PATTERNS OF CARCASS FAT DEPOSITION IN HEIFERS, STEERS AND BULLS

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Seventy-five young, full-fed, Shorthorn-sired cattle (36 heifers, 24 steers, 15 bulls) were slaughtered over a wide liveweight range (150–550 kg) to evaluate the influence of sex on the patterns of fat deposition. Growth coefficients for depot fat relative to half-carcass fat were homogeneous, and there were no differences ($P > 0.05$) among the adjusted means of depot fat at constant total fat. This indicates that depot fat partitioning among sexes is probably minor, provided comparisons are made at equal fatness. Total rate of fat deposition relative to muscle was similar for heifers and steers, but significantly ($P < 0.01$) lower for bulls. It is concluded that differences in fattening patterns among sexes result from a combination of fattening at a lighter weight of carcass muscle in heifers than steers and steers than bulls, and from a more rapid rate of fat deposition relative to muscle in heifers and steers than bulls. Relative to half-carcass fat, the rate of fat deposition was greatest in the subcutaneous depot in all sexes followed by intermuscular fat and finally body cavity fat. Relative growth of kidney fat was variable among the sexes, but it was generally similar to the subcutaneous depot. Relative rate of intermuscular fat deposition was greater in the forequarter than the hindquarter, while relative rate of subcutaneous fat deposition was similar in both the fore- and hindquarters.

Soixante-quinze jeunes bovins de père Shorthorn, alimentés à discrétion, ont été abattus à divers poids allant de 150 à 550 kg. L'objet de l'expérience était de déterminer l'incidence du sexe sur l'évolution de l'état d'engraissement: l'échantillon comprenait 36 génisses, 24 bouvillons et 15 taurillons. Les coefficients de croissance du gras de dépôt par rapport aux demi-carcasses étaient semblables et on n'a pas relevé non plus de différence significative entre les moyennes des valeurs de gras de dépôt corrigées en fonction d'un poids de gras total constant. Ceci indiquerait que la répartition du gras est sensiblement la même indépendamment du sexe de l'animal, pour autant que les comparaisons soient ramenées à un même état d'engraissement. Le taux total de déposition du gras par rapport à la musculature était le même chez les génisses et les bouvillons mais significativement ($P < 0.01$) moindre chez les taurillons. Ces différences viendraient, d'une part, de ce que l'engraissement s'exerce sur une masse musculaire moins importante chez les génisses que chez les bouvillons, et chez ces derniers que chez les taurillons, et d'autre part, de ce que le taux d'engraissement est plus rapide chez les génisses et les bouvillons que chez les taurillons. Dans chaque demi-carcasse, c'est dans le gras sous-cutané que le taux de déposition a été le plus intense, suivi par le gras intermusculaire, puis par le gras interne. L'accroissement relatif de la graisse péri-rénale a varié selon le sexe mais, dans l'ensemble, il s'accordait avec celui du gras sous-cutané. Le rythme de formation du gras intermusculaire était plus intense dans le quartier avant que dans l'arrière-main mais on n'a pas observé de différence comparable dans le cas de gras sous-cutané.

Fat is a major source of variation in carcass composition. The quantitative requirements in a carcass are best met when the proportion of muscle is maximum, bone a minimum and fat is at an optimum as determined by local consumer preference (Berg and Butterfield 1976). Numerous studies have been reported on fat deposition (Callow 1961; Butterfield 1965; Charles and Johnson 1976) and its relationship to other carcass characteristics (Luitingh 1962; Martin et al. 1971; Johnson et al. 1973; Purchas and Davies 1974). However, these studies have mainly been designed to examine carcass composition at constant end points. Thus, the dynamics of fat deposition in the process of carcass growth have not been clearly established. Berg et al. (1978) examined the growth of fat relative to various body-size dimensions in cattle of eight sire breeds and found no significant breed differences in the rate of fattening from 300 kg liveweight to slaughter at 12 or 15 mo of age. The work of Mukhoty and Berg (1971) also suggested that sex had little effect on the rate of fattening; sexes differed in fatness at common size dimensions, heifers being fatter than steers and steers fatter than bulls, which was considered by the authors to be a result of early onset of the fattening phase in heifers, followed by steers and then bulls.

The objectives of the present study were to describe the pattern of fattening in bulls, steers and heifers, and to examine possible sex influences on the rate of fattening, and fat distribution.

MATERIALS AND METHODS

Seventy-five Shorthorn-sired cattle consisting of 36 heifers, 24 steers (early and late castrates) and 15 bulls from the University of Alberta Beef Research Ranch, Kinsella were used in the present study. The dams were Hereford, Beef Synthetic and Charolais- and Brown Swiss-sired crossbreds (Berg 1975). Calves were born in April and May of 1966 and 1967. Calves nursed their dams without benefit of creep feed, were weaned in October at an average age of 6 mo and then placed on ad libitum feed of concentrate (Jones and Price 1977) plus 0.9 kg cut brome-alfalfa hay per head per day to slaughter.

Allotment of male calves as bulls, early castrates and late castrates was random within breed of dam group. Castration was performed between 2 and 3 mo and 6 and 7 mo for early and late castrates, respectively. Data for early and late castrates were pooled after preliminary analysis showed no differences in their patterns of fat deposition.

Animals were selected for slaughter over a wide weight range at random within each sex and breed-type of dam. Table 1 shows the number of animals for each sex and the range in liveweight, carcass weight, half carcass muscle weight and half carcass fat weight.

All animals were slaughtered at a local abattoir. After cooling overnight carcasses were quartered at the 11-12th rib and transported to the University meats laboratory. Left sides were anatomically dissected into bone, muscle and fat according to the technique of Butterfield and May (1966). Fat was divided into four depots: subcutaneous, intermuscular, body cavity and kidney fat. The subcutaneous and intermuscular depots were further subdivided into fore- and hindquarters depots.

The allometric equation (Huxley 1932) was used to describe the effect of sex on the relationship between half carcass fat and half carcass muscle. The data were transformed to logs and the slopes of the regression lines for each sex were compared using analysis of covariance (Neter and Wasserman 1974). Data were adjusted for the effects of breed of dam and year, which were subsequently found to be nonsignificant in all analyses. Group means for total fat and each depot fat were compared after adjusting to a common side muscle weight. Growth coefficients of the depot fats relative to total fat were also computed by the same method in order to define their patterns of maturity. Differences between adjusted means were tested for significance using the Student-Newman-Keuls test corrected for unequal subclass numbers (Steel and Torrie 1960).

RESULTS

The growth of total side fat and depot fat relative to total side muscle are shown in Table 2. Regression coefficients for steers and heifers were similar for all the fat depots. Bulls had significantly lower coefficients in all the analyses except in the case of body

Table 1. Range in liveweight, carcass weight, half carcass muscle weight and half carcass fat weight of the three sexes

	Heifers±SE	Steers±SE	Bulls±SE
Liveweight range 150–249 kg			
Number of animals	4	2	2
Liveweight (kg)	212±14.1	190±0.5	175±11.6
Carcass weight (kg)	132.5± 4.60	99.0± 1.00	87.5± 0.50
Muscle weight (kg)	37.48±0.845	31.37±0.190	28.98±0.145
Total fat (kg)	14.45±0.339	7.44±1.143	7.29±1.037
Liveweight range 250–349 kg			
Number of animals	18	7	5
Liveweight (kg)	303± 8.2	281± 6.58	285± 3.3
Carcass weight (kg)	168.2± 5.57	157.6±15.91	157.4± 3.98
Muscle weight (kg)	46.83±1.379	44.17±1.379	47.96±1.266
Total fat (kg)	22.63±1.370	21.13±1.128	16.72±1.571
Liveweight range 350–449 kg			
Number of animals	12	11	4
Liveweight (kg)	396± 10.5	399± 8.0	388± 10.3
Carcass weight (kg)	235.5± 6.58	234.3± 9.02	220.2± 5.85
Muscle weight (kg)	60.00±1.739	64.67±1.892	68.44±1.933
Total fat (kg)	40.60±1.799	36.36±2.099	24.58±1.368
Liveweight range 450–549 kg			
Number of animals	2	4	4
Liveweight (kg)	456± 7.5	495± 9.2	521± 11.1
Carcass weight (kg)	271.5± 4.51	300.7± 2.12	316.2± 5.49
Muscle weight (kg)	69.13±0.481	81.11±1.620	97.03±0.915
Total fat (kg)	51.45±1.339	48.23±1.581	40.26±3.782

cavity fat and kidney fat in the half carcass, and intermuscular fat in the hindquarter.

Rates of fat deposition in the depots relative to total muscle were also compared within sex (Table 2). For the half carcass, kidney and subcutaneous fat deposition was higher than in the intermuscular and body cavity depots in all sexes, but these differences were not significant ($P > 0.05$). Subcutaneous fat had a higher deposition

Table 2. Parameter estimates from the allometric relationship $Y = aX^b$ of total and depot fat (Y) with total side muscle (X) for three sexes

Dependent variable (Y)	Regression coefficient b						Effect of sex on slope
	Heifers	SE*b*	Steers	SE*b*	Bulls	SE*b*	
Half carcass							
Total fat	1.69	0.142	1.69	0.141	1.18	0.139	**
Subcutaneous fat	1.95	0.197	2.02	0.196	1.37	0.193	**
Intermuscular fat	1.50	0.132	1.47	0.131	1.05	0.129	**
Body cavity fat	1.26	0.186	1.35	0.184	0.90	0.182	NS
Kidney fat	2.06	0.271	1.91	0.269	1.47	0.265	NS
Forequarter							
Total fat	1.72	0.157	1.78	0.156	1.19	0.154	**
Subcutaneous fat	1.90	0.238	2.11	0.236	1.28	0.233	*
Intermuscular fat	1.67	0.165	1.63	0.164	1.17	0.162	*
Hindquarter							
Total fat	1.67	0.139	1.62	0.138	1.17	0.137	**
Subcutaneous fat	1.99	0.188	1.98	0.186	1.38	0.184	**
Intermuscular fat	1.18	0.132	1.20	0.131	0.97	0.129	NS

NS, $P > 0.05$, *$P < 0.05$; **$P < 0.01$.

rate in the hindquarter than intermuscular fat while the opposite was found to be true in the forequarter.

Adjusted means for total carcass fat and each depot fat are presented in Table 3 for the three sexes. At a common weight of muscle, heifers had more fat than steers, and steers had more fat than bulls. Slightly more fat was deposited in the hindquarter than the forequarter, but the proportional contribution from the major depots (subcutaneous and intermuscular) was markedly different. In the forequarter about 56% of the fat was intermuscular and 31% subcutaneous, whereas in the hindquarter 42% was subcutaneous and only 27% was intermuscular fat.

Growth coefficients for depot fats relative to total fat are presented in Table 4. There were no differences ($P > 0.05$) among sexes for the regressions (growth coefficients) of the half carcass fat depots or front and hindquarter depots relative to total fat. The highest growth coefficients were found for

Table 3. Fat weights (kg) adjusted to the mean of total side muscle†

	Log fat weight			Residual mean square	Fat weight (kg)		
	Heifers	Steers	Bulls		Heifers	Steers	Bulls
Half carcass							
Total fat	1.4958 *a*	1.4101 *b*	1.2458 *c*	0.00610	31.32 *a*	25.72 *b*	17.62 *c*
Subcutaneous fat	1.0935 *a*	0.9715 *b*	0.7836 *c*	0.01173	12.40 *a*	9.36 *b*	6.07 *c*
Intermuscular fat	1.0921 *a*	1.0266 *b*	0.8769 *c*	0.00526	12.36 *a*	10.63 *b*	7.89 *c*
Body cavity fat	0.4927 *a*	0.4926 *a*	0.3484 *b*	0.01039	3.11 *a*	3.11 *a*	2.83 *c*
Kidney fat	0.5002 *a*	0.3832 *b*	0.2071 *c*	0.02211	3.16 *a*	2.42 *b*	1.61 *c*
Forequarter							
Total fat	1.1664 *a*	1.0685 *b*	0.9024 *c*	0.00743	14.67 *a*	11.71 *b*	7.99 *c*
Subcutaneous fat	0.6929 *a*	0.5363 *b*	0.3965 *c*	0.01708	4.93 *a*	3.44 *b*	2.49 *c*
Intermuscular fat	0.9207 *a*	0.8326 *b*	0.6445 *c*	0.00823	8.33 *a*	6.80 *b*	4.41 *c*
Hindquarter							
Total fat	1.2208 *a*	1.1488 *b*	0.9828 *c*	0.00586	16.63 *a*	14.09 *b*	9.83 *c*
Subcutaneous fat	0.8723 *a*	0.7693 *b*	0.5692 *c*	0.01064	7.45 *a*	5.88 *b*	3.71 *c*
Intermuscular fat	0.5987 *a*	0.5764 *a*	0.4525 *b*	0.00527	3.97 *a*	3.77 *a*	2.83 *b*

†53.56 kg half carcass muscle.
a-c Means in the same row with different letters differ significantly at $P < 0.05$.

Table 4. Parameter estimates from the allometric relationship $Y = aX^b$ of depot fat (Y) with total side fat (X) for three sexes

Dependent variable (Y)	Growth coefficient *b*						Effect of sex on slope
	Heifers	SE*b*	Steers	SE*b*	Bulls	SE*b*	
Half carcass							
Subcutaneous fat	1.18	0.047	1.20	0.041	1.18	0.054	NS
Intermuscular fat	0.85	0.046	0.87	0.039	0.88	0.052	NS
Body cavity fat	0.76	0.095	0.78	0.081	0.77	0.107	NS
Kidney fat	1.23	0.134	1.10	0.114	1.22	0.152	NS
Forequarter							
Total fat	1.02	0.022	1.06	0.019	1.01	0.025	NS
Subcutaneous fat	1.17	0.079	1.29	0.068	1.12	0.090	NS
Intermuscular fat	0.97	0.059	0.96	0.051	0.99	0.067	NS
Hindquarter							
Total fat	0.98	0.021	0.95	0.018	0.99	0.024	NS
Subcutaneous fat	1.18	0.050	1.16	0.043	1.18	0.057	NS
Intermuscular fat	0.62	0.074	0.71	0.063	0.78	0.084	NS

NS, $P > 0.05$.

kidney fat and subcutaneous fat, respectively, which were significantly ($P < 0.05$) different to those found for intermuscular and body cavity fat. Growth coefficients for total fat and subcutaneous fat in the fore- and hindquarters were similar ($P > 0.05$), but the growth coefficient for intermuscular fat was significantly ($P < 0.05$) lower in the hindquarter.

Adjusted means (Table 5) show the comparison among sexes at a constant weight of total fat. No differences were recorded among sexes for the fat depots either in the half carcass or the fore- and hindquarter.

DISCUSSION

Sex Influences on Fat Growth Patterns

Many authors (reviewed by Field 1971; Preston and Willis 1974) have compared bulls, steers and heifers using various measures of carcass fatness. Although the overall conclusion has been that heifers are fatter than steers, which in turn are fatter than bulls, most comparisons have been made at either a constant age or a constant liveweight. There is little published information indicating whether sexes differ in the actual deposition rate of fat, or whether differences in fatness are entirely due to differences in the onset of fattening.

Mukhoty and Berg (1971) reported on the growth of fat relative to muscle and bone weight for different breeds and sexes. Their data indicated that the regression coefficients for fat were not significantly different among bulls, steers and heifers, although actual coefficients were highest for heifers and lowest for bulls. The results of the present study as shown in Fig. 1 suggest that rate of fat deposition relative to muscle was significantly greater in heifers than bulls. Further studies are warranted to study fattening rates among sexes. Mukhoty and Berg (1974) in a further analysis of their data found additionally that rate of fat deposition relative to a number of size dimensions (muscle, bone, cold carcass weight) was similar for bulls, steers and heifers. The discrepancy between the results of the present study and the results of Mukhoty and Berg (1971, 1974) was probably a result of heterogeneity of their data.

Significant differences were recorded between adjusted means (Table 3) for total and depot fat among bulls, steers and heifers. It follows that sex differences in fatness were a reflection that heifers commenced fattening at a lighter carcass muscle weight than steers, and steers than bulls. Thus, the difference in fattening pattern among the sexes was a result of a combination of more rapid fat deposition relative to muscle in heifers and steers than in bulls, and also to an earlier onset of the fattening phase with respect to muscle

Table 5. Fat weights (kg) adjusted to the mean of total side fat†

	Log fat weight			Residual mean square	Fat weight (kg)		
	Heifers	Steers	Bulls		Heifers	Steers	Bulls
Half carcass							
Subcutaneous fat	0.9923	0.9714	0.9782	0.00165	9.82	9.36	9.96
Intermuscular fat	1.0166	1.0253	1.0181	0.00151	10.39	10.60	10.43
Body cavity fat	0.4276	0.4925	0.4743	0.00645	2.68	3.07	2.98
Kidney fat	0.3953	0.3854	0.4015	0.01317	2.48	2.43	2.52
Forequarter							
Subcutaneous fat	0.5917	0.5380	0.5951	0.00484	3.91	3.45	3.94
Intermuscular fat	0.8361	0.8314	0.8035	0.00259	6.86	6.78	6.36
Hindquarter							
Subcutaneous fat	0.7707	0.7685	0.7612	0.00184	5.90	5.87	5.77
Intermuscular fat	0.5402	0.5739	0.5630	0.00417	3.47	3.75	3.66

†25.66 kg total fat.
Means for sex were all non-significant ($P > 0.05$).

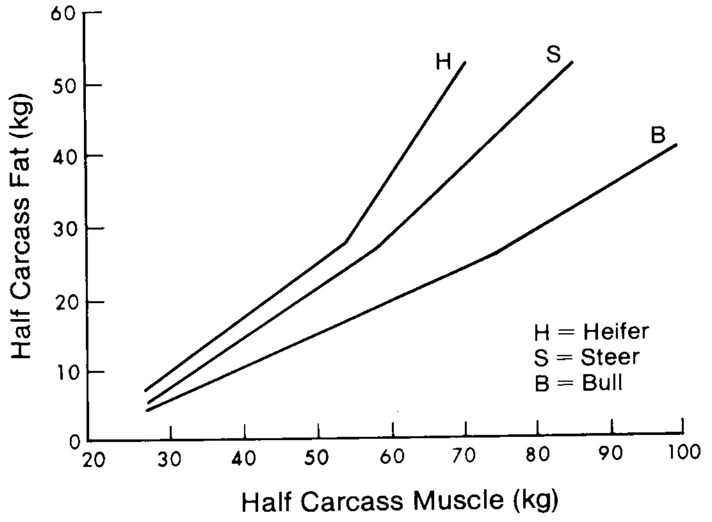

Fig. 1. Growth of fat relative to muscle in heifers, steers, and bulls plotted from the slaughter group means, adjusted for year and breed of dam.

weight in heifers than in steers and in steers than in bulls (Fig. 1).

Sex Influences on Fat Distribution

Growth coefficients for the individual fat depots regressed on total fat were homogeneous for all three sexes; there were also no significant differences between the adjusted means at constant total fat (Fig. 2). This provides evidence that differences among sexes in fat growth patterns are minor, and that fat distribution among sexes was similar, provided comparisons were made at equal total carcass fat. Kempster et al. (1976) and Berg et al. (1978) have reported similar findings for the effect of breed on bovine fat distribution.

A consistent finding of this study was that subcutaneous fat made an increasing contribution to total fat relative to intermuscular fat and body cavity fat, as fattening progressed (Table 4). This agrees generally with the work of Callow (1948), Berg and Butterfield (1976) and Berg et al. (1978). The highest growth coefficients were found for the kidney and subcutaneous fat depots.

Growth coefficients can also be compared between the fore- and hindquarters. In all ''sexes'' there was a more rapid accumulation of intermuscular fat in the fore- compared to the hindquarter. The same comparison for subcutaneous fat showed growth coefficients to be similar in both quarters. These patterns of carcass fat deposition could possibly be explained in terms of physical pressures within the fat storage depots as suggested by Berg and Butterfield (1976) and Berg et al. (1978). They hypothesized that the muscles and body shape create variable pressures and that the hindquarter intermuscular fat depot is more resistant to increase than the forequarter depot, resulting in a shift forward of intermuscular fat as fattening progresses. Subcutaneous fat depots expand under the skin in the less resistant areas, gradually resulting in the overall smooth appearance of very fat animals.

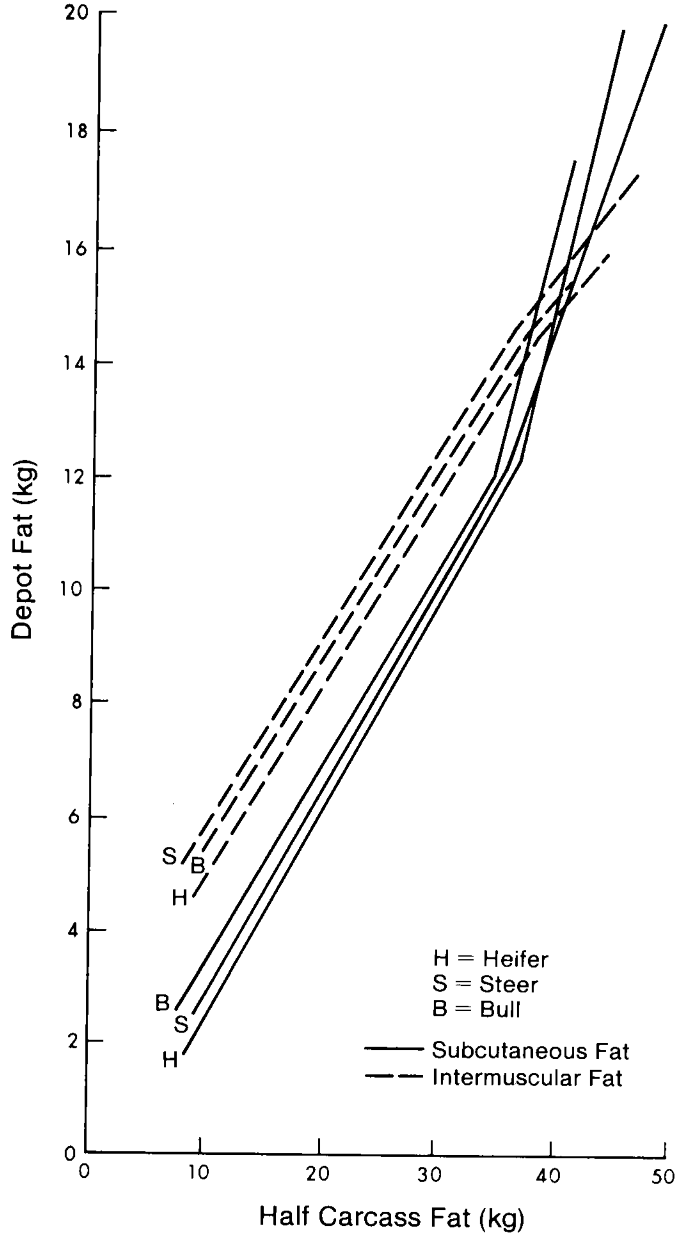

Fig. 2. Growth of the depot fats relative to half carcass fat in heifers, steers and bulls, plotted from the slaughter group means, adjusted for year and breed of dam.

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BERG, R. T. 1975. The University of Alberta Beef Breeding Project Re. No. 8. 54th Annu. Feeders' Day Rep., Department of Animal Science, Univ. of Alberta. pp. 30–42.

BERG, R. T. and BUTTERFIELD, R. M. 1976. New concepts of cattle growth. University of Sydney Press, Sydney, Australia.

BERG, R. T., ANDERSEN, B. B. and LIBORIUSSEN, T. 1978. Growth of bovine tissues. 3. Genetic influences on patterns of fat growth and distribution in young bulls. Anim. Prod. **27**: 63–69.

BUTTERFIELD, R. M. 1965. The relationship of carcass measurements and dissection data to beef carcass composition. Res. Vet. Sci. **6**: 24–32.

BUTTERFIELD, R. M. and MAY, N. D. S. 1966. Muscles of the ox. University of Queensland Press, Brisbane, Australia.

CALLOW, E. H. 1948. Comparative studies of meat. II. The changes in the carcass during growth and fattening and their relation to the chemical composition of the fatty and muscular tissues. J. Agric. Sci. Camb. **38**: 174–199.

CALLOW, E. H. 1961. Comparative studies of meat. VII. A comparison between Hereford, Dairy Shorthorn and Friesian steers on four levels of nutrition. J. Agric. Sci. Camb. **56**: 265–282.

CHARLES, D. D. and JOHNSON, E. R. 1976. Breed differences in amount and distribution of bovine carcass dissectible fat. J. Anim. Sci. **42**: 332–341.

FIELD, R. A. 1971. Effects of castration on meat quality and quantity. J. Anim. Sci. **32**: 849–858.

HUXLEY, J. 1932. Problems of relative growth. Methuen, London.

JOHNSON, E. R., PRYOR, W. J. and BUTTERFIELD, R. M. 1973. Studies of fat distribution in the bovine carcass. II. Relationship of intermuscular fat to the quantitative analysis of the skeletal musculature. Aust. J. Agric. Res. **24**: 287–296.

JONES, S. D. M. and PRICE, M. A. 1977. The incidence of feedlot bloat in bulls. 56th Annu. Feeders' Day Rep., Department of Animal Science, University of Alberta. pp. 62–64.

KEMPSTER, A. J., AVIS, P. R. D. and SMITH, R. J. 1976. Fat distribution in steer carcasses of different breeds and crosses. 2. Distribution between joints. Anim. Prod. **23**: 223–232.

LUITINGH, L. H. C. 1962. Developmental changes in beef steers as influenced by fattening, age and type of ration. J. Agric. Sci. Camb. **58**: 1–47.

MARTIN, A. H., FREDEEN, H. T. and WEISS, G. M. 1971. Characteristics of youthful beef carcasses in relation to weight, age and sex. III. Meat quality attributes. Can. J. Anim. Sci. **51**: 305–315.

MUKHOTY, H. and BERG, R. T. 1971. Influence of breed and sex on the allometric growth patterns of major bovine tissues. Anim. Prod. **13**: 219–227.

MUKHOTY, H. and BERG, R. T. 1974. Influence of breed and sex on growth patterns and linear relationships among major bovine tissues. Proc. 1st World Congress on Genetics Applied to Livestock Production. Madrid, Spain. pp. 839–849.

NETER, J. and WASSERMAN, W. 1974. Applied linear statistical models. Richard D. Irwin Inc., Homewood, Ill.

PRESTON, T. R. and WILLIS, M. B. 1974. Intensive beef production. Pergamon Press, Oxford.

PURCHAS, R. A. and DAVIES, H. L. 1974. Meat production of Friesian steers: the effect of intramuscular fat on palatability and the effect of growth rates on composition changes. Aust. J. Agric. Res. **25**: 667–677.

STEEL, R. G. D. and TORRIE, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Co. Inc., New York, N.Y.