EFFECTS OF BREED AND SEX ON THE PATTERNS OF FAT DEPOSITION AND DISTRIBUTION IN SWINE

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The growth and distribution of fat from 163 pig carcasses were compared among five breeds (Duroc × Yorkshire (D×Y), Hampshire × Yorkshire (H×Y), Yorkshire (Y×Y), Yorkshire × Lacombe-Yorkshire (Y×L-Y) and Lacombe × Yorkshire (L×Y)) and two sex-types (barrows and gilts) over a wide range in carcass weight. The growth pattern of fat and the fat depots were estimated from the allometric equation ($Y = aX^b$) using side muscle weight and side fat weight separately as independent variables. Growth coefficients (b) for intermuscular and subcutaneous fat depots were similar for the hindquarter but the intermuscular depot coefficient was slightly higher for the forequarter. The coefficient for body cavity fat was highest in all comparisons. No significant differences were detected for coefficients among breeds and between sexes using both total muscle and total side fat as independent variables. Significant breed and sex-type differences were found in the fat depots at a constant weight of side muscle. This would indicate that breed differences in fatness seemed to be more influenced by the initiation of fattening at different muscle weights than by any inherent differences in rate of fattening. Significant breed differences were also found in the fat depots at a constant fat weight, indicating that breed may influence fat distribution. Sex-type had no effect on fat distribution when the evaluation was made at constant fatness.

Nous avons comparé l'accroissement et la répartition du tissu graisseux dans 163 carcasses de porcs, castrats et coches, de divers poids, provenant de cinq races pures ou croisées, Duroc × Yorkshire, Hampshire × Yorkshire, Yorkshire, Yorkshire × Lacombe-Yorkshire et Lacombe × Yorkshire. Les courbes de croissance du tissu adipeux total et des divers dépôts de graisse ont été calculées par l'équation allométrique $Y = ax^b$), utilisant le poids des muscles et de la graisse de la demi-carcasse séparément comme variables indépendantes. Les coefficients de croissance (*b*) obtenus pour les dépôts de graisse intermusculaire et sous-cutanée étaient semblables dans l'arrière-train mais dans le quartier avant, les premiers ont produit des coefficients légèrement plus élevés que les seconds. Le coefficient obtenu pour la graisse viscérale a été régulièrement le plus élevé. On n'a pas observé de différences significatives selon les races ou les sexes quand on employait en même temps le poids des muscles et le poids de la graisse de la demi-carcasse comme variables indépendantes. Des différences significatives selon les races et les sexes ont, cependant, été observées dans les dépôts adipeux calculé en fonction d'un poids total de muscles constant, ce qui indique que les différences d'état d'engraissement liées à la race tiennent davantage au stade de développement musculaire auquel le processus

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d'engraissement est déclenché qu'à des différences inhérentes, génétiques, d'aptitude à l'engraissement. Des différences significatives liées à la race ont également été obtenues pour les dépôts adipeux calculés en fonction d'un poids total de graisse constant. Cela laisse à conclure que la race pourrait avoir une incidence sur la répartition des graisses dans la carcasse. Le sexe n'a pas eu d'effet sur la répartition des graisses quand le calcul était fait en fonction d'un poids de graisse constant.

Studies reporting the development of the fat depots in swine carcasses are important both to breeding and grading schemes, as total fatness is often estimated from measurements of subcutaneous fat depths. It is, however, not clearly known whether breed and sex affect mainly the rate or onset of fat accumulation or both.

There have been many reports in the literature on fat deposition in the pig, and these have either been evaluated at a constant endpoint (McMeekan 1940a,b; Doornenbal 1967; Martin et al. 1972), or using a serial slaughter design but without regression analysis (Richmond and Berg 1971a). Only two studies have examined the relative growth of the fat depots in pigs (Davies and Pryor 1977; Kempster and Evans 1979). Consequently, there is limited information regarding the rate of maturity of the various fat depots. The present paper reports the effects of breed and sex on the relative growth and distribution of fat in swine.

MATERIALS AND METHODS

The data for this study were derived from experiments reported by Wilson (1971) and Richmond and Berg (1971a). In total, 163 pig carcasses of five breeds, (Duroc × Yorkshire (D×Y), Hampshire × Yorkshire (H×Y), Yorkshire (Y×Y), Yorkshire × Lacombe-Yorkshire (Y×L-Y), and Lacombe × Yorkshire (L×Y)), and two sex-types (barrows and gilts) were used in this study. All pigs were weaned at 3 wk of age and fed a standard starting ration (14.63 J DE/kg and 20% crude protein) to 23 kg liveweight. Thereafter, various energy and protein levels were employed to measure the effect of plane of nutrition on live animal performance. Pigs were slaughtered at 68, 91, or 114 kg liveweight (see Richmond and Berg (1971a,b) and Wilson (1971) for further details on the management of these experiments).

Pigs were slaughtered at a commercial packing plant following routine procedures. The carcass comprised the eviscerated body following the removal of the head at the atlanto-occipital articulation, the thoracic limbs at the carpo-metacarpal articulation, and the pelvic limbs at the tarso-metatarsal articulation. It was split into two sides by a longitudinal saw cut as close as possible to the mid-line. Left sides were dissected into individual muscles, fat and bones at the University of Alberta Meats Laboratory, using modifications of the procedure of Butterfield and May (1966).

The three dissectable fat depots were the subcutaneous, intermuscular and body cavity depots. Half carcasses were divided at the 11th and 12th rib, so that fattening patterns could be compared between the fore- and hingquarters.

The growth of the fat depots relative to half carcass muscle was evaluated using the allometric equation (Huxley 1932). The data were transformed to logs, and the slopes of the regression lines for each breed and sex-type were compared using analysis of covariance (Neter and Wasserman 1974). If the slopes were homogeneous, a common slope was fitted and group means for total fat and each depot fat were compared after adjusting to a common side muscle weight. Plane of nutrition was not included in the model because of relatively low group numbers. Growth coefficients of the depot fats relative to total fat were also computed by the same method in order to define their pattern of maturity. Differences among adjusted means were tested for significance using the Scheffé test corrected for unequal subclass numbers (Neter and Wasserman 1974).

RESULTS

The mean unadjusted total and depot fat weights are presented in Table 1 by breed and sex-type. The individual fat weights had large standard deviations, which indicated a wide variations in fatness mainly brought about by the range in liveweight at slaughter.

The growth of total side fat and depot fats relative to total side muscle are shown in Table 2. The individual breed and sex-type

Table 1. Means (kg) and standard deviations (SD) of unadjusted fat weights by breed-type† and sex-type

	Breed type										Sex type			
	D×Y		H×Y		Y×Y		L×(Y-L)		L×Y		Barrows		Gilts	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
No. of carcasses	22		41		28		36		36		83		80	
Half carcass														
Total fat	9.94	5.94	10.53	4.63	10.21	5.93	10.99	4.06	11.25	3.89	11.44	4.94	10.18	4.02
Subcutaneous fat	8.17	4.97	8.65	3.87	7.96	4.49	8.34	3.08	8.51	2.89	8.97	3.85	7.98	3.27
Intermuscular fat	1.57	0.95	1.62	0.75	1.56	1.75	1.93	0.77	2.08	0.82	1.96	1.19	1.74	0.77
Body cavity fat	0.21	0.10	0.27	0.14	1.47	1.42	0.73	0.33	0.67	0.30	0.51	0.81	0.39	0.27
Forequarter														
Total fat	4.82	2.90	5.19	2.22	4.74	2.63	5.89	2.22	5.97	2.13	5.74	2.42	5.10	2.07
Subcutaneous fat	3.70	2.25	4.04	1.74	3.80	2.12	4.28	1.62	4.32	1.54	4.29	1.84	3.78	1.54
Intermuscular fat	1.05	0.68	1.09	0.51	0.87	0.51	1.32	0.55	1.38	0.52	1.28	0.60	1.18	0.54
Body cavity fat	0.06	0.04	0.07	0.04	0.08	0.06	0.28	0.15	0.26	0.15	0.17	0.15	0.14	0.12
Hindquarter														
Total fat	5.13	3.07	5.34	2.42	5.23	3.54	5.11	1.88	5.28	1.95	5.70	2.69	5.00	2.06
Subcutaneous fat	4.47	2.76	4.61	2.15	4.16	2.50	4.06	1.50	4.19	1.46	4.67	2.14	4.19	1.78
Intermuscular fat	0.52	0.29	0.53	0.29	0.69	1.48	0.60	0.24	0.69	0.38	0.68	0.86	0.56	0.25
Body cavity fat	0.14	0.08	0.20	0.12	0.38	0.37	0.45	0.20	0.40	0.18	0.34	0.77	0.24	0.16

†D×Y = Duroc × Yorkshire, H×Y = Hampshire × Yorkshire, Y×Y = Yorkshire, L×(Y-L) = Lacombe × (Yorkshire-Lacombe), L×Y = Lacombe × Yorkshire.

regressions were homogeneous in all cases, so the common regression coefficient was used. It should be pointed out that the standard errors in these data were quite large and therefore real differences may have escaped detection. There were differences in the rate of fat deposition among depots in the half carcass with subcutaneous fat and body cavity fat having coefficients greater than 1.0 ($P < 0.05$); the growth of intermuscular fat was not significantly different to 1.0 ($P > 0.05$). A result similar to that in the half carcass was found in the fat depots in the hindquarters, whereas in the forequarter all depots had coefficients greater than 1.0 ($P < 0.05$).

Breed means adjusted by applying the common regression to the population mean of total side muscle are shown in Table 3. There were no breed differences in half carcass total fat, or forequarter total fat; there were small but significant breed differences ($P < 0.05$) in hindquarter total fat. Small differences were also recorded among breeds for the fat depots in the half carcass, and when the fat depots were examined separately in the fore- and hindquarters. The D×Y were the fattest breed group, and H×Y the least fat when evaluated at a constant muscle weight.

Sex-type means adjusted to the population mean of total side muscle are also presented in Table 3. Barrows had a greater ($P < 0.05$) amount of fat in all depots than gilts.

The growth data of depot fat relative to total side fat are shown in Table 4. Observed differences were not significant in the rate of depot fat accumulation (growth coefficients) among depots relative to total side fat. However, the coefficients for the intermuscular fat depot of the quarter tended to be higher than those of the subcutaneous fat depot. For the hindquarter, coefficients for intermuscular and subcutaneous depots were quite similar. The body cavity fat depot had the highest growth coefficients in all comparisons.

Breed means, adjusted by applying the common regression coefficient, are shown in Table 5. At a constant total fat weight, L×Y-L and L×Y breed groups generally had more fat in the intermuscular and body cavity depots and less fat in the subcutaneous depots than the D×Y, H×Y, and Y×Y

Table 2. Parameter estimates from the allometric relationship $Y = aX^b$ of total and depot fat (Y) with total side muscle (X) for five breed-types and two sex-types

Dependent variable (Y)	b	SEb	t test†	Effect of breed-type		Effect of sex-type	
				Slope	Intercept	Slope	Intercept
Half carcass							
Total fat	1.39	0.095	>1.0	NS	*	NS	***
Subcutaneous fat	1.37	0.093	>1.0	NS	**	NS	***
Intermuscular fat	1.36	0.137	1.0	NS	**	NS	***
Body cavity fat	1.73	0.172	>1.0	NS	***	NS	***
Forequarter							
Total fat	1.38	0.091	>1.0	NS	NS	NS	***
Subcutaneous fat	1.36	0.091	>1.0	NS	NS	NS	***
Intermuscular fat	1.44	0.129	>1.0	NS	**	NS	***
Body cavity fat	1.68	0.195	>1.0	NS	***	NS	***
Hindquarter							
Total fat	1.39	0.102	>1.0	NS	*	NS	***
Subcutaneous fat	1.38	0.117	>1.0	NS	***	NS	***
Intermuscular fat	1.20	0.171	1.0	NS	NS	NS	**
Body cavity fat	1.75	0.188	>1.0	NS	***	NS	***

†The results of a t-test to determine if the coefficient (b) is significantly ($P < 0.05$) less than, greater than, or not significantly ($P > 0.05$) different from 1.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 3. Fat weights (kg) adjusted to the mean of total side muscle (15.09 kg) for five breed-types† and two sexes

Dependent variable	Fat weight for breed (kg)					Fat weight for sex (kg)	
	D×Y	H×Y	Y×Y	L×(Y-L)	L×Y	Barrows	Gilts
Half carcass							
Total fat	11.77	9.99	11.16	10.08	10.98	12.15 *d*	9.56 *e*
Subcutaneous fat	9.69 *a*	8.19 *bc*	9.02 *ab*	7.65 *c*	8.32 *abc*	9.56 *d*	7.64 *e*
Intermuscular fat	1.80	1.52	1.56	1.73	1.98	1.92 *d*	1.52 *e*
Body cavity fat	0.21 *a*	0.23 *a*	0.26 *a*	0.64 *b*	0.63 *b*	0.43 *b*	0.29 *e*
Forequarter							
Total fat	5.69	4.95	5.37	5.39	5.81	6.11 *d*	4.83 *e*
Subcutaneous fat	4.39	3.85	4.30	3.92	4.21	4.65 *d*	3.67 *e*
Intermuscular fat	1.19 *a*	1.01 *ab*	0.97 *ab*	1.18 *a*	1.33 *b*	1.26 *d*	1.01 *e*
Body cavity fat	0.06 *a*	0.06 *a*	0.07 *a*	0.24 *b*	0.23 *b*	0.13 *d*	0.09 *e*
Hindquarter							
Total fat	6.07 *a*	5.04 *bc*	5.75 *ab*	4.68 *c*	5.13 *abc*	5.94 *d*	4.71 *e*
Subcutaneous fat	5.29 *a*	4.34 *b*	4.58 *b*	3.72 *c*	4.08 *bc*	4.83 *d*	3.95 *e*
Intermuscular fat	0.60	0.49	0.54	0.54	0.63	0.62 *d*	0.50 *e*
Body cavity fat	0.14 *a*	0.17 *a*	0.17 *a*	0.39 *b*	0.38 *b*	0.28 *d*	0.19 *e*

†D×Y = Duroc × Yorkshire, H×Y = Hampshire × Yorkshire, Y×Y = Yorkshire, L×(Y-L) = Lacombe × (Yorkshire – Lacombe), L×Y = Lacombe × Yorkshire.
a-c Means in same row with different letters differ significantly at $P < 0.05$ for breed.
d-e Means in same row with different letters differ significantly at $P < 0.05$ for sex.

breeds. The L×Y-L and L×Y breeds had more fat in the forequarter and correspondingly less fat in the hindquarter than the D×Y, H×Y and Y×Y breeds.

Sex-type means adjusted to the population mean of total side muscle are presented in Table 5. There were no differences ($P > 0.05$) in the amount of depot fat in the half carcass, fore- or hindquarter when evaluated at a common weight of total fat.

Table 4. Parameter estimates from the allometric relationship $Y = aX^b$ of depot fat (Y) and total side fat (X) for five breed-types and two sex-types

Dependent variable (Y)	b	SEb	t-test†	Effect of breed-type		Effect of sex-type	
				Slope	Intercept	Slope	Intercept
Half carcass							
Subcutaneous fat	0.95	0.020	1.0	NS	***	NS	NS
Intermuscular fat	1.04	0.049	1.0	NS	***	NS	NS
Body cavity fat	1.24	0.070	>1.0	NS	***	NS	NS
Forequarter							
Total fat	0.97	0.013	1.0	NS	***	NS	NS
Subcutaneous fat	0.95	0.018	<1.0	NS	NS	NS	NS
Intermuscular fat	1.04	0.046	1.0	NS	***	NS	NS
Body cavity fat	1.12	0.095	1.0	NS	***	NS	NS
Hindquarter							
Total fat	1.03	0.013	1.0	NS	***	NS	NS
Subcutaneous fat	0.93	0.042	1.0	NS	***	NS	NS
Intermuscular fat	0.96	0.076	1.0	NS	NS	NS	NS
Body cavity fat	1.27	0.079	>1.0	NS	***	NS	NS

†The results of a t-test to determine if the coefficient (b) is significantly ($P < 0.05$) less than, greater than or not significantly ($P > 0.05$) different from 1.
***$P < 0.001$, NS = $P > 0.05$.

Table 5. Fat weights (kg) adjusted to the mean total side fat (10.68 kg) for five breed-types† and two sex types

Dependent variable	Fat weight for breed (kg)					Fat weight for sex (kg)	
	D×Y	H×Y	Y×Y	L×(Y-L)	L×Y	Barrows	Gilts
Half carcass							
Subcutaneous fat	8.82 *a*	8.75 *a*	8.65 *a*	8.09 *b*	8.09 *b*	8.44	8.51
Intermuscular fat	1.63 *ab*	1.62 *ab*	1.49 *a*	1.83 *b*	1.93 *b*	1.69	1.70
Body cavity fat	0.19 *a*	0.26 *a*	0.25 *a*	0.69 *b*	0.61 *b*	0.36	0.33
Forequarter							
Total fat	5.18 *a*	5.28 *a*	5.15 *a*	5.70 *b*	5.65 *b*	5.39	5.39
Subcutaneous fat	4.00	4.11	4.12	4.15	4.10	4.10	4.09
Intermuscular fat	1.09 *a*	1.08 *a*	0.93 *b*	1.25 *c*	1.29 *c*	1.11	1.13
Body cavity fat	0.06 *a*	0.06 *a*	0.07 *a*	0.26 *b*	0.23 *b*	0.11	0.10
Hindquarter							
Total fat	5.50 *a*	5.39 *a*	5.50 *a*	4.96 *b*	5.00 *b*	5.26	5.27
Subcutaneous fat	4.83 *a*	4.62 *a*	4.39 *a*	3.93 *b*	3.91 *b*	4.27	4.40
Intermuscular fat	0.54	0.52	0.52	0.57	0.61	0.55	0.56
Body cavity fat	0.13 *a*	0.19 *b*	0.16 *ab*	0.42 *c*	0.37 *c*	0.24	0.22

†D×Y = Duroc × Yorkshire, H×Y = Hampshire × Yorkshire, Y×Y = Yorkshire, L×(Y-L) = Lacombe × (Yorkshire – Lacombe), L×Y = Lacombe × Yorkshire.
a-c Means in the same row with different letters differ significantly at $P < 0.05$. There were no significantly different means for sex $P < 0.05$.

DISCUSSION

A. Breed and Sex Influences on Rate of Fat Deposition

A number of workers have studied the effects of breed, sex and plane of nutrition on carcass fatness (Richmond and Berg 1971b; Martin et al. 1972; Moody et al. 1978; Neely et al. 1979). While breed and sex differences in carcass fatness have often been established, the underlying causes of these differences have not been explained.

There were, in this present study, no significant differences in total or depot fat growth rate among breeds or between sex-types when comparisons were made relative to total side muscle weight. This would suggest that the breed and sex-type differences in adjusted means (Tables 3 and 4) were more influenced by the commencement of rapid fattening at different muscle weights, than by differences in the rate of fattening. Similar results were found in pigs by Davies (1974), who compared rate of fattening between Pietrain and Large White pigs, and Berg et al. (1979) in cattle who compared rate of fattening between steers and heifers.

B. Breed and Sex Influences on Fat Deposition Patterns

Growth coefficients for the individual fat depots regressed on total fat were homogeneous for all breeds and both sexes. In the half carcass, body cavity fat had the highest growth coefficient followed by the intermuscular depot, and finally the subcutaneous depot. Kempster and Evans (1979) and Davies and Pryor (1977) reported that the order of fat depot growth was subcutaneous fat followed by intermuscular fat. However, most studies show subcutaneous fat to grow at a similar rate to total fat. This is expected since subcutaneous fat makes up about 80% of the total. The main point of contention is the growth of the intermuscular depot. Possibly the weight ranges used in the respective studies influenced the results. The study of Davies and Pryor (1977) covered the liveweight range from 8 to 62 kg, and the trial of

Kempster and Evans (1979) from 46 to 92 kg. The present study covered the range from 68 to 114 kg; there seemed to be a slight shift in fat partitioning after 90 kg, with more fat deposited in the intermuscular depot relative to total fat than in the subcutaneous depot.

Body cavity fat had the highest growth coefficient both in this study and the one reported by Davies and Pryor (1977). These results contrast with those found in cattle (Berg et al. 1979), where body cavity fat had the lowest growth coefficients of all the fat deposits.

Growth coefficients can also be compared between the fore- and hindquarters. There was a more rapid accumulation of intermuscular fat in the forequarter compared to the hindquarter. It has been suggested that in cattle (Berg and Butterfield 1976), patterns of carcass fat deposition could be explained in terms of physical pressure within the fat storage depots. Thus, the hindquarter would be more resistant to intermuscular fattening, having less intermuscular space than the forequarter. This theory could also apply to the results found in this study.

C. Breed and Sex Influences on Fat Distribution

Breed regressions were homogeneous in all cases for each fat depot relative to total fat, indicating that fat depot growth followed a similar pattern in all breeds over the weight range of this study. The results showed small, but significant, differences among the five breeds for fat distribution when adjusted to the experimental mean of total side fat. The D×Y, H×Y and Y×Y animals tended to have more fat in the subcutaneous fat depot, and less fat in the intermuscular fat depot and body cavity fat depot than the L×Y-L and L×Y animals.

Sex regressions were homogeneous in all cases for each fat depot relative to total fat, indicating that fat depot growth followed a similar pattern over the weight range of this study. The results showed no significant differences between barrows and gilts for fat distribution when adjusted to the experimental mean of total side fat.

D. Comparison of Bovine and Porcine Fat Deposition Patterns

There have been several reports in the literature of fat growth patterns in cattle (Seebeck and Tulloh 1968; Kempster et al. 1976; Berg et al. 1978, 1979). All these studies have clearly demonstrated the differential accumulation of fat, with subcutaneous fat having a higher growth coefficient than intermuscular fat when compared relative to total carcass fatness. Johnson et al. (1972) reported that subcutaneous fat was only a small proportion of total fat in young calves; but at slaughter weight, subcutaneous fat approached intermuscular fat as the predominant fat depot.

Comparing the present results with the above cattle studies, species differences were found for the relative growth of most of the fat depots. Intermuscular and subcutaneous fats had similar growth coefficients in hogs which is in contrast to the above cattle studies where subcutaneous fat generally had growth coefficients greater than those of intermuscular fat. Species differences are possibly the result of adaptations to different evolutionary pressure, i.e. the pig has approximately 80% of its fat in the subcutaneous depot probably as an aid to thermal and mechanical insulation. Similar species adaptations in tissue distribution have been discussed by Berg and Butterfield (1976).

Thus, it has been demonstrated that fat growth in swine followed similar patterns among breeds and between sex-types. Differential fat growth does occur, but the differences among the depot coefficients were generally small, which essentially agrees with the work of Davies and Pryor (1977). In this study, breed exerted a small but significant ($P < 0.05$) influence on fat distribution at a constant side fat weight. However, the differences recorded in fat distribution were mainly from the breeding groups derived from separate studies carried out at different periods of time, so factors other than breed could have influenced the results. Sex had no marked effect on fat distribution in swine at constant side fat weight.

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