FATTENING PATTERNS IN CATTLE. 1. FAT PARTITION AMONG THE DEPOTS

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A trial is reported comparing half-carcass fat partitioning in 12 bulls and 12 heifers each of two breed-types: Hereford (HE) and Dairy Synthetic (DY). These animals were serially slaughtered from weaning (163 ± 15.1 (SE) days) to approximately 16 mo of age. After slaughter, one side of each carcass was broken into eight wholesale cuts, which were separated into fat (subcutaneous fat (SF), intermuscular fat (IF) and body cavity fat (BCF)), muscle and bone. The partition of fat was investigated by examining the development of each depot relative to two independent variates (fat percent and fat weight in the side), using the allometric equation. Relative to fat percent in the side, the regression coefficients for depot fat accumulation were all homogeneous for sex, and only one coefficient (SF in the forequarter) was significantly different ($P < 0.05$) for breed. Relative to fat weight in a side, the regression coefficients for both breed and sex showed several significant differences. Adjusted means at constant total fat weight showed HE animals to have more SF, and less IF than DY animals. There were no significant differences in the adjusted means for sex.

Nous avons comparé sur 12 taurillons et 12 génisses appartenant à deux groupes de races, Hereford (HE) et Dairy Synthetic (DY) le mode de répartition du gras dans la demi-carcasse. Les bêtes ont été abattues à dates successives à partir du sevrage (163 j ± 15.1 (ET)) jusqu'à l'âge de 16 mois. Chaque demi-carcasse a été découpée en huit morceaux de gros dont on a ensuite séparé les graisses sous-cutanée (SF), intermusculaire (IF), splanchnique (BCF), les muscles et les os. Le mode de répartition des graisses a été déterminé d'après le développement relatif de chaque dépôt par rapport à deux variables indépendantes (pourcentage de gras et poids de gras de la demi-carcasse), au moyen de l'équation allométrique. Par rapport au pourcentage de gras, les coefficients de régression obtenus pour l'accumulation de graisses de dépôt étaient tous homogènes quel que soit le sexe et seulement un coefficient (SF du quartier avant) était significativement différent ($P < 0.05$) d'une race à l'autre. Par rapport au poids de gras de la demi-carcasse, les coefficients de régression ont produit plusieurs différences significatives selon le sexe ou la race. Quand les moyennes étaient ajustées sur un poids constant de gras total, on constatait que les bêtes de type HE avaient plus de SF et moins de IF que celles de type DY. Il n'y a toutefois pas eu de différence significative entre les sexes.

The overall aim of beef production is the efficient production of carcasses of the type and quality demanded by the consumer. There have been several recent studies designed to evaluate muscle and bone growth (Kempster and Jones 1977; Kempster et al. 1977; Berg et al. 1978a,b; Jones et al. 1978, 1980) in beef cattle, and knowledge has increased to such a point that accurate equations are available to predict

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these tissues (Price et al. 1976, 1977) by partial dissection.

Studies designed to evaluate fat accretion and distribution are limited so far in beef cattle. Fat has no clear-cut anatomical boundaries as have the other tissues, which has caused some confusion and a tendency for research workers to evaluate the development of the carcass tissues on a fat-free basis (Elsley et al. 1964). However, it has been shown that the fat depots grow differentially, intermuscular fat attaining a greater proportion earlier than subcutaneous fat (Callow 1961; Royal Smithfield Club 1966; Johnston et al. 1972).

The major confusion appears to revolve around fat partitioning. Kempster et al. (1976), in a study involving a large number of carcasses of heterogeneous origin, reported breed differences in fat partition, and concluded that dairy cattle tend to deposit a higher proportion of their total fat internally at the expense of subcutaneous fat, when compared to beef cattle. Berg et al. (1978c), in a more controlled study, found only minor differences in fat partition among the progeny of eight sire breeds, and concluded that fat growth patterns were similar when comparisons were made relative to total fat weight. Clearly, these results have great importance in Canadian beef grading, which uses a single measure of subcutaneous fat to predict retail cut-out.

The present study was set up to examine the partitioning of fat in bulls and heifers of both beef and dairy type.

MATERIAL AND METHODS

The experiment was conducted at the University of Alberta Beef Research Ranch and at Kinsella, using bulls and heifers of two breed-types, Hereford (HE) and Dairy Synthetic (DY). The Herefords were purebred and the Dairy Synthetics were a composite of about 60% large dairy breeds (Holstein and Brown Swiss) and 40% beef breeds, mainly Hereford and Angus (Berg 1975). The experimental design has recently been reported elsewhere in detail (Jones et al. 1980). Briefly, 12 heifers of each breed were used, grouped four to a pen by breed within sex, and fed a high concentrate ration from weaning to slaughter. The cattle were serially slaughtered in a blocked random sequence so that the first four animals killed included a bull and a heifer of each breed. This sequential slaughter plan was continued to the end of the trial. Age at slaughter ranged from 6 to 16 mo.

Following slaughter and overnight chilling, the quartered left side of each carcass was taken to the University Meats Laboratory where it was broken into eight wholesale cuts as outlined by Levie (1970), except that the carcasses were quartered between the 11th and 12th ribs. The eight wholesale cuts were the chuck, shank, brisket, rib, loin, flank, sirloin and hip. The rib-chuck separation was made between the 5th and 6th ribs. The shank and brisket were removed from the chuck, just above the lateral condyle of the humerus. The plate was combined with the brisket in this study after separation from the rib. The flank was removed by continuing the rib-plate separation through to the tip of the hip. The loin was separated from the hip on a line between the 4th and 5th sacral vertebrae to approximately 2.5 cm in front of the aitch bone. A boneless sirloin cut was removed from the posterior end of the loin. The cuts were separated into muscle, subcutaneous fat (SF), intermuscular fat (IF), body cavity fat (BCF) and bone.

The accumulation of physically separated fat in each cut relative to the increase in two independent variates (fat percent in a side, fat weight in a side) was evaluated using Huxley's allometric equation ($Y = aX^b$) (Huxley 1932). The data were transformed to logs, and the slopes of the regression lines for each breed and sex were compared using analysis of co-variance (Neter and Wasserman 1974). If the slopes were homogeneous, a common slope was fitted and group means were compared after adjusting to the covariate mean. Differences among adjusted means were tested for significance using the Scheffé test corrected for unequal subclass numbers (Neter and Wasserman 1974).

RESULTS AND DISCUSSION

One HE bull was removed from the trial to be used for a different project. Otherwise, no other losses were encountered and the animals remained healthy.

The mean unadjusted fat weights are presented in Table 1 for the left side and quarters. It is interesting to note that

Table 1. Means (kg ± SD) of unadjusted fat weights by breed and sex

	Breed				Sex			
	Hereford		Dairy Synthetic†		Heifer		Bull	
No.:	23	SD	24	SD	24	SD	23	SD
Half carcass								
Total fat	22.70	14.344	23.02	12.435	23.21	13.399	22.51	13.397
Subcutaneous fat	9.05	6.221	8.03	4.809	8.82	5.546	8.23	5.575
Intermuscular fat	9.96	5.847	10.77	5.360	10.34	5.445	10.41	5.794
Body cavity fat	3.69	2.431	4.22	2.471	4.05	2.586	3.87	2.331
Forequarter								
Total fat	11.86	7.635	12.09	6.468	12.26	7.102	11.68	7.010
Subcutaneous fat	3.54	2.508	2.93	1.666	2.16	4.672	3.01	2.101
Intermuscular fat	6.94	4.300	7.59	4.036	7.29	4.069	7.26	4.294
Hindquarter								
Total fat	10.84	6.755	10.93	6.001	10.94	6.352	10.83	6.410
Subcutaneous fat	5.51	3.778	5.10	3.223	5.38	3.476	5.22	3.545
Intermuscular fat	3.02	1.590	3.17	1.365	3.05	2.438	3.14	1.524

†Dairy Synthetic = composite averaging 30% Holstein, 30% Brown Swiss, and 40% other breeds. The difference between the sum of subcutaneous and intermuscular fat in a quarter and total quarter fat is made up by body cavity fat.

different breeds and sexes of similar age that have been offered free choice of similar feed have similar weights of carcass fat. This would essentially agree with previous data presented by Berg and Butterfield (1976), but differ from those of Bondari and Willham (1977) and O'Mary et al. (1979).

The growth of the fat depots in the left side and the quarters relative to fat percent in the side are shown in Table 2. The greatest relative contribution to increasing total side fat was made by the SF depot followed by the BCF and IF depots. There were no significant sex differences in the relative growth of the depots, and only one breed difference for the SF depot in the forequarter: HE animals having a higher regression coefficient than DY animals. However, some caution must be exercised when examining these results, as the regression coefficients for all the SF depots were consistently larger than other depots for HE animals compared to DY animals, but only significantly larger in the forequarter. Berg et al. (1978a) have stressed the lack of sensitivity in the test of homogeneity of regression.

Depot fat weights, adjusted to the mean of side fat percent for the two breeds and two sexes, are given in Table 3. The breed × sex interaction was not significant ($P > 0.05$). At a constant fat percent, DY animals were larger than HE animals and consequently had a significantly greater weight of fat in all depots. Fat percent in the side has been suggested by Kempster (1980) to be a useful independent variable in carcass studies, since it allows comparisons at equal physiological maturity. When this is done for each depot (Table 3), it is clear that HE cattle partition a greater percentage of fat into the subcutaneous depot in both the fore- and hindquarters than DY cattle.

At constant physiological maturity, bulls were larger than heifers, and had a significantly greater weight of fat in all the depots (Table 3). When the depots were expressed as a percentage of total fat (Table 3), no important differences were detected in

Table 2. Estimates from the allometric relationship $Y = aX^b$ of depot fat weight (Y) with fat percentage in a side (X) for two breeds and two sexes

Dependent variable	Breed					Sex				
	Growth coefficient b				Effect of breed	Growth coefficient b				Effect of sex
(Y)	Hereford	SEb	Dairy Synthetic†	SEb	on b	Heifer	SEb	Bull	SEb	on b
Half carcass										
Subcutaneous fat	2.45	0.099	2.12	0.131	NS	2.32	0.104	2.35	0.138	NS
Intermuscular fat	1.96	0.089	1.95	0.117	NS	1.88	0.087	2.07	0.116	NS
Body cavity fat	2.07	0.119	2.06	0.156	NS	2.03	0.118	2.12	0.157	NS
Forequarter										
Total fat	2.12	0.091	2.07	0.119	NS	2.03	0.089	2.22	0.118	NS
Subcutaneous fat	2.68	0.143	2.13	0.189	*	2.54	0.151	2.38	0.201	NS
Intermuscular fat	2.01	0.099	2.11	0.130	NS	1.94	0.095	2.24	0.126	NS
Hindquarter										
Total fat	2.15	0.085	1.99	0.112	NS	2.06	0.086	2.15	0.113	NS
Subcutaneous fat	2.33	0.094	2.14	0.124	NS	2.21	0.095	2.34	0.126	NS
Intermuscular fat	1.82	0.092	1.60	0.121	NS	1.75	0.094	1.73	0.125	NS

†Dairy Synthetic = composite averaging 30% Holstein, 30% Brown Swiss and 40% other breeds.
NS = $P > 0.05$, * = $P < 0.05$.

Table 3. Depot fat weights (kg) adjusted to the mean of side fat percentage (20.45%)

	Fat weight (kg)					
	Hereford	Dairy Synthetic†	Sig.	Heifer	Bull	Sig.
Half carcass						
Subcutaneous fat	5.71 (37.3)‡	7.64 (34.6)	*	5.21 (35.6)	8.37 (36.4)	*
Intermuscular fat	7.07 (46.2)	10.43 (47.3)	*	6.90 (47.1)	10.69 (46.5)	*
Body cavity fat	2.51 (16.5)	3.99 (18.1)	*	2.53 (17.3)	3.95 (17.1)	*
Forequarter						
Total fat	8.03 (52.1)	11.58 (52.3)	*	7.79 (52.8)	11.93 (51.6)	*
Subcutaneous fat	2.11 (13.8)	2.80 (12.7)	*	1.92 (13.1)	3.08 (13.4)	*
Intermuscular fat	4.81 (31.5)	7.23 (32.8)	*	4.73 (32.3)	7.34 (31.9)	*
Hindquarter						
Total fat	7.38 (47.9)	10.54 (47.7)	*	6.96 (47.2)	11.17 (48.4)	*
Subcutaneous fat	3.56 (23.3)	4.80 (21.8)	*	3.25 (22.2)	5.26 (22.9)	*
Intermuscular fat	2.24 (14.6)	3.16 (14.3)	*	2.14 (14.6)	3.31 (14.4)	*

†Dairy Synthetic = composite averaging 30% Holstein, 30% Brown Swiss, and 40% beef breeds.
‡Figures in parentheses refer to depot fat weight as a percentage of side fat weight.
* = $P < 0.05$.

depot fat partitioning for bulls and heifers.

The growth of the fat depots in the left side and the fore- and hindquarters relative to the second independent variable, total side fat weight, is shown in Table 4. There were some significant breed effects in the growth coefficients for SF in the half carcass, and also in the forequarter. Growth coefficients for SF were consistently higher for HE and DY cattle. Conversely, growth coefficients for IF were generally higher for DY than HE cattle.

Regression coefficients for depot fat were also compared between sexes (Table 4) and heifers had a significantly higher coefficient for SF, and a lower coefficient for intermuscular fat than bulls in the forequarter. All other coefficients for each depot were homogeneous.

These results indicate that when comparing these types of cattle (beef vs. dairy), some differences in fat partition are apparent, as found by the Royal Smithfield Club (1966). The slight sex difference in fat partitioning found in the forequarter was not observed in the recent work of Berg et al. (1979).

There is conclusive evidence from these data that within the normal slaughter range, SF is a relatively faster growing depot than IF.

Growth coefficients can also be compared between the fore- and hindquarters. In both breeds and sexes, there was a more rapid accumulation of IF in the fore- compared to hindquarters. The same comparison for SF showed regression coefficients to be similar in both quarters. These patterns of carcass fat deposition have been suggested to be caused by physical pressure surrounding the depots (Berg and Butterfield 1976).

Table 5 shows the depot fat weights for both breeds and both sexes adjusted to a constant weight of total fat. The breed × sex interaction was not significant ($P > 0.05$). Several breed differences were found, generally in the form of HE animals having more SF and less IF than DY animals. There were no differences for body cavity fat; neither were there any significant differences between sexes for adjusted weight of any of the depot fats; this agrees with the work of Berg et al. (1979).

The results of this experiment show that the use of different expressions of the same variable (side fat percent, side fat weight) could lead to different conclusions. The regression coefficients associated with the use of side fat percent (Table 2) were, with one exception, homogeneous when the two breeds and two sexes were compared. However, it was noticeable that the HE

Table 4. Estimates from the allometric relationship $Y = aX^b$ of depot fat weight (Y) with total side fat weight (X) for two breeds and two sexes

	Breed					Sex				
	Growth coefficient *b*				Effect of breed on *b*	Growth coefficient *b*				Effect of sex on *b*
	Hereford	SE*b*	Dairy Synthetic†	SE*b*		Heifer	SE*b*	Bull	SE*b*	
Half carcass										
Subcutaneous fat	1.14	0.026	1.04	0.035	*	1.13	0.028	1.06	0.034	NS
Intermuscular fat	0.92	0.015	0.96	0.020	NS	0.92	0.015	0.96	0.019	NS
Body cavity fat	0.97	0.036	1.01	0.048	NS	0.99	0.037	0.97	0.046	NS
Forequarter										
Total fat	0.99	0.010	1.02	0.014	NS	0.99	0.011	1.02	0.013	NS
Subcutaneous fat	1.25	0.049	1.06	0.067	*	1.26	0.051	1.07	0.063	*
Intermuscular fat	0.94	0.018	1.04	0.025	**	0.94	0.019	1.03	0.024	**
Hindquarter										
Total fat	1.01	0.012	0.98	0.016	NS	1.01	0.012	0.98	0.015	NS
Subcutaneous fat	1.09	0.028	1.04	0.037	NS	1.08	0.029	1.05	0.035	NS
Intermuscular fat	0.85	0.027	0.79	0.036	NS	0.85	0.028	0.80	0.035	NS

†Dairy Synthetic = composite averaging 30% Holstein, 30% Brown Swiss, and 40% other breeds.
NS = $P > 0.05$; * = $P < 0.05$; ** = $P < 0.01$.

Table 5. Depot fat weights (kg) adjusted to the mean of total fat weight (18.48 kg)

	Fat weight (kg)					
	Hereford	Dairy Synthetic†	Sig.	Heifer	Bull	Sig.
Half carcass						
Subcutaneous fat	6.97	6.25	*	6.68	6.53	NS
Intermuscular fat	8.37	8.81	*	8.50	8.68	NS
Body cavity fat	2.99	3.33	NS	3.15	3.17	NS
Forequarter						
Total fat	9.62	9.66	NS	9.75	9.53	NS
Subcutaneous fat	2.61	2.26	7*	2.50	2.37	NS
Intermuscular fat	5.74	6.06	*	5.89	5.90	NS
Hindquarter						
Total fat	8.84	8.80	NS	8.70	8.93	NS
Subcutaneous fat	4.32	3.96	*	4.13	4.14	NS
Intermuscular fat	2.60	2.72	NS	2.58	2.75	NS

†Dairy Synthetic = composite averaging 30% Holstein, 30% Brown Swiss, and 40% other breeds.
NS = $P > 0.05$; * = $P < 0.05$.

animals had larger coefficients for the SF depots than DY animals. The main difference between the analyses using side fat percent and those using side fat weight as an independent variable was the size of the standard errors of the regression coefficients (Table 2 and 4). It seems probable from these data that the use of untransformed data (side fat weight) provide a more sensitive test of treatment effect on growth coefficients of fat depots.

The results strongly suggest that there are differences in fat partition between beef and dairy breeds in agreement with the studies of the Royal Smithfield Club (1966) and Kempster et al. (1976). Only minor differences in fat partition between beef and dairy breeds were found by Berg et al. (1978c), possibly because all the dams were of the same breed and there were not extreme dairy types among the eight sire breeds.

Fat partitioning has major importance in relation to Canadian beef grading, since in the A and B grades, yield is assessed from measurement of fat thickness at the 12th rib. The results of the present experiment would suggest that this measurement of fat thickness would mean different amounts of total fat in the whole carcass (and hence different cutability), DY cattle being fatter at the same fat thickness than HE cattle. This has also been discussed by Charles and Johnson (1976). Further work is necessary to identify the factors controlling these breed differences in fat partitioning in order that grading systems can deal more equitably with carcasses from all breed types.

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