THE INFLUENCE OF BREED ON THE EFFICIENCY OF GROWTH AND MUSCLE DEPOSITION IN BULLS AND HEIFERS

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Two breeds (Hereford (HE), and Dairy Synthetic (DY)), and two sexes (bulls and heifers) were compared for various measures of efficiency in beef production. DY animals had greater ($P<0.001$) birthweights, and greater weaning weights ($P<0.001$) than HE animals. At weaning, 16 animals of each breed-sex combination were grouped four to a pen and fed a high-concentrate cereal diet ad libitum to one of two slaughter weights (485 kg, 575 kg). Average daily gain and liveweight gained per 100 MJ dietary energy (DE) was greater ($P<0.05$) for DY bulls than HE bulls. Average daily gain, but not liveweight gained per 100 MJ DE was greater ($P<0.05$) for DY heifers than HE heifers. There were no differences ($P<0.05$) in muscle gain per unit of liveweight among breed-sex combinations. At a constant liveweight DY bulls produced significantly ($P<0.05$) more muscle than HE bulls, and DY heifers, significantly more ($P<0.05$) than HE heifers. Muscle gain per 100 MJ DE was highest for DY bulls and lowest for DY heifers. For a constant amount of feed energy (23 241 MJ DE) DY bulls produced 20.1 kg (16%) more muscle than HE heifers. The overall results thus indicate that breed and sex cause important differences in the amount of carcass muscle produced for a constant energy intake.

Nous avons comparé divers paramètres des aptitudes bouchères chez des bovins de deux races, Hereford (HE) et synthétique laitier (DY) et de deux sexes, taurillons et génisses. Les sujets DY révélaient des valeurs plus élevées, au seuil de 0.01, que les Hereford pour le poids à la naissance et au sevrage. Au sevrage, 16 bêtes de chaque combinaison race-sexe ont été placés à quatre par parquet et ont reçu à volonté un régime d'engraissement (concentré) jusqu'à leur arrivée aux poids de 485 ou de 575 kg. Le gain moyen quotidien (GMQ) et la valorisation de l'énergie (gain de poids par 100 MJ ED) étaient significativement plus élevés (seuil de è%) chez les taurillons DY que chez les Hereford. Pour les génisses, les DY l'emportaient pour le GMQ mais pas pour la valorsiation de l'énergie alimentaire. On n'a pas relevé de différence significative entre les bêtes pour le gain de poids du maigre par unité de poids vif. A poids vif semblable, les taurillons et les gênisses DY produisaient significativement plus de maigre que les Hereford. Les taurillons DY affichaient le gain de maigre le plus élevé par 100 MJ ED et les génisses DY le gain le plus bas. Pour un même niveau d'ingestion d'énergie alimentaire (23 241 MJ ED), les taurillons DY ont fourni 20.1 kg (16%) plus de maigre que les génisses Hereford. L'analyse générale de ces résultats semble montrer que la race et le sexe sont d'importants facteurs de différence en ce qui regarde la production de maigre à un méme niveau d'ingestion d'énergie.

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A great quantity of research has been published comparing the performance of different breeds and sexes on feedlot diets (Preston and Willis 1974; Smith et al. 1976b; Andersen et al. 1977). It is also generally true that large-framed breeds grow faster than small-framed breeds, bulls grow faster than steers and heifers, and lowering the energy concentration of the diet results in reduced gains and higher finished weights, all without apparent interaction. However, most of the experiments leading to these conclusions have been based on analyses conducted mainly at some constant endpoint (e.g., age, liveweight or fatness). Thus, the patterns of changes leading to treatment differences (breed, sex, diet) are often obscured, and these biological differences among breeds and sexes have not been adequately documented. It has also been traditional to regard liveweight performance and carcass composition of meat animals as separate entities (Smith et al. 1976b; Koch et al. 1976), and few researchers have attempted to measure the biological efficiency of producing muscle in cattle.

The following experiment was designed to study the effects and interactions of breed, sex and liveweight on the biological efficiency of producing meat in beef cattle.

MATERIALS AND METHODS

The experiment was conducted at the University of Alberta Research Ranch at Kinsella using 16 bull and 16 heifer calves from each of two breeds, Hereford (HE) and Dairy Synthetic (DY) (Berg 1975).

All calves were born in April and May 1976 and were left with their dams on pasture until weaning in October. No supplementary feeding was provided. Following weaning, the bulls and heifers were separately grouped, four to a pen, and fed a high-concentrate finishing ration ad libitum (71% barley, 24% oats, and 5% pelleted high protein supplement) (Jones et al. 1978). All four animals in a pen were slaughtered when the pen mean weight reached approximately 485 or 575 kg. Allocation to the slaughter weight categories was at random. Records were kept of total feed consumed per pen, and the animals were weighed individually every second week.

Following slaughter and overnight chilling, the carcasses were appraised and graded in the normal manner. The carcasses were trucked to the University Meats Laboratory, and the right side of each carcass was partially dissected to estimate half-carcass muscle. This involved the removal of eight muscles from the hindquarter as outlined by Price and Berg (1976).

Six HE cattle (five bulls and one heifer) died of bloat during the experiment, and one DY heifer was found to be pregnant. The post-weaning data from these animals were excluded from the study.

Feed conversion ratios were expressed on a pen basis as weight of feed required for each kilogram of body weight gained, adjusted by linear regression to a constant initial weight. The constant initial weight used was the starting weight of the (DY) bulls as these were the heaviest animals at the start of the trial. Cumulative feed amounted to the total pen feed adjusted to the above constant starting weight to when the animals in a pen were slaughtered. Energy values for feed were assigned from table values (National Research Council 1976). Regressions involving feed intake data within each breed-sex subclass were thus based on four observations. Muscle weights at the start of the trial were estimated from cattle of similar breeding and weight from previously collected data (Price and Berg 1976). The data base used for this prediction of muscle weight contained over 300 anatomical dissections from animals of similar breeding reared on the same management system.

The experimental design was multiway: two breeds (HE and DY), two sexes (bulls and heifers), with four pens per treatment combination, each pen having four animals. The effects of breed and sex on birthweight, and pre-weaning performance were analyzed by a two-way analysis of variance. To investigate the biological efficiency of post-weaning meat production, various parameters were considered to be of importance. These included the relationships between liveweight and age, liveweight gained on trial and cumulative feed, carcass muscle and liveweight, and finally carcass muscle and cumulative feed. Treatment effects (breed, sex) on these relationships were evaluated by comparison of the regression coefficients obtained from a least squares analysis of covariance. Least squares analyses of covariance incorporating individual coefficients for each breed-sex group were computed (Gujarati 1970; Mehlenbacher 1978, unpublished observations). In all analyses, residual mean square was used as error. Treatment means were compared after adjusting to the mean of the covariate. Differences among adjusted means were tested for significance using the Student-Newman-Keuls test (Steel and Torrie 1960) using a technique to adjust for the unequal subclass numbers.

RESULTS

Pre-weaning Performance

At birth, DY calves were 4.3 kg ($P<0.001$) heavier than HE calves and bulls were 4.9 kg ($P<0.001$) heavier than heifers (Table 1). There was no significant sex × breed interaction for birthweight. Pre-weaning gain and weaning weight at approximately 6 mo of age differed ($P<0.001$) for both breed and sex, again without significant interaction. DY calves were heavier at birth, grew faster to weaning, and had a higher weaning weight than HE calves, and bulls exceeded heifers for all of these traits.

Performance on Test

Average daily gains (regression coefficients) during the test (Table 2) were significantly higher ($P<0.05$) for DY bulls compared to HE bulls (17%), and for DY heifers compared to HE heifers (7%). Liveweight means adjusted to the covariate mean of 286 days (animal age) showed the effects of high average daily gains both pre-test and on test. Adjusted to this age, DY bulls were 63 kg heavier than HE bulls ($P<0.05$), and DY heifers were 30 kg heavier than HE heifers ($P<0.05$).

DY bulls had 10% greater ($P<0.05$) liveweight gain per 100 MJ DE than HE bulls (Table 3), but HE and DY heifers did not differ ($P>0.05$). DY bulls gained 58 kg more ($P<0.05$) than HE bulls and DY heifers 38 kg more ($P<0.05$) than HE heifers for a constant amount (16 796 MJ DE) of feed energy.

Carcass Muscle Content and Efficiency

In muscle per kilogram liveweight, the two sexes of each breed did not differ ($P>0.05$). At a constant liveweight of 532 kg (Table 4) DY bulls had 28.9 kg more carcass muscle than HE bulls ($P<0.05$), and DY heifers had 24.4 kg more carcass muscle than HE heifers ($P<0.05$).

Table 1. Means (±SE) of pre-weaning traits for the two breeds and two sexes

Treatments	n	Birth weight (kg)	Pre-weaning gain (kg/day)	Weaning weight (kg)
Breed				
Hereford	32	34.4	0.84	152
Dairy Synthetic	32	38.7	1.14	218
SE means		0.89	0.016	2.8
Sig.		***	***	***
Sex				
Heifer	32	34.1	0.94	176
Bull	32	39.0	1.04	194
SE means		0.89	0.016	2.8
Sig.		***	***	***

***$P<0.001$.

Table 2. Regressions of liveweight on age and the means of liveweight adjusted to a constant animal age (286 days)

	Hereford bull	Dairy Synthetic bull	Hereford heifer	Dairy Synthetic heifer
n	11	16	15	15
Regression coefficient (kg/day)	1.22*a*±0.01	1.43*b*±0.02	0.98*c*±0.01	1.05*d*±0.01
Liveweight means (kg)	330*a*±2	393*b*±1	268*c*±2	298*d*±1

a-d Means or regression coefficients that do not have a common letter differ significantly ($P<0.05$).

Table 3. Gains per unit of feed energy and the means of liveweight gained adjusted to a constant intake (16 796 MJ DE)

	Hereford bull	Dairy Synthetic bull	Hereford heifer	Dairy Synthetic heifer
Regression coefficient (kg/100 MJ DE)	1.28*a* ± 0.03	1.41*b* ± 0.06	1.09*c* ± 0.02	0.95*c* ± 0.03
Liveweight gained (kg)	239*a* ± 2	297*b* ± 2	178*c* ± 4	216*d* ± 2

a-d Means or regression coefficients that do not have a common letter differ significantly ($P<0.05$).

Table 4. Muscle† per kilogram liveweight and muscle weights adjusted to a constant liveweight (532 kg)

	Hereford bull	Dairy Synthetic bull	Hereford heifer	Dairy Synthetic heifer
Regression coefficient (kg muscle/kg liveweight)	0.28*a* ± 0.069	0.34*a* ± 0.105	0.24*a* ± 0.044	0.20*a* ± 0.091
Muscle weight (kg)	170.1*a* ± 3.01	199.0*b* ± 2.39	149.8*c* ± 2.49	174.2*a* ± 2.48

†Carcass muscle was obtained from 2 × side muscle weight predicted from sample muscle weights (Jones et al. 1978).
a-c Means or regression coefficients that do not have a common letter differ significantly ($P<0.05$)

Per 100 MJ DE, DY bulls produced 0.04 kg more ($P<0.05$) muscle than HE bulls, and HE heifers produced 0.04 kg more ($P<0.05$) muscle than DY heifers. At a constant energy intake DY bulls produced 20.1 kg more ($P<0.05$) carcass muscle than HE bulls, and DY heifers produced 6.0 kg more ($P<0.05$) carcass muscle than HE heifers. In quantitative terms for a constant energy input of 23 241 MJ DE, DY bulls produced 16.1% more muscle than HE bulls. DY heifers produced 6.5% more muscle than HE heifers. Two different figures for MJ DE were used as the results in Table 3 were based on bi-weekly feed intake data, whereas the results in Table 5 were based on four pen means for each breed and sex combination.

DISCUSSION

The pre-weaning performance of DY cattle was superior to that of HE cattle (greater pre-weaning gain). The findings that large-framed dairy animals have heavier, faster growing calves than the traditional beef breeds are in general agreement with those reported in the literature (Mason 1971; Smith et al. 1976b).

The normal growth pattern of most meat animals approximates a curve (Brody 1945) such that as mature size is approached, both liveweight gain and feed efficiency decline. The animals in this experiment were still in the rapid growing part of their growth curve, and a linear approach is considered adequate to describe their growth performance.

Table 5. Muscle† per unit of digestible energy and muscle weights adjusted to a constant energy intake (23 241 MJ DE)

	Hereford bull	Dairy Synthetic bull	Hereford heifer	Dairy Synthetic heifer
Regression coefficient (kg muscle/100 MJ DE)	0.47*a* ± 0.005	0.51*b* ± 0.005	0.13*c* ± 0.001	0.09*d* ± 0.001
Muscle weight (kg)	124.8*a* ± 3.59	144.9*b* ± 5.19	92.3*c* ± 3.50	98.3*c* ± 3.09

†Carcass muscle was obtained from 2 × side muscle weight predicted from sample muscle weights (Jones et al. 1978), less estimated muscle at start of trial.
a-d Means or regression coefficients that do not have a common letter differ significantly ($P<0.05$).

The weight/age relationships clearly showed large differences in the regression coefficients of the different breeds and sexes. DY bulls continued to grow at a faster rate than HE bulls, and DY heifers grew faster than HE heifers. This was a result similar to that reported by Smith et al. (1976b).

The feeding of a constant amount of feed energy produced a greater amount of liveweight on the trial for DY bulls over HE bulls and no significant difference between DY and HE heifers. After adjusting to a constant initial weight, the adjusted means for liveweight gained on the trial (Table 3) show the large superiority of DY bulls and heifers over HE bulls and heifers, respectively, for a constant amount of feed energy. These differences are probably largely explained by differences in the composition of the gain, DY having less fat in their gain than HE animals, and bulls having less fat in their gain than heifers (Klosterman et al. 1972).

The results of this study showed that bulls had a 30% advantage in average daily gain over heifers and a 19% advantage in liveweight gain per unit of feed energy, all without significant interaction.

The relationship between estimated carcass muscle weight and liveweight showed DY bulls to have the greatest muscle gain per unit of liveweight, but statistically no breed or sex differences were found. The values were lower than those reported by Berg et al. (1978), but the cattle in this study were evaluated at a more advanced stage of growth, which possibly explains the lower rates of muscle gain. Muscle weight at a constant liveweight was greatest for DY bulls and least for HE heifers. Muscle weight at constant liveweight has been proposed as a net index for beef production (Berg et al. 1978). It combines dressing percentage and lean-meat yield into one figure.

There is a large amount of information in the literature on the actual energy costs of protein and fat deposition (Webster 1974), which have involved detailed measurements. There are no reports, however, on the feed cost in order to produce lean meat in different breeds and sexes. The analysis conducted in this study showed that the rate of muscle gain per unit of feed energy was highest for DY bulls and lowest for DY heifers. Consequently, at a common energy intake, breeds and sexes differed widely in the amount of muscle produced. DY bulls produced 16% more muscle than HE bulls and DY heifers produced 6% more than HE heifers.

There are still some problems in the interpretation of these data. For example in Table 5, DY heifers gained significantly less muscle per unit of feed energy than HE heifers, but still produced similar amounts of muscle at a constant energy endpoint. This paradox suggests that DY heifers gained more muscle than HE heifers per unit of feed energy in the earlier stages of the feeding period. In other words, there is probably an overall curvilinear relationship between muscle weight and feed energy intake, which could not be measured in this study as it was outside the range of the data. Additionally (Table 3), DY heifers made gains similar to HE heifers, yet were significantly heavier for a constant intake of feed energy. This result is difficult to explain and may relate to the small number of feed intake observations that were recorded in this study. Further data of this type should be collected as there is a lack of information in the literature on the overall efficiency of muscle deposition.

The final product of beef production is red meat (muscle), and the major costs of producing it are those of feed. Thus, the relationship between carcass muscle and cumulative feed energy should provide both a biological and an economic measure of efficiency. The overall results have indicated large differences between breeds and sexes in the amount of carcass muscle produced for a constant energy intake in this study.

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