THE GROWTH AND DISTRIBUTION OF MUSCLE IN BULLS AND HEIFERS OF TWO BREEDS

S. D. M. JONES[1], M. A. PRICE, and R. T. BERG

Department of Animal Science, University of Alberta, Edmonton, Alta. T6G 2H1.
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A trial is reported comparing muscle growth and distribution in 12 bulls and 12 heifers of each of two breed-types: Hereford (HE) and Dairy Synthetic (DY). Serial slaughter was carried out from weaning (163 ± 15.1 days) to approximately 15 mo of age. After slaughter, the left side of each carcass was broken into quarters and then eight wholesale cuts, which were separated into fat, muscle and bone. The growth pattern of muscle in each cut relative to total side muscle was estimated from the growth coefficient, b, in the allometric equation ($Y = aX^b$). Growth coefficients were homogeneous among breeds and sexes, indicating that neither breed nor sex influenced relative muscle growth. Some significant ($P < 0.05$), though minor, sex and breed differences were found when muscle weight distribution was adjusted to constant side muscle weight. Notably DY heifers had significantly ($P < 0.05$) more muscle in the high-priced cuts (sum of round, sirloin, loin and rib) than either HE heifers or bulls of either breed-type. When muscle weight was adjusted to constant side weight, bulls were found to have a greater weight of muscle in the high-priced cuts than heifers, and DY animals to have more than HE animals.

L'article compare la croissance musculaire et la répartition des muscles des bovins à viande à partir du sevrage, 163 jours plus ou moins 15.1 jusqu'à environ 15 mois. On a utilisé pour l'expérience 12 taurillons et 12 génisses appartenant à deux races, soit Hereford et Synthétique laitier (DY). A l'abattage, la moitié gauche de chaque carcasse a été débitée en quartiers puis en 12 morceaux de gros, dont on a séparé le gras, le maigre et les os. La courbe de croissance du maigre de chaque morceau par rapport à la musculature totale de la demi-carcasse a été estimée à partir du coefficient de croissance b dans l'équation allométrique $Y = aX^b$. Les coefficients de croissance étaient homogènes indépendamment du sexe et de la race, montrant par là que ces deux variables ne déterminent pas la croissance musculaire relative. On a relevé quelques différences significatives ($P < 0.05$), encore que de peu d'importance, liées au sexe et à la race quand la répartition du poids des muscles était ramenée à un poids constant du maigre de la demi-carcasse. En particulier, les génisses DY avaient significativement plus ($P < 0.05$) de muscle dans les morceaux nobles: ronde, surlonge, longe et côte, que les génisses He ou les taurillons des deux races. Quand le poids des muscles était ramené à un poids constant de remi-carcasse, le poids du maigre représenté par les morceaux nobles était supérieur chez les taurillons que chez les génisses et chez les sujets DY que chez les Hereford.

There have been several recent reports concerning genetic effects on muscle growth and distribution in young bulls (Berg et al. 1978), and in steers (Kempster et al. 1976; Truscott et al. 1976). Mukhoty and Berg

[1]Present address (S.D.M.J.): Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario N1G 2W1.

(1973) reported a study using heifers as well as young bulls and steers.

Although Butterfield (1963) reported no significant breed differences in muscle distribution of cattle, some small differences have been shown by others (Seebeck and Tulloh 1968b; Murray et al. 1974). If these differences are real it might be expected that the largest differences would appear when beef and dairy cattle of different sexes were compared for their muscle weight distribution. No research has been reported comparing muscle distribution in cattle with beef- and dairy-type conformation.

The present study was set up to examine muscle growth and distribution in bulls and heifers of both beef and dairy type.

MATERIALS AND METHODS

The experiment was conducted at the University of Alberta Research Ranch 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% Holstein and Brown Swiss and 40% beef breeds (Berg 1975). The DY animals were thus of a dairy type and conformation. Twelve bulls and twelve heifers of each breed were used. The cattle were born in April and May 1978, and weaned early in October, without having had access to creep feed. Following weaning, bulls and heifers were grouped separately (four to a pen) by breed and fed a high concentrate finishing ration (Jones et al. 1978). One Hereford bull was subsequently removed from the trial to be used elsewhere.

The cattle were serially slaughtered, in random order within breed × sex group over a wide liveweight range commencing at weaning and terminating when the cattle were approximately 15 mo of age. The warm carcass weight and age ranges at slaughter were: HE bulls, 81.6–308.9 kg, 186–465 days; HE heifers, 45.8–255.4 kg, 155–459 days; DY bulls, 105.7–336.5 kg, 160–418 days; and DY heifers, 112.5–289.8 kg, 177–443 days.

Following slaughter and overnight chilling, the left side of each carcass was quartered and taken to the University meats laboratory, where it was broken into eight wholesale cuts (Fig. 1) as outlined by Levie (1970) except that it was quartered between the 11th and 12th ribs. The plate and brisket were also combined as one cut. The high-priced cuts were the sum of the round, sirloin, loin and rib. The cuts were separated into muscle, subcutaneous fat, intermuscular fat, body cavity fat and bone. Small amounts of waste (mainly nervous and connective tissue) were included as bone.

The growth coefficient of muscle in each cut relative to the increase in weight of total muscle in the side was calculated using the logarithmic form of Huxley's allometric equation ($Y = aX^b$). If the regressions were homogeneous, a common slope was fitted and group means for muscle weight in a cut were compared after adjusting to a common side muscle weight. Differences among adjusted means were established by the Scheffé test using a technique for unequal subclass numbers (Neter and Wasserman 1974).

RESULTS AND DISCUSSION

The unadjusted muscle weights had large standard deviations (Table 1) reflecting the wide range in side weight brought about by the serial slaughter design.

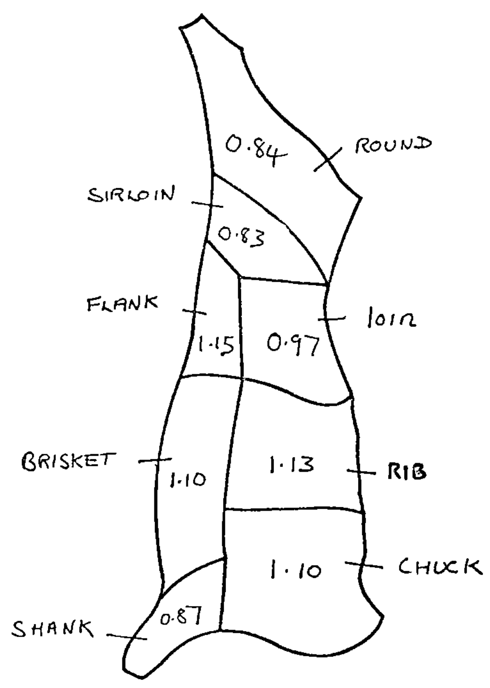

Fig. 1. Growth coefficient for beef wholesale cuts.

Table 1. Means (kg) and standard deviations (SD) of unadjusted muscle weights in each cut by breed and sex

	Hereford				Dairy Synthetic			
	Heifer	SD	Bull	SD	Heifer	SD	Bull	SD
No.	12		11		12		12	
Shank	2.32	0.767	2.91	0.901	2.90	0.665	3.50	1.049
Brisket	4.76	1.962	6.08	1.963	5.69	1.523	7.75	2.745
Rib	4.45	1.898	6.51	2.253	6.09	1.976	7.99	3.023
Chuck	9.98	3.816	14.58	5.244	12.60	3.306	19.93	7.621
Flank	3.12	1.274	4.23	1.343	3.93	1.121	5.03	1.927
Sirloin	3.15	0.997	3.97	1.041	4.21	0.812	5.22	1.644
Loin	6.57	2.543	8.02	2.431	8.41	2.081	10.07	3.083
Round	9.82	3.155	12.93	3.384	13.33	2.861	16.71	4.698
Total muscle	44.19	16.128	59.26	18.066	57.17	13.807	76.23	25.392

The growth of muscle in each cut relative to total side muscle is shown in Table 2. The individual regressions for each breed-type within sex were homogeneous for each cut, so the common regression coefficient was used. The growth coefficients indicated that as total side muscle weight increased, the proportion in the shank, sirloin, round and the high-priced cuts decreased, while the proportion in the brisket, rib, flank and chuck increased; the proportion in the loin remained constant (Table 2).

The growth coefficients reported in this paper are in general agreement with those of Kempster et al. (1976), and Berg et al. (1978). They differ slightly from those published by Seebeck and Tulloh (1968a), as those authors found the loin to have a growth coefficient significantly greater than 1.0. As suggested by Kempster et al. (1976), these differences are probably caused by the method of cutting: Seebeck and Tulloh (1968a) included part of the flank, which has a high growth coefficient, in their loin cut. A later publication (Seebeck and Tulloh 1968b) based on an anatomical dissection of the opposite side from carcasses used in the former publication indicated that the growth coefficient of the loin was less than 1.0.

Most experiments, irrespective of dissection technique, have shown that the amount of muscle in the high-priced cuts declines with increasing muscle development; this study is no exception. Only one report

Table 2. The growth of muscle in each of the eight wholesale cuts relative to total muscle in the side of carcasses from young bulls and heifers

	Common growth coefficient b†	SEb	Effect of breed/ sex on elevation
Shank	0.87*	0.033	NS
Brisket	1.10*	0.036	NS
Rib	1.13*	0.041	NS
Chuck	1.10*	0.022	***
Flank	1.15*	0.031	**
Sirloin	0.83*	0.029	*
Loin	0.97	0.022	***
Round	0.84*	0.015	***
High-priced cuts‡	0.93*	0.009	***

†t-test to determine if the growth coefficient is significantly ($P < 0.05$) different from 1.0.
‡High-priced cuts are the round, sirloin, loin and rib.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

(Murray et al. 1974) has suggested that high-priced muscles grow at the same rate as total muscle.

Berg et al. (1978) reported that muscle development followed a centripetal growth impetus from distal to proximal limb muscles, with higher coefficients for the fore- than hind-limb. This agrees with the results of the present study along with those of Kempster et al. (1976). Additionally, Berg et al. (1978) suggested that along the dorsal line there is a progressive increase in growth impetus from rump to neck, and a similar shift forward from flank to brisket along the ventral line. These results are supported in general by those of Kempster et al. (1976), but in the present study the flank muscles had a greater growth coefficient than the brisket muscles (Fig. 1). Along the dorsal line, a progressive increase of growth impetus was recorded in an anterior direction, except that the rib muscles had a slightly greater growth impetus than the chuck muscles (Fig. 1).

Significant breed and sex differences in muscle weight, adjusted to the population mean of dissected muscle in a side, were found for five of the eight wholesale cuts (Table 3). Generally, the largest differences in muscle distribution were seen between HE heifers and DY bulls. HE heifers had more muscle in the shank, brisket, rib, flank and loin and less muscle in the chuck, sirloin and round than DY bulls at a constant muscle weight. However, in overall terms these differences were small. In terms of high-priced cuts, DY heifers had significantly more muscle than DY bulls and both sexes of Hereford cattle. It is interesting to note that DY cattle had more muscle in the high-priced cuts than HE cattle, despite long-term selection in the Hereford breed for 'beef' traits.

As reported by Berg et al. (1978), the largest differences in muscle weight distribution were found between extremes of maturity types (early vs. late fattening). It is thus convenient to explain the present small breed differences in muscle weight distribution as maturity differences, a hypothesis which is difficult to prove outright without further dissection of cattle that have reached 'maturity.' On the other hand, differences in size, shape and muscling cannot be discounted as having an effect on muscle weight distribution of different breeds. It is clear that the breeders have had very little success in changing muscle weight distribution, and this strongly suggests that the functional needs of the species have resulted in an optimum weight distribution with some minor variation. Thus, breed differences, although small, are probably a combination of maturity differences and minor genetic differences.

The effect of sex on muscle weight distribution showed HE and DY bulls to have more muscle in the chuck and less in the loin than HE and DY heifers. This agrees with Mukhoty and Berg (1973), who concluded that bulls have a higher proportion of their muscles in the neck and shoulder regions, and heifers have a greater percentage in the proximal muscles of the hind leg, and in the muscles of the abdomen. These contentions are in line with those of Berg and Butterfield (1976) who considered that bulls have a more prolonged impetus for muscle growth, and could be regarded as having progressed further in their muscle differentiation than heifers. Steers are generally considered to be intermediate to bulls and heifers.

At a constant side weight (Table 4), bulls within breed had a greater weight of dissected muscle in the rib, chuck, sirloin, round and high-priced cuts than heifers, the difference being significant in most cases ($P < 0.05$). This increased yield of muscle was particularly noticeable in the chuck (20% increase) and round (10% increase). Thus, at similar side weights, bulls being less fat produce correspondingly more muscle than heifers, and this more than makes up for their 'inferior' muscle distribution.

At a constant weight of subcutaneous fat (Table 5), the largest differences in dissected muscle weight were recorded between DY bulls and HE heifers. DY heifers produced a

Table 3. Weight of dissected muscle (kg) in each cut by breed within sex adjusted to the population mean of dissected muscle in a side (54.85 kg)

	Muscle weight (kg)			
	Hereford		Dairy Synthetic	
	Heifer	Bull	Heifer	Bull
Shank	2.84	2.71	2.80	2.64
Brisket	5.96	5.55	5.40	5.37
Rib	5.55	5.96	5.70	5.46
Chuck	12.67 *ab*	13.19 *a*	12.02 *b*	13.68 *a*
Flank	3.94 *a*	3.86 *a*	3.72 *a*	3.41 *b*
Sirloin	3.81 *a*	3.74 *a*	4.09 *b*	3.96 *ab*
Loin	8.04 *a*	7.45 *b*	8.05 *a*	7.37 *b*
Round	11.88 *a*	12.20 *a*	12.91 *b*	12.76 *b*
High-priced cuts†	29.36 *a*	29.41 *a*	30.83 *b*	29.62 *a*

†High-priced cuts are the round, sirloin, loin and rib.
a,b Means in the same row with different letters differ significantly at $P < 0.05$.

weight of dissected muscle similar to that of HE bulls. Proportionately, heifers still had a muscle distribution superior to that of bulls, and only minor differences between breeds could be found. These data illustrate the importance of delayed fattening in the bull compared to the heifer and in late-fattening breeds (DY) compared to early-fattening breeds (HE), when fed the same ration, in the amount of extra muscle that can be produced when evaluated at a constant end point such as constant carcass weight or constant subcutaneous fat weight.

In conclusion, along with most other recent studies, there were no breed or sex differences or interactions on the growth patterns of muscles in a cut relative to total side muscle. This indicates that muscle growth followed similar patterns in bulls and heifers. Differential growth of muscle does occur following a centripetal pattern in the limbs, and also a generalized increase in growth impetus from the round forward along the dorsal line. At a constant weight of muscle, breed influences on muscle weight distribution were minor and judged to be commercially unimportant. However, there was a significant effect of sex on muscle distribution, heifers having a greater proportion of muscle in the high-priced cuts than

Table 4. Weight of dissected muscle (kg) in each cut by breed within sex adjusted to the population mean of side weight (90.32 kg)

	Muscle weight			
	Hereford		Dairy Synthetic	
	Heifer	Bull	Heifer	Bull
Shank	2.62	2.75	2.79	2.83
Brisket	5.39	5.65	5.37	5.87
Rib	5.02 *a*	6.08 *b*	5.66 *ab*	5.96 *b*
Chuck	11.45 *a*	13.44 *b*	11.96 *a*	14.95 *c*
Flank	3.55	3.93	3.70	3.74
Sirloin	3.53 *a*	3.79 *ab*	4.07 *b*	4.24 *bc*
Loin	7.36	7.58	8.02	7.97
Round	10.98 *a*	12.38 *b*	12.85 *b*	13.68 *c*
High-priced cuts†	26.97 *a*	29.87 *b*	30.69 *bc*	31.93 *c*

†High-priced cuts are the sum of the muscle in the round, sirloin, loin and rib.
a-c Means in same row with different letters differ significantly at $P < 0.05$.

Table 5. Weight of dissected muscle (kg) in each cut by breed within sex adjusted to the population mean weight of subcutaneous fat (3.09 kg)

	Muscle weight			
	Hereford		Dairy Synthetic	
	Heifer	Bull	Heifer	Bull
Shank	2.17 *a*(5.4)†	2.77 *ab*(4.9)	2.84 *ab*(5.1)	3.33 *b*(4.7)
Brisket	4.26 *a*(10.6)	5.70 *ab*(10.1)	5.49 *ab*(9.8)	7.21 *b*(9.9)
Rib	3.91 *a*(9.7)	6.16 *ab*(10.9)	5.80 *ab*(10.4)	7.38 *b*(10.3)
Chuck	9.03 *a*(22.5)	13.59 *ab*(24.2)	12.23 *ab*(22.0)	18.37 *b*(25.7)
Flank	2.77 *a*(6.9)	3.98 *ab*(7.1)	3.78 *ab*(6.8)	4.64 *b*(6.5)
Sirloin	2.94 *a*(7.3)	3.82 *ab*(6.8)	4.14 *ab*(7.4)	4.96 *b*(6.9)
Loin	5.97 *a*(14.8)	7.65 *ab*(13.6)	8.18 *ab*(14.7)	9.56 *b*(13.4)
Round	9.14 *a*(22.7)	12.49 *ab*(22.2)	13.08 *ab*(23.5)	16.01 *b*(22.4)
High-priced cuts‡	22.02 *a*(54.5)	30.18 *ab*(53.7)	31.29 *ab*(56.3)	37.99 *b*(53.2)

†Figures in parentheses refer to percentage of total muscle weight within breed and sex.
‡High-priced cuts are the round, sirloin, loin and rib.
a,*b* Means in the same row with different letters differ significantly at $P < 0.05$.

bulls. When muscle weights were corrected to constant side weight or to constant subcutaneous fat weight, late fattening and its relation to dissected muscle yield was shown to be of more importance than the intrinsic differences in muscle distribution between sexes.

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