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Physical and chemical composition of the carcass of three different types of pigs grown from 25 to 115 kg live weight

C. T. Whittemore[1]†, D. M. Green[1], J. D. Wood[2], A. V. Fisher[2] and C. P. Schofield[3]

[1]*The University of Edinburgh, Institute of Ecology and Resource Management, Agriculture Building, West Mains Road, Edinburgh EH9 3JG, UK*
[2]*Division of Food Animal Science, Department of Clinical Veterinary Science, University of Bristol, Langford, Bristol BS40 5DU, UK*
[3]*BBSRC Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS, UK*

† E-mail : c.t.whittemore@ed.ac.uk

Abstract

A total of 74 pigs representing three commercially available crossbred types, Landrace (50%), Pietrain (50%) and Meishan (25%), were given food ad libitum *over a 25- to 115-kg growth period and serially slaughtered for physical and chemical analysis in five groups at 32, 42, 63, 82 and 114 kg live weight (W). Results are presented in the order of pig type as above. Pig types grew at similar overall rates of live body gain, but the Meishan type ate more food and had greater back fat depth. The Pietrain type was least fat. Dissected fatty tissue grew substantially faster than the carcass as a whole; allometric exponents being 1·64, 1·34 and 1·52 ($P < 0·05$) for the Landrace, Pietrain and Meishan types respectively. Dissected lean tissue gains were 0·419, 0·427 and 0·308 kg daily ($P < 0·01$), and dissected fatty tissue gains were 0·251, 0·158 and 0·218 kg daily ($P < 0·05$); the Meishan type being slowest for lean gain and the Pietrain type slowest for fatty tissue gain. The Pietrain type had the largest cross-sectional area of the* longissimus dorsi *muscle, and the Meishan type the smallest. The pelvic limb of the Meishan type lost density (as measured by specific gravity) fastest, and that of the Pietrain slowest as the pigs grew. The Meishan type had a lower proportion of its carcass lean and a higher proportion of its carcass fat in the pelvic limb than did the other two types. For each kg of live-weight gain, 0·037, 0·041 and 0·032 kg ($P < 0·05$) of chemical protein was deposited in the pelvic limb of the three types respectively. Equivalent values for chemical lipid were 0·041, 0·035 and 0·041 ($P < 0·05$). The Meishan type retained protein at a relatively slower rate in the pelvic limb than in the body as a whole. The Pietrain type had the greatest ultimate protein mass in the pelvic limb. Estimation of whole body protein content as a linear function of pig live weight gives coefficients of 0·154, 0·178 and 0·168 kg ($P < 0·05$) for the three types respectively. Equivalent values for whole body lipid content were 0·269, 0·214 and 0·274 ($P < 0·05$). Best estimates of the daily rates of protein retention in the body of the whole live pig were 0·152, 0·197 and 0·142 kg/day for the Landrace, Pietrain and Meishan types respectively.*

Keywords: *carcass composition, pigs.*

Introduction

Production efficiency and choice of slaughter weight depends upon the proper description of pig type with regard to the characteristics of the growth of edible tissues. Optimization demands as exact a definition as possible of the pig's production capacity, particularly of its physical and chemical carcass components. These characteristics are presently inadequately defined for commercial production systems, even though a variety of pig types are available to the industry. Importantly, characterization should include information on the changes that occur in the dissectible tissues as the different pig types grow.

European genotypes may be arbitrarily typed into two groups: female lines and male lines. Amongst the female lines the Large White/Landrace cross predominates, but recently some blood from the fatter but more prolific Meishan importations have been introduced into conventional stocks. Amongst the male lines the Pietrain exemplifies the source of meaty (blocky) characteristics. These three types may thus provide examples of 'lean', 'blocky' and 'fatty' pigs presently available to commercial producers.

The reports of Quiniou *et al.* (1996a, 1996b and 1999) would indicate that Pietrain × Large White pigs may eat less, grow live weight at a similar rate, but retain more protein daily than Large White pigs, while the Meishan pig may grow slower than the Large White.

Through the medium of examination by serial slaughter from 25 to 115 kg live weight the present report deals with the growth of the physically dissected and chemically analysed carcass, and the differing relationships between the carcass components for the three different breed combinations. Pigs were kept under commercial conditions of feeding, housing and management. Food intake and live growth performance determined through automatic and continuous measurement have been reported elsewhere (Green *et al.*, 2003).

Material and methods

Animals and feeding

The data collected related to three differing pig types that were the progeny of JSR Genepacker 90 primiparous females mated by AI with semen from PIC nucleus lines selected to generate types with tendencies to be 'lean', 'blocky', or 'fatty'. The genetic makeup of the slaughter pigs was reflective of practical pig types. To achieve this the males used were respectively : 100% Landrace (hereafter slaughter pigs referred to as Landrace type), 100% Pietrian (hereafter slaughter pigs referred to as Pietrain type) and 50% Meishan/25% Large White/ 25% Landrace (hereafter slaughter pigs referred to as Meishan type). All 75 pigs placed on test were female. Pigs were allocated to one of five slaughter groups that remained on trial for various lengths of time to achieve various slaughter weights up to 115 kg, as shown in Table 1. One pig (a Meishan type pig from group 4) was withdrawn. Pigs were weighed at the start of the experiment and at the point of their slaughter. An Avery system with a mechanical linkage suspending the platform from an electronic weigh head was used to weigh the pigs with an estimated error of 2%. Daily live-weight gain was calculated for each pig in each group as (end weight – start weight)/number of days in the group. Daily food intake for each pig was measured with a FIRE® feeding station (Green *et al.*, 2003), data from which were then summed to give the total food intake from start to the point of withdrawal of the pig from the experiment according to the allocated group (Table 1). Average daily food intake was computed as the total food intake for the period divided by the number of days in the period. Pigs were given *ad libitum* a practical diet comprising (g/kg) : barley 150, wheat 461, soya-49 175, rapeseed ext. 124, peas 25, molasses 20, fat 23, limestone 7, dibasic calcium phosphate 5, salt 3·2, lysine (50%) 3·8, pre-mix 3. The chemical composition of the diet (g/kg fresh weight) was determined from an average of six subsamples taken throughout the experiment as follows : dry matter 883, moisture 117, oil (acid hydrolysis) 47·2, oil (ether extract) 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, retinol (mg) 2, alpha-tocopherol (mg) 40, neutral-detergent fibre 112, acid-detergent fibre 51·3, calculated digestible energy 14·5 (MJ/kg).

Determination of subcutaneous fat depth and longissimus dorsi *muscle dimensions*

Fatness was measured indirectly by ultrasonic probe at the start of the experiment, and directly by mechanical intrascope probe (which was used to measure the distance between the skin surface and the muscle/fat interface) on the hot carcass as pig groups serially completed their experimental periods (Table 1). Fat was measured at the P2 position 65 mm from the mid line at the point of the last rib. The depth and width of the *longissimus dorsi* muscle was determined on the cut face at the same point. Lipid was determined by chemical analysis as given below.

Housing

Pigs were loose housed in fully slatted pens. Each pen was equipped with a FIRE® Feeder. The pigs were maintained in their type groups for reasons of welfare and performance optimization. The performance of the feeding stations was continuously monitored. The building was manufactured by Brian Thomas Ltd, and had a fully controlled environment. The pigs were stocked to comply with Livestock Regulations. Ventilation was by means of Optimavent units that circulate the air in the rooms as well as mixing in-coming air with the circulating air. The temperature at the start of the trial period was 22ºC and was reduced by 0·5ºevery week until a temperature of 18ºC was reached. Gas heating was used where necessary to achieve the desired temperature. Water was available through two bite-type drinkers per pen.

Experimental design

The experiment was planned to run from 25 to 115 kg live weight. Twenty-five Landrace, 25 Pietrain, and

24 Meishan pigs completed the experiment. They were allocated into five slaughter groups according to Table 1. The number of days elapsed from the start of the experiment to the point of slaughter for each group was similar, but not the same due to slaughterhouse scheduling. Individual pigs reached their slaughter points at different weights, with the result that each pig type was represented by pigs slaughtered at live weights that were relatively evenly spaced throughout the total growth period. Thus it was found reasonable to express many parameters against the base of live weight.

Statistical analyses

Descriptive statistics for live growth performance are laid out as means with their respective standard errors. Analysis of variance for differences between pig types with regard to live pig performance used a general linear model. The model included pig type, group, and pig type by group interaction. An interaction between pig type and group was considered possible in the event of the pig types having significantly different patterns of growth with regard to time on experiment. End weights for the pig types were not consistent across the groups, so end weight was used as a covariate. Results for comparisons between pigs for live pig performance are presented as adjusted least squares means together with an average standard error of the mean (s.e.). The s.e. was calculated as (error mean square (EMS)/n)$^{1/2}$, where n is the number of animals per treatment. The standard error of the difference (s.e.d.) was defined as s.e $\times$ $2^{1/2}$; where n was different for the pig types (25, 25 and 24), s.e.d. = (EMS $\times$ $(1/n_1 + 1/n_2))^{1/2}$. Differences between two means were estimated as significant ($P < 0{\cdot}05$) if they were greater than the product of s.e.d. and t. Regression analysis was used to describe the various relationships as appropriate. Parameter values are given with their respective standard errors. Linear and non-linear regression relationships were determined by use of least squares non-linear regression in SIGMAPLOT 5, a product of SPSS Science (Chicago, Illinois). The SigmaPlot curve fitter uses the Marquardt-Levenberg algorithm (Marquardt, 1963; Press *et al.*, 1986) to find the coefficients (parameters) of the independent variable(s) that give the 'best fit' between the equation and the data. This algorithm seeks, by iteration until the differences between the residual sum of squares no longer decreases significantly, the values of the parameters that minimize the sum of the squared differences between the values of the observed and predicted values of the dependent variable (convergence).

Table 1 *Live growth performance of pigs in each group (with standard error of the mean in brackets)*

	Landrace type					Pietrain type					Meishan type				
Group	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
No.	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5
Start weight (kg)	27·8	25·4	26·6	27·2	29·6	25·2	25·8	24·4	29·0	29·6	26·8	27·2	28·2	28·0	27·3
	(1·50)	(1·12)	(0·87)	(1·98)	(2·46)	(1·71)	(1·02)	(0·68)	(1·34)	(1·72)	(0·58)	(1·36)	(0·74)	(1·78)	(1·05)
Days in group	17	31	52	73	101	17	37	58	79	107	13	34	48	69	104
End weight (kg)	36·0	35·0	63·0	77·6	115·8	31·2	45·4	64·4	84·4	116·2	29·6	45·4	62·0	84·5	102·7
	(2·02)	(3·21)	(1·97)	(5·87)	(5·14)	(1·85)	(2·32)	(1·72)	(2·99)	(2·08)	(1·08)	(2·93)	(2·02)	(4·21)	(4·03)
Weight gain (kg/day)	0·482	0·313	0·702	0·690	0·854	0·353	0·532	0·690	0·701	0·810	0·216	0·535	0·704	0·819	0·738
	(0·121)	(0·094)	(0·028)	(0·055)	(0·031)	(0·019)	(0·058)	(0·019)	(0·021)	(0·026)	(0·096)	(0·074)	(0·039)	(0·042)	(0·034)
P2 backfat depth (mm)	6·4	5·6	8·2	12·2	16·2	4·8	7·0	9·0	10·0	12·2	5·4	9·2	10·0	14·3	20·6
	(0·68)	(0·87)	(0·66)	(0·74)	(1·46)	(0·58)	(0·84)	(0·89)	(0·32)	(0·97)	(0·25)	(1·02)	(0·84)	(1·44)	(3·53)
Food intake (kg/day)	1·00	0·956	1·28	1·61	2·04	0·67	1·19	1·48	1·69	2·03	0·83	1·41	1·69	2·09	2·09
	(0·053)	(0·146)	(0·066)	(0·170)	(0·110)	(0·035)	(0·065)	(0·048)	(0·035)	(0·069)	(0·064)	(0·141)	(0·083)	(0·113)	(0·118)

Table 2 *Allometric relationships between the dissected lean and fatty tissues (kg) of the whole carcass and the live weight of pigs grown from 25 to 115 kg. In the function* $Y = a.X^b$, Y *(kg) = total dissected lean tissue or total dissected fatty tissue, and* X *= live weight (kg) (standard errors of the coefficient and exponent are given in brackets)*

Y (kg)	*a*	*b*	r^2	s.e. of the estimate
Landrace type (no. = 10)				
Total dissected lean tissue	0·368 (0·0781)	1·012 (0·0471)	0·99	1·625
Total dissected fatty tissue	0·00930 (0·00662)	1·641 (0·1529)	0·96	1·786
Pietrain type (no. = 10)				
Total dissected lean tissue	0·335 (0·0545)	1·060 (0·0363)	0·99	1·230
Total dissected fatty tissue	0·0305 (0·00698)	1·337 (0·0505)	0·99	0·483
Meishan type (no. = 10)				
Total dissected lean tissue	0·324 (0·0633)	1·023 (0·0440)	0·99	1·193
Total dissected fatty tissue	0·0185 (0·00707)	1·521 (0·0846)	0·98	1·013

Dissection and chemical composition of the dissected components of the body

Animals were slaughtered by electrical stunning and exsanguination. Immediately after evisceration, warm carcass weight and P2 fat thickness were recorded. The left side of each carcass was prepared by removal of head, feet, tail, and flare and kidney fat, and then cut into six joints (shoulder, foreloin, hindloin, belly, flank and pelvic limb) as described by Brown and Wood (1979). A full side dissection was carried out on 30 of the 74 pigs and for the remaining 44 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). Values for the weights of lean and fatty tissues dissected from the half carcass and from the pelvic limb of that half carcass of 10 Landrace, 10 Pietrain and 10 Meishan type pigs were accumulated for each pig. This gave carcass total tissue weights and carcass pelvic limb tissue weights for individual pigs at their various individual slaughter weights through the trial. For the remaining 15 Landrace, 15 Pietrain and 14 Meishan type pigs this procedure was followed for the pelvic limb only. Specific gravity of the whole pelvic limb was determined by weighing in air and in water (and correcting for temperature) according to the method of Adam and Smith (1964). The chemical analysis for protein and for lipid of the bulked pelvic limb lean and bulked pelvic limb fatty tissues for each individual pig was determined for all 74 pigs according to method of the Association of Official Analytical Chemists (AOAC, 1980). Chemical analysis for one (Meishan type) pig was the subject of possible mislabelling and put aside. For the fully dissected pigs the bulked samples for each individual pig comprised the lean and fatty tissues separately from both the pelvic limb and from the rest of the dissected carcass (four bulked samples per pig). The chemical composition of the dissected carcass bone, skin, head, feet, tail, blood and viscera (including kidney and flare fat), was not determined directly, but by regression from earlier analyses of similarly dissected materials by Tullis (1982).

Results

Performance of the live pigs

The start and end weight (kg), P2 backfat depth (mm) and food intake (kg) for the five groups of each of the three pig types is shown in Table 1. Target end points for each group were predetermined by calendar date with an intention of giving intervals between slaughter points of approximately 20 kg throughout the 25 to 115 kg growth period. Differences between days in group and end weight suggest that the more valuable comparisons between pig types would be for daily weight gain and daily food intake, and that the analyses should include group × type interaction and end weight as a covariate. Adjusted least squares means for live-weight gain (kg/day) over all pigs for Landrace, Pietrain and Meishan pig types respectively were 0·616, 0·589 and 0·613 (average s.e. = 0·020, $P > 0{\cdot}05$). The interaction between pig type and group approached significance ($P = 0{\cdot}074$). That pig types did not behave consistently over the five groups is evident from Table 1. Adjusted least squares means for food intake (kg/day) over all pigs for Landrace, Pietrain and Meishan pig types respectively were 1·39, 1·36 and 1·64 (average s.e. = 0·024, $P < 0{\cdot}001$). The interaction between pig type and group was significant ($P < 0{\cdot}01$). That pig types did not behave consistently over the five groups is again evident from Table 1. The Meishan type ate more food daily than the other two types. Adjusted least squares means for P2 backfat depth (mm at time of slaughter) over all pigs for Landrace, Pietrain and Meishan pig

Table 3 *Linear relationships between the dissected lean and fatty tissues (kg) of the whole carcass and the age (days) of pigs grown from 25 to 115 kg. In the function* Y = a + bX, Y *(kg) = total dissected lean tissue or total dissected fatty tissue, and* X *= age (days) (standard errors of the constant and the coefficient are given in brackets)*

Y (kg)	*a*	*b*	r^2	s.e. of the estimate
Landrace type (no. = 10)				
Total dissected lean tissue	–22·8 (4·29)	0·419 (0·0360)	0·94	3·385
Total dissected fatty tissue	–18·9 (4·03)	0·251 (0·0339)	0·87	3·182
Pietrain type (no. = 10)				
Total dissected lean tissue	–22·6 (2·84)	0·427 (0·0226)	0·98	2·175
Total dissected fatty tissue	–10·4 (1·42)	0·158 (0·0113)	0·96	1·083
Meishan type (no. = 10)				
Total dissected lean tissue	–13·0 (3·56)	0·308 (0·0294)	0·93	2·891
Total dissected fatty tissue	–14·3 (2·88)	0·218 (0·0237)	0·91	2·335

types respectively were 9·86, 8·11 and 12·08 (average s.e. = 0·469, $P < 0·001$). The interaction between pig type and group was once again significant ($P < 0·001$). The Meishan type was fattest, the Pietrain least fat, with the Landrace intermediate.

Dissected lean and fat in the carcass

Total carcass lean and fatty tissue may be expressed as an allometric function of pig live body weight using those pigs for which complete carcass lean and fatty tissue dissection data were obtained. Parameter estimates following fitting of the function $Y = a \times X^b$ are given in Table 2. Values for b show that the dissected tissues grew faster than the live body, although only slightly so in the case of lean ($b \approx 1$). For fatty tissue the rate of gain was substantially faster than the live body, with b values of 1·6, 1·3 and 1·5 ($P < 0·05$) for the Landrace, Pietrain and Meishan types respectively. The Pietrain type fattened significantly more slowly than the other two types. Expression of total carcass lean and fatty tissue as a linear function of pig age gives estimates of daily dissected tissue gain (kg) in the form of the b value for the regression of tissue weight on age. Parameter values for the fitted functions are given in Table 3 and show the Meishan to be the slowest type with regard to lean tissue gain, and the Pietrain to be the slowest type with regard to fatty tissue gain.

Those pigs for which the total dissected lean and fatty tissues in the whole carcass (DL_C and DF_C) were obtained, were also separately dissected to determine

Table 4 *Linear* (Y = a + b . X) *and allometric* (Y = a . X^b) *descriptions of whole body carcass dissected lean* (DL_C) *and whole body carcass dissected fatty tissue* (DF_C) *mass as a function of dissected lean in the pelvic limb* (DL_{PL}) *and dissected fatty tissue in the pelvic limb* (DF_{PL}) *(standard errors are given in brackets)*

	Landrace type	Pietrain type	Meishan type
Dissected lean: linear [DL_C (kg) = $a + b$. DL_{PL}]			
a	0·361 (0·497)	–1·26 (0·729)	–1·44 (0·511)
b	2·88 (0·051)	3·072 (0·0671)	3·179 (0·0612)
r^2	0·99	0·99	0·99
s.e. of estimate	0·712	0·906	0·605
Dissected fatty tissue: linear [DF_C (kg) = $a + b$. DF_{PL}]			
a	–0·396 (0·415)	–0·088 (0·497)	–0·834 (0·427)
b	4·35 (0·137)	4·07 (0·198)	4·93 (0·151)
r^2	0·99	0·98	0·99
s.e. of estimate	0·794	0·748	0·683
Dissected lean: allometric [DL_C (kg) = a . $DL_{PL}{}^b$]			
a	2·97 (0·163)	2·63 (0·175)	2·58 (0·120)
b	0·992 (0·0219)	1·047 (0·0259)	1·070 (0·0201)
r^2	0·99	0·99	0·99
s.e. of estimate	0·729	0·889	0·540
Dissected fatty tissue: allometric [DF_C (kg) = a . $DF_{PL}{}^b$]			
a	3·88 (0·267)	4·01 (0·286)	4·10 (0·212)
b	1·060 (0·0444)	1·005 (0·0587)	1·101 (0·0377)
r^2	0·99	0·98	0·99
s.e. of estimate	0·754	0·749	0·598

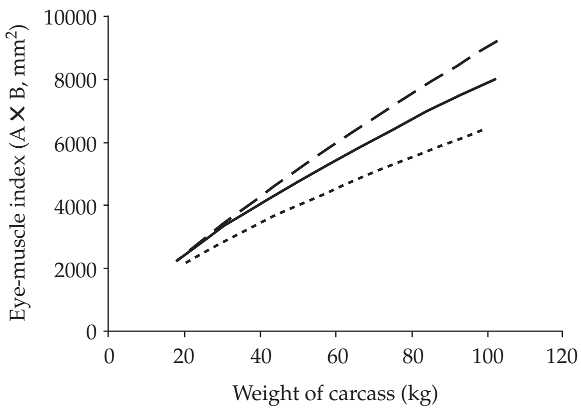

Figure 1 Allometric relationship between size of eye muscle ('A' width × 'B' depth, mm^2) and carcass weight (kg), for Landrace type (——), Pietrain type (— —) and Meishan type (- - - -) of pig.

the lean and fatty tissues in the pelvic limb (DL_{PL} and DF_{PL}). This allows expression of the relationship between the dissected tissues of the pelvic limb and those of the whole carcass. Linear and allometric expressions are given in Table 4. In the case of the linear functions the constant terms were small and not different from zero. The *b* coefficients suggest that the Meishan type may have in its pelvic limb less of its total carcass lean and more of its total carcass fatty tissue, as compared with the other two types. In the allometric functions, exponent values are close to unity, but suggest that, in comparison with the other types, the lean tissue of the pelvic limb of the Meishan type to be growing slower than that of the whole carcass.

The cross-sectional dimensions of the *longissimus dorsi* muscle (the eye muscle) may be used as an indicator of muscularity. The width and depth (mm) of the muscle was determined at the P2 position, and the product of the two dimensions ('A' and 'B') used to give an index. The following allometric relationships (± s.e.) with the weight of the carcass (W_c, kg) were derived (for Landrace type there was one missing plot).

Meishan type (no. = 24):

$$\text{eye muscle index (width} \times \text{depth, mm}^2) = 270\ (47{\cdot}0) \times W_c^{0{\cdot}689\ (0{\cdot}0426)}$$

$r^2 = 0{\cdot}94$, s.e. of estimate = 352.

Landrace type (no. = 24):

$$\text{eye muscle index (width} \times \text{depth, mm}^2) = 270\ (44{\cdot}9) \times W_c^{0{\cdot}733\ (0{\cdot}0397)}$$

$r^2 = 0{\cdot}95$, s.e. of estimate = 440.

Pietrain type (no. = 25):

$$\text{eye muscle index (width} \times \text{depth, mm}^2) = 206\ (34{\cdot}3) \times W_c^{0{\cdot}822\ (0{\cdot}0392)}$$

$r^2 = 0{\cdot}96$, s.e. of estimate = 456.

Table 5 *Linear* (Y = a + b . *W*) *and Gompertz* (Y = A.*exp*(-*exp*(- B . (*W* – *W**)))) *descriptions of protein* (Pt_{PL}) *and lipid* (Lt_{PL}) *mass in the dissected lean + fatty tissues of the pelvic limb as a function of live body weight* (*W*) (*standard errors are given in brackets*)

	Landrace type	Pietrain type	Meishan type
Protein: linear [Pt_{LP} (kg) = *a* + *b* . W]			
a	–0·0647 (0·0882)	–0·0616 (0·0806)	–0·0570 (0·0825)
b	0·0367 (0·0012)	0·0409 (0·0011)	0·0316 (0·0012)
r^2	0·98	0·98	0·97
s.e. of estimate†	0·189	0·163	0·160
Lipid: linear [Lt_{LP} (kg) = *a* + *b* . W]			
a	–0·982 (0·123)	–0·799 (0·143)	–0·841 (0·144)
b	0·0413 (0·00170)	0·0353 (0·00191)	0·0407 (0·00205)
r^2	0·96	0·94	0·95
s.e. of estimate†	0·263	0·288	0·279
Protein: Gompertz [Pt_{LP} (kg) = *A* . exp(-exp(- *B* . (W – W*)))]			
A	6·18 (0·749)	6·93 (0·662)	5·22 (0·844)
W*	63·1 (7·86)	63·4 (6·17)	58·7 (10·2)
B	0·0176 (0·00285)	0·0175 (0·00217)	0·0176 (0·00358)
r^2	0·97	0·99	0·97
s.e. of estimate†	0·200	0·157	0·168
Lipid: Gompertz [Lt_{LP} (kg) = *A* . exp(-exp(- *B* . (W – W*)))]			
A	5·48 (0·668)	47·2 (89·7)	7·16 (2·16)
W*	72·7 (6·34)	265 (205)	85·7 (18·3)
B	0·0241 (0·00385)	0·0064 (0·0039)	0·0177 (0·00468)
r^2	0·97	0·96	0·96
s.e. of estimate†	0·253	0·222	0·262

† (error (or residual) mean square)$^{1/2}$

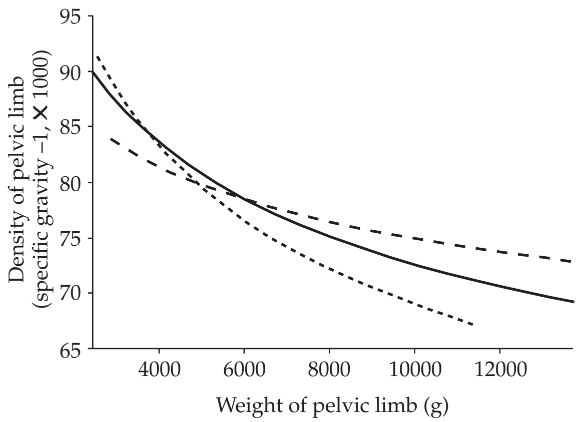

Figure 2 Allometric relationship between the density and the weight of the pelvic limb for Landrace type (——), Pietrain type (– – –) and Meishan type (- - - -) of pig.

The Pietrain type had a significantly greater value ($P < 0·05$) for the exponent, while differences in the coefficient were not significant. The greater area of the eye muscle in the Pietrain type and the lesser area in the Meishan type is evident from Figure 1.

Protein and lipid composition

Table 5 gives the linear ($Y = a + b \times W$) and Gompertz ($Y = A \times \exp(-\exp(-B.(W - W^*)))$) descriptions of chemical protein ($Y = Pt_{PL}$) and lipid ($Y = Lt_{PL}$) mass in the dissected lean + fatty tissues of the pelvic limb as a function of live body weight (W). As the pelvic limb is a highly representative subsample of the whole carcass (Table 4, Table 6, and below), the accumulation of protein and lipid in the dissectable tissues of the pelvic limb as the pig grows in live weight is strongly indicative of the dissectable carcass as a whole.

In the case of the linear functions all the parameter values were significant ($P < 0·001$) with the exception of the constant terms (a) for protein, none of which was significant ($P > 0·05$). For protein, the values for the b parameter suggest that for each kg of live-weight gain some 37 g, 41 g and 32 g of protein is retained in the dissected lean + fatty tissues of the pelvic limb of the Landrace, Pietrain and Meishan types respectively. These values were all significantly different ($P < 0·05$). For lipid, the values for the a parameter are negative for all pig types, approach 1 kg in value, and are not different between the pig types. The values for the b parameter suggest that for each kg of live-weight gain some 41 g, 35 g and 41 g of lipid is retained in dissected lean + fatty tissues of the pelvic limb of the Landrace, Pietrain and Meishan types respectively. The Pietrain type had significantly less lipid in the live-weight gain when compared with the other two ($P < 0·05$).

The density of the pelvic limb was determined to give an indication of relative content of lipid. The following allometric relationships (± standard error) between density (as specific gravity –1, × 1000) and the weight of the limb in air (W_{PL}, kg) were derived (for Meishan and Pietrain types there were two missing plots).

Meishan type (no. = 22):

$$\text{density} = 460\ (61·0) \times W_{PL}^{-0·206\ (0·0155)}$$
$$r^2 = 0·90, \text{ s.e. of estimate} = 2·81.$$

Landrace type (no. = 25):

$$\text{density} = 300\ (38·5) \times W_{PL}^{-0·154\ (0·0149)}$$
$$r^2 = 0·82, \text{ s.e. of estimate} = 2·96.$$

Pietrain type (no. = 23):

$$\text{density} = 173\ (20·0) \times W_{PL}^{-0·091\ (0·0132)}$$
$$r^2 = 0·70, \text{ s.e. of estimate} = 2·36.$$

As may also be surmised from Figure 2, at higher slaughter weights the pelvic limb was least dense in the Meishan type, and most dense in the Pietrain

Table 6 *Relationships between the chemical composition of the dissected lean + fatty tissues of the pelvic limb (Pt_{PL} and Lt_{PL}) and the chemical composition of the dissected lean + fatty tissues of the whole carcass of the pig (Pt_C and Lt_C) determined by dissection and chemical analysis of the 29 fully dissected and chemically analysed pigs on trial. In the function* $Y = a . X^b$, Y *(kg)* = Pt_C *or* Lt_C *, and* X *(kg)* = Pt_{PL} *or* Lt_{PL} *(standard errors of the coefficient and exponent are given in brackets)*

Y (kg)	*a*	*b*	r^2	s.e. of the estimate
Landrace type (no. = 10)				
Pt_C	3·07 (0·153)	0·958 (0·0403)	0·99	0·382
Lt_C	4·18 (0·319)	1·067 (0·0593)	0·99	0·781
Pietrain type (no. = 10)				
Pt_C	2·84 (0·054)	1·040 (0·0152)	0·99	0·139
Lt_C	4·23 (0·269)	0·974 (0·0659)	0·98	0·688
Meishan type (no. = 9)				
Pt_C	2·74 (0·239)	1·155 (0·0821)	0·97	0·575
Lt_C	4·60 (0·263)	1·028 (0·0538)	0·99	0·619

type. The Pietrain type was also significantly ($P < 0{\cdot}01$) the slowest to lose density and the Meishan the fastest to lose density with increasing limb weight as the pigs grew. The Landrace type was intermediate, and significantly different from the other two types.

The Gompertz (1825) function may be useful to describe data showing tendency to a sigmoidal response and an asymptote. In Table 5 all the parameter values of the Gompertz functions were significant ($P < 0{\cdot}001$) with the exception of those relating to the expression of lipid retention in the pelvic limb of the Pietrain type, all of which were not significant. In this case the parameter values had little meaning, as (apart from having large errors) the data showed no evidence of any asymptote. The least fat pig type, the Pietrain, showed evidence of the most rapid acceleration of lipid retention as live weight increased. Overall, the use of the Gompertz function over the weight range of the present data showed no advantage in interpretation or accuracy over the linear function.

Table 6 shows the relationships between the chemical composition of the dissected lean + fatty tissues of the pelvic limb (Pt_{PL} and Lt_{PL}) and the chemical composition of the dissected lean + fatty tissues of the whole carcass of the pig (Pt_C and Lt_C). These were determined by dissection and chemical analysis of the 29 fully dissected pigs on trial for which there were full chemical analyses. All the parameter values were significant ($P < 0{\cdot}001$), the correlation coefficients high, and the error of the estimate low. These functions may therefore be used to calculate the chemical composition of the whole body of those 45 pigs for which only dissection of the pelvic limb was completed. There is little difference between pig types for the parameter values, although it would appear that in the case of the Meishan type the whole carcass retains protein at a progressively faster rate than the pelvic limb, which is not the case for the other two types.

Discussion

This report seeks primarily to present effective descriptions of three pig types differing in their physical and compositional form. The pigs were given a high quality diet *ad libitum* with the objective of observing performance from 25 to 115 kg live weight under commercial conditions. As a single diet was used for all three pig types, which in the event have been shown to differ in the characteristics of their growth, it might be surmised that type differences could have been accentuated by different diets being offered (perhaps according to protein retention rate, or by choice feeding).

The growth rate of the Meishan type was diminished during the last stage of growth, but a definitive conclusion would be premature in the absence of data covering a subsequent group '6' period. All the pigs showed a propensity for periods of rapid growth. Average live-weight gains were similar for all the pig types, even though the Meishan ate more food. The poorer food conversion ratio for the Meishan type in the later stages of growth would be consistent with increasing fatness of the Meishan at this time, and the failure of the same type to curb food intake in the face of a reduced rate of growth. The Meishan was the fatter type and the Pietrain the leaner. Of the three types, the Pietrain appears to have the greatest ultimate protein mass in the pelvic limb.

As measured by the backfat depth at the P2 site, the Meishan type was fatter than the other two types, and the Pietrain less fat than the Landrace. The backfat depth of the Pietrain appeared to increase rather slowly with increasing live weight. Fatness at the heavier live weights was markedly variable in the case of the Meishan; this group contained the extremes of both fatness and thinness. All types differed in their fatness in ascending order, Pietrain, Landrace, Meishan. It was evident that the relationship between P2 backfat depth and chemical lipid was not good. It may not be assumed that similar conclusions will necessarily be drawn from analysis of P2 data as from the content of lipid. The possibility of a contrary finding for this relationship is important as it is commonly assumed that P2 is an acceptable predictor of body fat content for the various pig types, whereas this only seems safe for the Landrace, not for the Pietrian, or for the Meishan. It would appear not just that, in common with the finding of Planella and Cook (1991), there is a need for population-specific prediction of body fat content from P2; but further, in some cases the relationship may be inadequate for any prediction.

Carcass dissection of the lean and fatty tissues indicated that the Pietrain type fattened noticeably more slowly than the other two types, indicating its carcass value (in terms of lean meat) to be maintained to higher live weights. The Meishan type had the fastest fatty tissue gains whilst the Pietrain type had the slowest. The pelvic limb of the Meishan type appears, in comparison with the other two types, to have a less enhanced value with regard to lean content relative to the rest of the body, and this situation worsens as the animals increase in weight. The cross sectional area of the *longissimus dorsi* muscle clearly indicated the greater muscle dimension of the Pietrain type as compared to the Meishan type, with the Landrace intermediate. The

Table 7 *Relationships between chemical composition (protein (Pt) and lipid (Lt)) of the dissected lean + fatty tissues of the pelvic limb and the chemical composition of the body of the whole pig. In the function* Y = a . X^b, Y *(kg) is the whole body protein, or whole body lipid, and* X *(kg) is the sum of the protein determined from the dissected lean and fatty tissues in the pelvic limb (for protein), or the sum of the lipid determined from the dissected lean and fatty tissues in the pelvic limb (for lipid) (standard errors of the coefficient and exponent are given in brackets)*

Y (kg)	*a*	*b*	r^2	s.e. of estimate
Landrace type (no. = 25)				
Whole body protein	5·63 (0·102)	0·849 (0·0154)	0·99	0·389
Whole body lipid	6·92 (0·213)	0·968 (0·0259)	0·99	0·807
Pietrain type (no. = 25)				
Whole body protein	4·95 (0·059)	0·935 (0·0094)	0·99	0·226
Whole body lipid	6·30 (0·139)	0·973 (0·0202)	0·99	0·574
Meishan type (no. = 24)				
Whole body protein	5·27 (0·098)	1·004 (0·0182)	0·99	0·358
Whole body lipid	7·60 (0·209)	0·922 (0·0250)	0·99	0·794

determination of the specific gravity of the pelvic limb, following the methodology of Adam and Smith (1964), proved informative. Although differences in bone density would confuse a direct relationship between density and lipid content, a clear picture of differences between all three of the pig types emerged from the density measurements. The loss in density of the pelvic limb (which may be taken as indicative of fattening) as the animals grew was in the order Meishan, Landrace, Pietrain.

The potential and actual rate of protein retention is, together with *ad libitum* food intake, arguably the most important descriptor of pig type. The best mode of expression remains in dispute. Over longer periods of growth, where the diminution of the rate of gain as maturity approaches is observed, some form of sigmoidal expression is favoured, often from the family including the Gompertz function (Gompertz, 1825). For shorter periods of growth, including the 20- to 120-kg phase normally associated with meat production from pigs, it has been found difficult to justify on the grounds of data presented any other than a simple linear description (Whittemore and Green, 2002). Allometry has been forwarded as an alternative by Schinckel and de Lange (1996). The present report has expressed the increase in protein mass with increasing live weight by other functions as well as linear but it is strikingly evident that the appropriate expression for

Table 8 *Linear* (Y = a + b . X) *and allometric* (Y = a . X^b) *descriptions of whole body protein (Pt) and body lipid (Lt) mass as a function of live body weight (W) (standard errors are given in brackets)*

	Landrace type	Pietrain type	Meishan type
Protein: linear [Pt (kg) = *a* + *b* . W]			
a	1·345 (0·356)	0·477 (0·3778)	0·219 (0·4361)
b	0·154 (0·0049)	0·178 (0·0051)	0·168 (0·0062)
r^2	0·98	0·98	0·97
s.e. of estimate	0·760	0·764	0·845
Lipid: linear [Lt (kg) = *a* + *b* . W]			
a	–5·924 (0·785)	–4·666 (0·800)	–4·930 (0·900)
b	0·269 (0·0108)	0·214 (0·0107)	0·274 (0·0128)
r^2	0·96	0·95	0·95
s.e. of estimate	1·679	1·618	1·744
Protein: allometric [Pt (kg) = *a* . W^b]			
a	0·301 (0·0380)	0·227 (0·0311)	0·194 (0·0354)
b	0·873 (0·0288)	0·952 (0·0305)	0·971 (0·0413)
r^2	0·98	0·98	0·97
s.e. of estimate	0·718	0·751	0·841
Lipid: allometric [Lt = *a* . W^b]			
a	0·0210 (0·0075)	0·0109 (0·0040)	0·0331 (0·0125)
b	1·496 (0·0778)	1·591 (0·0797)	1·417 (0·0838)
r^2	0·96	0·97	0·95
s.e. of estimate	1·727	1·281	1·753

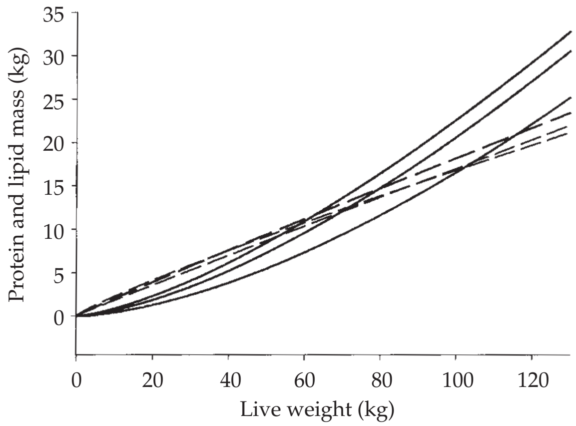

Figure 3 Increase in whole body protein mass (– – –) and whole body lipid mass (———) as a function of pig live weight.

description of the rate of protein retention, but not necessarily for prediction, is invariably linear.

The growth of pelvic limb protein and lipid provide indicative information, but do not provide quantification of the key values; those of the whole body protein and lipid content. However, this may be estimated if the information gathered in the present experiment is supplemented from elsewhere. The use of such imported data extends the present data set, but limits interpretation not only because there may be differences between experiments, but there may also be specific differences relating to pig type. The determined protein and lipid moieties in the dissected lean and fatty tissues comprise some 0·6 of total body protein and some 0·7 of total body lipid (Sandberg, 2002). The remainder is the protein and lipid to be found in the non-dissected tissues; bone, viscera, blood, skin, head, feet, and tail. It would appear that the protein and lipid content of viscera may not vary greatly for actively growing pigs, as indicated by comparison of values determined by Sandberg (2002) with those from Tullis (1982) and Wagner *et al.* (1999). The data from the physically dissected and chemically analysed whole pigs of Tullis (1982) were therefore used (**Appendix 1**) to supplement the present data set. This allowed the determination of whole body protein and lipid content from knowledge of the protein and lipid content of the dissected tissues of the pelvic limb. Values for the necessary regression parameters are given in Table 7. All are significant ($P < 0{\cdot}001$). The relationships appropriate to the three pig types were different.

Table 8 presents whole body protein (Pt) and lipid (Lt) mass as linear and allometric functions of live weight (W). All parameter values are significant ($P < 0{\cdot}001$), with the exception of the constant for the linear expression of Pt on W. The slope of the regression of Pt on W was greatest, and of Lt on W was least, for the Pietrain pig type. The linear and allometric expression of protein mass (Pt) as a function of live-body weight (W) at the point of slaughter suggests the Landrace retain protein as a proportion of the body as a whole at a slower rate than the other types. The allometric relationship was close to or less than 1 for protein, but substantially greater than 1 for lipid. A pattern of increasing rate of lipid retention with increasing live weight was apparent for all breed types. Figure 3 presents the allometric function of protein and lipid mass on pig live weight. As may be observed, the response of protein mass is much more linear than that of lipid, despite the two occurring simultaneously. The order of lipid mass is Meishan > Landrace > Pietrain, while that for protein mass is Pietrain > Meishan = Landrace. The point at which the protein and lipid masses become equal (and animals begin to fatten) occurs at around 50 kg live weight for the Meishan type, 70 kg live weight for the Landrace type and 110 kg for the Pietrain type.

Linear regression of estimated whole body protein and whole body lipid (using the allometric functions in Table 8) upon pig age may give estimates of daily rates of protein retention (Pr, kg/day) and lipid retention (Lr, kg/day). For Pr, respective values (s.e. in brackets) for the Landrace, Pietrain and Meishan types were 0·152 (0·0100), 0·197 (0·0083) and 0·142 (0·0076). For Lr, respective values were 0·258 (0·0198), 0·198 (0·0112) and 0·230 (0·0126).

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Appendix 1

The chemical composition of dissected lean and fat, and of the weights of all body components with the exception of blood and gut contents were determined directly. The residual information was estimated by relationships calculated *de novo* from the data sets of Tullis (1982), who used similar techniques (Appendix Table 1).

Appendix Table 1 *Relationships calculated from Tullis (1982) and used for the determination of the chemical composition of non-carcass lean and fat components, according to the function* $Y = a \cdot X^b$, *where* Y *is the weight (kg) of chemical in the component and* X *is the weight (kg) of the component (standard errors of the coefficient and exponent are given in brackets)*

Y (kg)	*a*	*b*
Blood†		
Protein (Pt)	0·207 (0·0138)	1·003 (0·0424)
Lipid (Lt)	0·0013 (0·0002)	1·080 (0·0787)
Bone		
Protein (Pt)	0·197 (0·0099)	1·001 (0·0219)
Lipid (Lt)	0·0590 (0·0121)	1·433 (0·0860)
Skin		
Protein (Pt)	0·421 (0·0432)	1·001 (0·0567)
Lipid (Lt)	0·0227 (0·0489)	0·895 (0·1220)
Non-carcass‡		
Protein (Pt)	0·240 (0·0351)	0·739 (0·0551)
Lipid (Lt)	0·0127 (0·0049)	2·100 (0·1310)
Head, feet and tail		
Protein (Pt)	0·200 (0·0154)	0·921 (0·0314)
Lipid (Lt)	0·092 (0·0265)	1·402 (0·1050)

† Blood was estimated as 0·0179 (s.e. 0·0057) . $W^{1\cdot093\ (0\cdot0630)}$.
‡ Gut fill was estimated as 0·176 (s.e. 0·0501) . $W^{0\cdot706\ (0\cdot0576)}$.