		3891 (11.8%)[b]	
Hindloin	11	973 (8.8%)	1027 (9.3%)	1040 (9.5%)
	33	3145 (9.5%)	3372 (10.2%)	3614 (11.0%)
Flank	11	355 (3.2%)	335 (3.0%)	428 (3.9%)
	33	1233 (3.7%)	1257 (3.8%)	1590 (4.8%)
Pelvic limb	11	3604 (32.8%)	3506 (31.9%)	3415 (31.0%)
	33	10 357 (31.4%)	10 026 (30.4%)	9476 (28.7%)

[a] Equivalent percentage values (of prepared side weight) are shown in parentheses.
[b] Pooled-within-pig type.

and flank but a relatively light pelvic limb (more than 2 percentage units lighter than the 'Pietrain' type at 33 kg prepared side weight). The 'Landrace' type had a light shoulder but a heavy foreloin.

3.4. Tissue distribution

Results from regression of $\log_{10}$ weight of tissue in joint on $\log_{10}$ weight of the same tissue in the side are shown in Table 9. Differences in the relative growth coefficient were significant for just two tissue/joint combinations: for intermuscular fat growth in the flank ('Pietrain' type most, 'Meishan' type least) and lean in the pelvic limb ('Landrace' type most, 'Meishan' type least). Differences between the pig types were significant for the constant a in the regressions involving subcutaneous fat, intermuscular fat and lean, in two joints in each case. For all three tissues there were differences between pig types in the amount occurring in the foreloin: as a proportion of the total side depot fat that occurred in this joint, the 'Pietrain' type had the smallest amount (of both subcutaneous and intermuscular) whilst the 'Landrace' type had more of its lean in the foreloin than the other two types (Table 10). The 'Meishan' type had more of its intermuscular fat in the shoulder joint than the other two pig types and less in its pelvic limb. At heavier side weights, the 'Landrace' type had more of its lean in the pelvic limb, and less in its flank, than the other two types. There were no significant differences in bone distribution.

Table 9
Estimates of parameters from the regression of $\log_{10}$ weight of tissue in joint (g) on $\log_{10}$ weight of tissue in dissected half carcass (g) and the significance of differences between pig type coefficients (b) and constants (a)

Tissue/joint		'Pietrain' type	'Landrace' type	'Meishan' type	Signif.	r^2, %	RSD
Subcutaneous fat							
Shoulder	b	0.894	0.839	0.983	NS	95.8	0.068
	a	−0.223	−0.094	−0.543	NS		
Foreloin	b	1.039	1.080	0.959	NS	98.2	0.051
	a	−0.983	−1.073	−0.643	<0.05		
Hindloin	b	1.107	1.210	1.057	NS	96.8	0.075
	a	−1.296	−1.619	−1.055	NS		
Belly	b	1.088	1.053	1.098	NS	96.4	0.074
	a	−1.146	−0.993	−1.251	<0.05		
Flank	b	0.916	0.979	1.184	NS	93.7	0.096
	a	−0.738	−0.980	−1.695	NS		
Pelvic limb	b	1.029	1.011	0.923	NS	98.2	0.048
	a	−0.442	−0.668	−0.382	NS		
Intermuscular fat							
Shoulder	b	0.990	0.902	0.960	NS	98.9	0.027
	a	−0.326	−0.043	−0.201	<0.05		
Foreloin	b	1.220	1.308	1.239	NS	98.5	0.043
	a	−1.736	−1.929	−1.735	<0.001		
Hindloin	b	0.988	1.119	1.135	NS	95.1	0.068
	a	−1.203	−1.573	−1.676	NS		
Belly	b	1.303	1.343	1.379	NS	95.5	0.080
	a	−1.921	−2.098	−2.176	NS		
Flank	b	1.117	0.694	0.442	<0.05	69.3	0.139
	a	−1.949	−0.681	0.232	NS		
Pelvic limb	b	0.834	0.914	0.884	NS	96.6	0.046
	a	−0.043	−0.329	−0.288	<0.01		
Lean							
Shoulder	b	0.955	0.914	0.949	NS	99.5	0.014
	a	−0.323	−0.156	−0.304	NS		
Foreloin	b	1.134	1.091	1.089	NS	99.2	0.022
	a	−1.341	−1.319	−1.343	<0.05		
Hindloin	b	1.076	1.098	1.066	NS	96.6	0.044
	a	−1.374	−1.428	−1.291	NS		
Belly	b	1.059	1.000	1.086	NS	97.1	0.040
	a	−1.213	−1.001	−1.329	NS		
Flank	b	1.066	0.979	1.247	NS	94.8	0.056
	a	−1.820	−1.508	−2.453	<0.001		
Pelvic limb	b	0.953	1.026	0.948	<0.05	99.6	0.013
	a	−0.272	−0.574	−0.262	NS		
Bone							
Shoulder	b	1.087	0.988	0.988	NS	98.3	0.022
	a	0.674	−0.423	−0.402	NS		
Foreloin	b	1.030	1.044	0.995	NS	91.4	0.051
	a	−0.867	−0.913	−0.771	NS		
Hindloin	b	0.737	1.150	0.956	NS	86.9	0.063
	a	−0.239	−1.554	−0.954	NS		
Belly	b	1.121	1.083	0.986	NS	93.8	0.045
	a	−1.443	−1.366	−1.006	NS		
Pelvic limb	b	0.917	0.927	1.045	NS	98.3	0.021
	a	−0.245	−0.264	−0.669	NS		

3.5. Muscle shapes

The shape of muscles was indicated by expressing their widths, or weights, relative to their lengths. The results of regressions of $\log_{10}$ width or weight on $\log_{10}$

Table 10
Predicted values (ŷ) for tissue weights in joints (g) from three pig types at nominal side weights (after preparation) of 11 and 33 kg[a] Equivalent percentage values (of matching total side tissue weight) are shown in parentheses

Tissue/joint	11 kg[a]			33 kg[a]		
	‘Pietrain’ type	‘Landrace’ type	‘Meishan’ type	‘Pietrain’ type	‘Landrace’ type	‘Meishan’ type
Subcutaneous fat						
Shoulder		273 (27.2%)[b]			1299 (22.9%)[b]	
Foreloin	137 (13.6%)	147 (14.6%)	172 (17.1%)	822 (14.5%)	951 (16.8%)	901 (15.9%)
Hindloin		110 (11.0%)[b]			801 (14.1%)[b]	
Belly	132 (13.1%)	148 (14.7%)	111 (11.1%)	868 (15.3%)	912 (16.1%)	743 (13.1%)
Flank		89 (8.9%)[b]			526 (9.3%)[b]	
Pelvic limb		235 (23.4%)[b]			1284 (22.7%)[b]	
Intermuscular fat						
Shoulder	306 (44.2%)	330 (47.7%)	336 (48.6%)	1161 (43.6%)	1113 (41.8%)	1226 (46.0%)
Foreloin	61 (8.8%)	61 (8.8%)	54 (7.8%)	277 (10.4%)	357 (13.4%)	322 (12.1%)
Hindloin		38 (5.5%)[b]			165 (6.2%)[b]	
Belly		55 (7.9%)[b]			340 (12.8%)[b]	
Flank	17 (2.5%)	19 (2.7%)	31 (4.5%)	75 (2.8%)	50 (1.9%)	56 (2.1%)
Pelvic limb	211 (30.5%)	185 (26.7%)	167 (24.1%)	650 (24.4%)	634 (23.8%)	551 (20.7%)
Lean						
Shoulder		2150 (32.1%)[b]			5671 (30.2%)[b]	
Foreloin	744 (11.1%)	805 (12.0%)	762 (11.4%)	2399 (12.8%)	2483 (13.2%)	2345 (12.5%)
Hindloin		589 (8.8%)[b]			1772 (9.4%)[b]	
Belly		677 (10.1%)[b]			1994 (10.6%)[b]	
Flank	181 (2.7%)	173 (2.6%)	208 (3.1%)	544 (2.9%)	474 (2.5%)	752 (4.0%)
Pelvic limb	2372 (35.4%)	2253 (33.7%)	2316 (34.6%)	6345 (33.8%)	6500 (34.6%)	6163 (32.8%)
Bone						
Shoulder		502 (35.2%)[b]			1112 (35.7%)[b]	
Foreloin		237 (16.6%)[b]			532 (17.1%)[b]	
Hindloin		118 (8.3%)[b]			251 (8.0%)[b]	
Belly		121 (8.5%)[b]			279 (8.9%)[b]	
Flank	–	–	–	–	–	–
Pelvic limb		442 (31.0%)[b]			937 (30.0%)[b]	

[a] Estimated values based on the following total tissue weights (g) in the side that approximate across the three pig types to side weights (after preparation) of 11 and 33 kg:

	11 kg	33 kg
Subcutaneous fat	1004	5662
Intermuscular fat	692	2665
Lean	6694	18 797
Bone	1425	3119

[b] Pooled-within-pig type.

length are shown in Table 11 for the five pelvic limb muscles selected for this purpose.

For the majority of muscles there were no significant pig type differences in regression coefficients (b estimates). However, apart from the *semimembranosus*, there were differences in the constant term a. This was also true of the volume of the entire pelvic limb. The fit (r^2) of the logarithmic data to the linear model was better for the weight than the width values. For some muscles, the relative magnitude of the regression parameter estimates was similar between width and weight. For example, *vastus lateralis* (the only muscle to differ significantly in growth coefficient b between pig types) had growth coefficients in the increasing order ‘Pietrain’ type < ‘Meishan’ type < ‘Landrace’ type for both weight and width whilst the corresponding constants a were in the opposite (decreasing) order for both measurements. Of the remaining muscles, which differed only in the constant a, two showed the same consistency in ranking between weight and width, whilst for the other two there was some discrepancy, indicating that the relation between width and weight in these particular muscles was not uniform across the pig types.

Estimated values of muscle weights at approximate values of 11 and 33 kg for prepared side weights (comparison at equal muscle length across pig types) are shown in Table 12. The outstanding feature of this

Table 11
Estimates of parameters from the regressions of $\log_{10}$ width (mm) and weight of muscle (g) on $\log_{10}$ length of muscle (mm), and $\log_{10}$ pelvic limb volume (cm^3) on $\log_{10}$ pelvic limb length (mm). The significance of differences between pig type coefficients (*b*) and constants (*a*) is given.

Muscle	*Y* variable		'Pietrain' type	'Landrace' type	'Meishan' type	Significance	r^2, %	RSD
Gluteobiceps	Weight	*b*	3.331	3.319	2.881	NS	91.8	0.064
		a	−5.329	−5.378	−4.317	<0.001		
	Width	*b*	1.055	1.080	0.977	NS	72.2	0.043
		a	−0.384	−0.464	−0.228	<0.05		
Semimembranosus	Weight	*b*	2.689	2.950	2.844	NS	83.0	0.089
		a	−3.515	−4.140	−3.925	NS		
	Width	*b*	0.882	1.189	1.003	NS	65.5	0.051
		a	−0.010	−0.728	−0.298	NS		
Gluteus medius	Weight	*b*	2.629	2.897	2.568	NS	89.9	0.069
		a	−3.416	−4.081	−3.340	<0.01		
	Width	*b*	1.123	1.047	0.794	NS	81.3	0.036
		a	−0.416	−0.268	0.317	<0.05		
Vastus lateralis	Weight	*b*	2.044	3.015	2.652	<0.05	81.2	0.094
		a	−1.981	−4.106	−3.366	<0.01		
	Width	*b*	0.690	1.031	0.865	<0.05	78.0	0.034
		a	0.656	−0.079	0.257	<0.05		
Semitendinosus	Weight	*b*	3.372	2.984	3.115	NS	83.6	0.093
		a	−5.538	−4.608	−5.038	<0.001		
	Width	*b*	1.216	1.065	1.351	NS	74.5	0.047
		a	−1.011	−0.630	−1.388	<0.001		
Rectus femoris	Weight	*b*	2.873	2.788	3.125	NS	93.1	0.056
		a	−3.802	−3.598	−4.449	<0.001		
	Width	*b*	1.002	0.996	1.094	NS	78.5	0.037
		a	−0.340	−0.299	−0.559	<0.001		
Pelvic limb	Volume	*b*	3.891	4.097	4.035	NS	95.6	0.045
		a	−6.739	−7.355	−7.227	<0.001		

Table 12
Predicted values ($\hat{y}$) for pelvic limb muscle weights (g) and pelvic limb volume (cm^3) in three pig types at nominal side weights (after preparation) of 11 and 33 kg

Muscle	11 kg[a]			33 kg[a]		
	'Pietrain'type	'Landrace' type	'Meishan' type	'Pietrain' type	'Landrace' type	'Meishan' type
Gluteobiceps	533	445	447	1493	1243	1090
Semimembranosus	393	365	344	857	859	785
Gluteus medius	263	224	230	664	621	567
Vastus lateralis	164	121	120	322	327	287
Semitendinosus	150	166	123	398	392	302
Rectus femoris	163	173	124	418	431	344
Pelvic limb volume	3943	3365	3093	9974	8940	8096

[a] Estimated values based on the following lengths (mm) that approximate across the three pig types to side weights (after preparation) of 11 and 33 kg:

	11 kg	33 kg
Gluteobiceps	262	357
Semimembranosus	187	250
Gluteus medius	166	236
Vastus lateralis	113	157
Semitendinosus	194	259
Rectus femoris	124	172
Length of pelvic limb	448	575

result was the relatively light muscle weights in the 'Meishan' type, particularly at the heavier side weight. The 'Pietrain' type had appreciably heavier weights than the 'Landrace' type but this was not universal. It applied more at the lighter side weight but was seen in the laterally sited *gluteobiceps* and *gluteus medius* at the heavier carcass weight. The 'Pietrain' type also had a very much bigger pelvic limb volume than the 'Landrace' type, and the 'Landrace' type a bigger volume than the 'Meishan' type, at the same leg length.

4. Discussion

The design of the overall experiment, involving the automated recording of pig live weight and shape/size, was provision of groups for slaughter, separated by weight and, therefore, age. Variation within these groups was substantial, the mean coefficient of variation in weight being 10.6%, and there was a relatively evenly spaced distribution of pigs with respect to both age and weight at slaughter. Analysis by regression methods was, therefore, apt for the carcass components in this study. However, the use of the allometric equation to describe the growth of carcass components has been criticized; in the study by Wagner, Schinkel, Chen, Forrest, and Coe (1999), examining growth of components in relation to empty body weight over a live weight range of 25–152 kg, either an augmented allometric (for fat-free lean, bone and skin) or an exponential function (for fat) fitted the data better than the simple allometric equation. But in a later study, in which pigs ranged from 100 to 152 kg and growth of body components was determined relative to carcass weight, the same group of researchers found that the allometric equation fitted the data equally as well as more complex nonlinear functions (Schinckel, Wagner, Forrest, & Einstein, 2001). Preliminary plots of data in our study showed that relations between variables in the logarithmic form were, for the most part, linear and the allometric equation was a suitable choice.

The aim of this study was to compare carcass characteristics during growth and development in three pig types that differed in conformation. There was no attempt to score or allocate classes for conformation across all carcasses and to use conformation as a covariate. Rather, the intention was to determine whether breed-type associated differences in carcass conformation at three levels resulted in carcass differences that were likely to have commercial importance. Other studies have examined conformation in a narrower role. For example, Kempster and Evans (1981) determined the value of conformation, assessed visually on a five-point scale, as a predictor of lean content when used in addition to carcass weight and P_2 fat thickness in pigs from several breeding companies. They concluded that addition of conformation did reduce variation in lean to bone ratio but the overall improvement in lean prediction was small. This conclusion was based on the reduction in the residual standard deviation (RSD) of lean content (from 2.45% excluding conformation, to 2.44% including conformation) which, although significant, is obviously of little practical importance. However, the mean percentages of carcass lean in the five conformation classes at equal carcass weight and P_2 ranged from 47.6 to 50.7 with progressively incremental values along the range. These differences would have commercial significance and the error in making subjective conformation assessments may well have been a factor in the minor reduction in the RSD.

4.1. Carcass shape

As the pigs grew, their shape changed. If it had not, and the heavier pigs were simply larger scaled versions of lighter ones, the growth coefficients from the regressions of some measure of carcass bulk (weight/volume) on an associated linear dimension would have a value of 3.0. In fact, the growth coefficients for carcass weight relative to body length had values around 3.5 whilst for the pelvic limb, whose length was early maturing compared with body length, the growth coefficients for volume relative to limb length were even higher, with values around 4.0. A thickening of the carcass and its regions occurred, as the rates of growth of the soft tissues, particularly subcutaneous fat, accelerated relative to bone.

The shape of the body or the carcass of a pig is too complex to be accurately described by a few linear measurements but they do quantify major differences in proportions and, therefore, serve as an index of overall shape. Relative to carcass length, the ‘Pietrain’ type had the widest ham and shoulder, confirming the assumption of a blocky conformation in this type. Differences between ‘Landrace’ and ‘Meishan’ types were not so pronounced in these measurements although the ‘Meishan’ type had a deeper shoulder and a slightly wider belly over the range of carcass size studied, attributes that would generally be regarded as undesirable elements of conformation. The ‘Landrace’ type did have a slightly longer body than the ‘Meishan’ type at higher carcass weights, and a markedly longer body than the ‘Pietrain’ type. The term ‘attenuated’ (= slender) was therefore appropriate for the ‘Landrace’ type.

4.2. Carcass composition

The differences in carcass composition between the ‘Pietrain’ type and the representative of the white breeds, namely the ‘Landrace’ type, were in general agreement with the results of other studies. Quiniou, Noblet and Dourmad (1996) showed that, at a carcass weight of around 84 kg, Pietrain × Large White castrated males had more than three percentage units more lean than Large White castrates. In the present study, this difference between the ‘Pietrain’ type and the ‘white’ (‘Landrace’) type in lean content was greater in females at a lighter carcass weight than in the castrates in the study by Quiniou et al. (1996) but was less than the difference between purebred lines of Pietrain and Large White females, at even lighter carcass weights, in the study of Davies (1974). Our values, and hence differences, were very similar to those of Fortin et al. (1987a) for females, albeit purebred.

Our results for the 'Pietrain' type were different from those of most studies reviewed by Wood (1989) in that the higher lean content was accompanied by a growth rate which did not differ from that of the 'white' type. In most of the previous studies the Pietrain type was characterized by a low appetite and slow growth.

A feature of the 'Meishan' type carcass was the significantly larger amount of skin in this type compared with the other two. This result is in agreement with that of White, Lan, McKeith, Novakowski, Wheeler, and McLaren (1995) who showed that the Meishan had significantly thicker skin than the Yorkshire breed.

Several studies have indicated that the Meishan has a fat carcass. White et al. (1993) reported higher chemical fat percentages in Meishan castrated males than in comparative Yorkshire carcasses on an age or weight basis. In a study of growth, carcass and meat quality traits in Wild Boar, Pietrain and Meishan pigs, Muller, Moser, Bartenschlager, and Geldermann (2000) concluded that high lean content was associated with Pietrain and high fat content with Meishan genes. However, White et al. (1995) found that the Meishan was an early maturing type which had higher percentages of body fat than the Yorkshire at 41 and 71 days of age but at 280 days the percentages were similar. In our study, the relative growth coefficient for subcutaneous fat was lowest in the 'Pietrain' type, implying that this was a type maturing at a relatively low weight regarding fat development whilst the 'Landrace' type matured at a relatively high weight. The 'Meishan' type was intermediate in the relative growth of subcutaneous fat but was much the fattest of the three types. Therefore, there was no simple relation between maturity characteristics and carcass composition.

4.3. Joint and tissue distribution

In the following discussion the statements apply across all three pig types, unless otherwise indicated, as there were few significant differences between them in the growth coefficient, *b*.

The lowest growth coefficients for joint weights were for the two joints containing the limbs, namely the shoulder and pelvic limb. These were therefore early maturing, as others have shown (e.g. Fortin et al., 1987b). The lowest coefficients for each of the dissected tissues were also for these two joints, apart from bone in the shoulder, which ranked third behind pelvic limb and hindloin. The highest growth coefficient for joint weight was for the flank (late developing). Interestingly, this high growth was more attributable to lean than fat growth: the highest *b* value for lean in any joint was for the flank, whereas *b* was intermediate for subcutaneous fat in the flank and for intermuscular fat in two of the pig types (a significant type effect here) it was the lowest in the flank. Conversely, in the other ventrally located joint, the belly, which ranked second only behind the flank in growth rate, it was fat and not lean which accounted for this rapid growth, and also bone. The growth coefficient for subcutaneous fat in the belly ranked second in size behind that for the hindloin whilst for intermuscular fat the highest coefficient was for the belly itself; the coefficient for bone in the belly was the highest of all the joints, but for lean it was intermediate.

Differences between pig types in the relative weight of joints were not consistently reflected in the weights of the component tissues. The light pelvic limb in the 'Meishan' type at heavier side weights is mirrored in low intermuscular fat and lean. Similarly, the heavy foreloin in the 'Landrace' type reflected more subcutaneous fat, intermuscular fat and lean. Conversely, the heavy shoulder in the 'Meishan' type resulted from more intermuscular fat but there were no significant differences from the other pig types in the amounts of any of the other tissues. These results showed that there were differences between pig types in the distribution of tissues in the carcass that would be commercially important to processors preparing retail cuts. However, out of the 24 possible occurrences (six joints×four tissues), there were but nine significant differences in tissue distribution between types, two involving subcutaneous fat, four involving intermuscular fat, three involving lean and none involving bone.

There are some discrepancies between the results for tissue distribution in the current study and that of Fortin et al. (1987b). The relative growth coefficient for lean in the pelvic limb of the purebred Pietrain in the study by Fortin et al. (1987b) was very similar to that of the 'Pietrain' type in the current one (0.951 and 0.953, respectively), and the corresponding values for the comparative 'white' types (purebred Large White and 'Landrace' type) were 0.966 and 1.026. Despite the lower growth coefficient in the Pietrain than the Large White, Fortin et al. (1987b) predicted more muscle in the pelvic limb of the Pietrain at a total side muscle of 14.57 kg whereas in our study the 'Landrace' type had more muscle in the pelvic limb than the 'Pietrain' type at weights of total side lean above 13.7 kg.

4.4. Muscle shape

The blocky conformation of the 'Pietrain' type, as indicated by the carcass dimensions, was further illustrated in the shape of some of the pelvic limb muscles. The difference between the 'Pietrain' type and the others in muscle weight at a set muscle length was particularly evident at the lighter comparative side weight, but even here it did not apply to all muscles: the *semitendinosus* and *rectus femoris* were as heavy in the 'Landrace' type. There was, therefore, a specific muscle effect, akin to the situation in muscle hypertrophy (double muscling) resulting from mutation in the myostatin gene (Kambadur, Sharma, Smith, & Bass, 1997). In cattle exhibiting double muscling, the hypertrophied muscles tend to be either dorsally located in the thoracic region, close to the vertebrae (Hanset, Detal, & Michaux, 1989), or superficially, in the proximal part of the pelvic limb (Shahin, Berg, & Price, 1991).

The 'Meishan' type contrasted strongly with the other two types in muscle shape, having the lightest muscle at the set muscle length in every case at the heavier side weight. These differences were expressed cumulatively in the volume of the pelvic limb, relative to its length, which was greatest in the 'Pietrain' type and smallest in the 'Meishan' type. The Meishan type also had the smallest amount of intermusclar fat and bone, as well as lean, in that joint.

The results of this study showed that the carcasses of three morphologically different pig types with the same daily carcass weight gain differed significantly in many compositional characteristics during growth to commercial slaughter weight.

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