EFFECTS OF DIETARY ROUGHAGE LEVEL ON THE FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF BULLS AND STEERS

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An experiment is described comparing bulls and implanted steers fed diets containing three roughage levels (20, 50 and 80% alfalfa–brome hay) with two pens of four cattle in each 'sex' × dietary roughage level subgroup. Cattle were about 12 mo old and 230 kg at the start of the trial. Each animal was slaughtered when it reached 500 kg. No significant castration × roughage level interactions were found for any of the feedlot or carcass traits studied. Increasing the level of roughage in the diet resulted in a significant decrease in average daily gain ($P<0.01$) and an increase in average daily feed ($P<0.01$) and feed per kilogram gained ($P<0.01$) to 500 kg. Differences in daily digestible energy (DE) consumption and DE and feed cost per kilogram gained were not significant. Increasing the roughage level reduced all measures of carcass fatness ($P<0.05$) but had no significant effect on the muscle content. Castration significantly reduced growth rate ($P<0.01$) and increased feed requirement per unit of gain ($P<0.05$). Steer carcasses were lighter ($P<0.01$) and fatter ($P<0.01$) than those of bulls and had lighter sample muscle weights ($P<0.01$) and smaller sample muscle:bone ratios ($P<0.01$).

On a comparé, sur des taurillons et sur des bouvillons munis d'un implant anabolisant, trois régimes de proportions différentes de fourrage grossier (20, 50 et 80% de foin luzerne-brome), chaque combinaison sexe × régime comportant deux parquets de quatre sujets chacun. Les bêtes avaient environ 12 mois au départ et pesaient 230 kg, et l'abattage s'est fait au poids de 500 kg. Aucun des caractères de la performance à l'engraissement ni de la carcasse n'a donné d'interaction significative castration × régime. L'accroissement de la proportion de foin a entraîné une diminution significative du gain quotidien moyen et une augmentation de la consommation journalière et de l'indice de consommation jusqu'à l'abattage. La consommation journalière d'énergie digestible (ED), de même que les rapports ED/croît et coût des aliments/croît n'ont pas différé d'un traitement à l'autre. Les rations plus riches en foin ont abaissé les valeurs de l'état d'engraissement des carcasses mais n'ont pas eu d'effet significatif sur le degré de développement musculaire. La castration a significativement réduit l'indice de croît et accru l'indice de consommation et, par ailleurs, les bouvillons avaient des carcasses plus légères et plus grasses, des muscles repères plus légers et des rapports muscles/os moins élevés que les taurillons.

The use of high levels of grain in finishing diets for beef cattle makes the feeder economically vulnerable to the fluctuations which commonly occur in grain prices. There is also a growing concern that the ability of ruminants to utilize roughages as a feed source is not adequately exploited for meat production. Increasing the roughage content of diets for cattle would be expected to set beef production on a more stable long-term course; it would, however, also result in changes in both feedlot performance and the final product: decreased liveweights at a given age, and less carcass fat at a given weight.

In the long-term it is expected that the use of bulls rather than steers for beef production will increase. This will result in increased liveweights at a given age combined with less fat at a given carcass weight (Turton 1969; Field 1971).

Increasing dietary roughage levels and using bulls instead of steers are thus both likely to affect carcass grades in some feeding situations unless accompanied by appropriate changes in management. In addition, Price and Yeates (1969) have indicated that as growth rate decreases, differences between bulls and steers in growth rate and feed efficiency become less pronounced.

In the following trial, castration and dietary roughage level acting together have been studied in terms of their effects on performance of cattle in the feedlot and on carcass characteristics.

MATERIALS AND METHODS

Fifty-three head of steers and bulls of primarily Hereford and University of Alberta Beef Synthetic (Berg 1975) breeding were selected for this experiment. They had been born at the University of Alberta Research Ranch at Kinsella in April and May 1974 and were weaned in October; the steers were castrated in mid-November. During the 1974–75 winter they were fed alfalfa–grass hay ad libitum along with mineral supplements on a free-choice basis for 140 days. The 26 bulls gained 0.29 kg daily, ate 5.7 kg of hay per day and required 19.9 kg of hay per kilogram of gain during this period. Corresponding values for the 27 steers were 0.22, 5.5 and 24.5 kg, respectively.

On 26 Mar. 1975, the animals were trucked to the Beef Cattle Test Station at Ellerslie and given hay, salt and a mineral mixture on a free-choice basis for a 13-day adjustment period. The cattle were also offered barley during this period to condition them to grain feeding.

The largest 24 steers and 24 bulls were selected for the feeding trial and allotted to 12 pens on the basis of breed, weight and "sex." The design was a factorial arrangement of the two "sexes" and three diets, with two pens per treatment and four animals per pen. The three diets contained 20, 50 and 80% alfalfa–brome hay, prepared with a forage harvester adjusted to give a 0.54-cm cut (Table 1). The hay dry matter contained 17.3% crude protein, 33.6% acid detergent fibre and 2.6 Mcal of digestible energy per kilogram. Animals on all treatments received 4.5 kg of feed on 8 Apr. 1975, the first day of the trial. The total feed offered was increased by 0.45 kg per head daily and the cattle were on full feed within 2 wk. Cattle were fed twice daily during the adjustment period and once daily for the remainder of the trial. Salt and a 1:1 mixture of salt and dicalcium phosphate were available free-choice.

All steers were implanted with "Ralgro" (Commercial Solvents Ltd.) on 8 Apr., and all animals were treated for warbles on 13 May 1975. The cattle were weighed on 2 consecutive days at the beginning, and then weekly throughout the trial. Slaughtering occurred on the day following a weigh day, and cattle for slaughter were weighed again on that morning. Slaughter weight was then defined as the mean of the last two weights. Water was restricted for approximately 16 h before weighing although feed was continuously available. Shavings were used for bedding.

Digestibility measurements were made with 'representative' hay which was fed to four mature sheep (45 kg liveweight) to provide an energy intake of 156 kcal/kg$^{.75}$. The sheep were confined in individual metabolism crates during the 5-day period in which total fecal material was collected. The sheep had been adapted to the crate, hay and feeding level for 13 days before digestibility measurements began.

Most of the cattle remained healthy throughout their stay in the feedlot. One steer fed the diet containing 50% hay died midway through the test from a cause not related to dietary treatment. One steer on each of the 20 and 80% roughage diets was removed before achieving the designated slaughter weight because of repeated bloating. Carcass data from these three steers were not used.

The remaining 45 cattle were slaughtered at weights as near as possible to 500 kg, at an Edmonton abattoir. The carcasses were dressed and graded in the normal manner, and the graders also measured and recorded the minimum fat depths and cross-sectional areas of the longissimus muscle at the 11/12 rib quartering position under the Agriculture Canada Beef Carcass Appraisal Service (Agriculture Canada 1972). For the purpose of analysis, grade was reduced to a numerical score, based on the assumption that the differences in grades for these cattle were a function of fat cover alone. The graders' comments on Agriculture Canada form ML107 (Beef Carcass Appraisal Record) were consistent with this assumption in all cases. Thus C1, representing a fat cover of less than 2.5 mm was scored 1; B1 (fat cover 2.5–5.1 mm) scored 2; A1 (fat cover 5.1–10.2 mm) scored 3; A2 (fat cover 10.2–15.2 mm) scored 4; A3 (fat cover 15.2–20.3) scored 5.

The chilled left hindquarter and the humerus and radius/ulna from the left forequarter were taken to the Meat Laboratory on the day following slaughter. Carcass muscle and bone content were estimated by partial dissection: eight large, easily accessible muscles (Mm. tensor fasciae latae, biceps femoris, gluteus medius, vastus lateralis, rectus femoris, semitendinosus, gracilis, and semimembranosus — Price and Berg 1976) and the long bones of the front and hind limb (humerus, radius/ulna, femur and tibia — Price and Berg 1977) were dissected from the hindquarter and weighed.

The data were analyzed using two-way analysis of variance. Where a significant effect of roughage treatment was found ($P<0.05$), means were separated using the Newman-Keuls test (Steel and Torrie 1960) at $P=0.05$.

RESULTS AND DISCUSSION

Feedlot Performance

All 48 cattle were weighed on day 97 of the experiment (14 July 1975). By the following weigh-day (day 104), one steer had died of a cause unrelated to the experimental treatments, and the first bull reached 500 kg and was slaughtered. The feedlot performance results were therefore analyzed from day 1 to two different endpoints: firstly to a constant time (day 97, the day before the first bull was removed for slaughter) (Table 2), and secondly to a constant weight (500 kg, the predetermined slaughter weight for all cattle) (Table 3). For the latter comparisons, the data for the three steers that were not slaughtered at 500 kg were removed and replaced by the appropriate pen mean for each characteristic, with the loss of one degree of freedom.

No interactions of roughage level and castration were found to be significant in either set of comparisons. Analyses involv-

Table 1. Formulation and composition of experimental diets

	Cost	% roughage in diet		
	(¢/kg)	20	50	80
			Ingredient %	
Alfalfa grass hay	6	20	50	80
Barley, dry rolled	11	76	46.25	15.90
Rapeseed meal	14	3.0	3.0	3.0
Trace mineralized salt	7.4	0.25	0.25	0.25
Limestone	4.4	0.50	-	-
Dicalcium phosphate	30	-	0.25	0.60
Vitamin premix†	24.2	0.25	0.25	0.25
		100.0	100.0	100.0
			Analysis	
Dry matter (%)		89.1	89.6	89.6
Crude protein (% DM)		12.4	13.2	14.2
Calcium (% DM)		0.87	1.40	2.19
Phosphorus (% DM)		0.38	0.38	0.38
DE (Mcal/kg DM)‡		3.4	3.1	2.8
Feed cost (¢/kg as fed)		10.08	8.66	7.23

†To supply 5,000, 840 and 5 IU of vitamins A, D and E, respectively, per kilogram of total diet.
‡Using the determined value of 2.6 Mcal/kg DM for hay and NAS-NRC (1976) values for other dietary ingredients.

ing liveweight alone were conducted on a per animal basis, those involving feed, on a per pen basis, since animals were weighed individually, but feed consumption was measured by pen.

Days 1–97

The rates of gain of all groups during the trial were high (Tables 2 and 3). This may have been at least partially caused by compensatory gain following their poor winter gains (Wilson and Osbourne 1960; Allden 1970).

In all facets of this experiment, the analysis of variance showed no significant interaction between roughage level and castration, indicating that bulls and steers respond similarly to changes in roughage level. This does not support the finding of Price and Yeates (1969) that reduced growth rate reduces the difference between bulls and steers. The high growth rates of all groups in the present trial may, however, account for this.

Rates of gain were lower in the 80% roughage group than in the other two ($P<0.05$) and daily feed consumption was greater ($P<0.05$) in the high roughage than the low roughage group, resulting in a greater ($P<0.05$) feed requirement per unit of gain in the 80% than the 50%, and in the 50% than the 20% roughage groups (Table 2). Similar findings have been reported elsewhere (McCullough 1970; Agriculture Canada 1974). There was, however, no significant difference in digestible energy (DE) intake (Table 2). It is well-known (Montgomery and Baumgardt 1965) that

Table 2. Treatment and interaction effects on feedlot performance days 1–97

		n	Liveweight (kg)		Daily gain (kg)	Daily DM intake (kg)	Daily DE intake (Mcal)	DM/kg gain (kg)	DE/kg gain (Mcal)	Feed cost/kg gain (¢)
			Day 1	Day 97						
					Treatments					
Roughage level										
20%		16	228.4	394.1	1.71*a*	8.82*a*	30.0	5.18*a*	17.59	58.5
50%		16	226.0	385.0	1.64*a*	9.49*ab*	29.4	5.80*b*	17.98	56.1
80%		16	228.7	372.0	1.48*b*	9.78*b*	27.4	6.63*c*	18.57	53.5
SEM†			3.33	5.61	0.035	0.204	0.66	0.154	0.484	1.53
Sig			NS	NS	**	*	NS	**	NS	NS
Bulls		24	231.2	392.6	1.66	9.37	29.0	5.67	17.43	54.1
Steers		24	224.2	374.8	1.55	9.35	28.9	6.06	18.66	58.0
SEM†			2.72	4.58	0.028	0.166	0.54	0.125	0.395	1.25
Sig			NS	*	*	NS	NS	NS	NS	NS
					Interactions					
Sex	Roughage level									
Bull	20%	8	330.6	401.6	1.76	8.80	29.9	4.98	16.96	56.4
Bull	50%	8	230.7	395.9	1.70	9.56	29.6	5.61	17.40	54.2
Bull	80%	8	232.2	380.2	1.53	9.77	27.4	6.40	17.94	51.9
Steer	20%	8	226.1	386.6	1.66	8.84	30.1	5.36	18.22	60.6
Steer	50%	8	221.2	374.1	1.58	9.43	29.2	5.98	18.55	57.9
Steer	80%	8	225.1	363.7	1.43	9.78	27.4	6.86	19.19	55.3
SEM†			4.71	7.93	0.049	0.288	0.93	0.218	0.684	2.16
Sig			NS	NS	NS	NS	NS	NS	NS	NS

†Standard error of means.
$*P<0.05$ $**P<0.01$.
a-c Means in the same column (within main effect) bearing the same letter are not significantly different ($P<0.05$).

Table 3. Treatment and interaction effects on feedlot performance from day 1 to slaughter at about 500 kg liveweight

		n	Liveweight (kg) Day 1	Liveweight (kg) Slaughter	Daily gain (kg)	Days on feed	Slaughter age (days)	Daily DM/animal (kg)	Daily DE/animal (Mcal)	DM/kg gained (kg)	DE/kg gained (Mcal)	Feed cost/kg gain (¢)
Treatments												
Roughage level												
20%		15	231.2	503.1	1.57*a*	174.0*a*	520.6	9.07*a*	30.8	5.81*a*	22.2	65.7
50%		15	230.5	500.5	1.48*a*	182.1*a*	527.6	9.93*b*	30.8	6.71*b*	23.2	64.8
80%		15	232.2	502.2	1.34*b*	201.8*b*	544.2	10.74*c*	30.1	8.04*c*	25.1	64.8
SEM†			2.90	1.85	0.310	4.15	9.30	0.201	0.61	0.221	0.74	2.01
Sig			NS	NS	**	**	NS	**	NS	**	NS	NS
Bulls		24	231.2	504.6	1.56	176.2	521.5	9.87	30.5	6.39	21.9	60.8
Steers		21	231.4	499.2	1.38	195.7	540.1	9.95	30.7	7.31	25.1	69.5
SEM†			2.37	1.51	0.253	3.39	7.59	0.165	0.50	0.181	0.60	1.64
Sig			NS	*	**	**	NS	NS	NS	*	*	**
Interactions												
Sex	*Roughage level*											
Bull	20%	8	230.6	506.5	1.67	165.4	509.2	9.09	30.9	5.45	20.8	61.6
Bull	50%	8	230.7	506.4	1.57	176.0	527.9	9.84	30.5	6.29	21.8	60.8
Bull	80%	8	232.2	501.0	1.44	187.4	527.2	10.68	29.9	7.45	23.3	60.1
Steer	20%	7	232.0	499.7	1.47	182.7	531.9	9.07	30.8	6.23	23.8	70.5
Steer	50%	7	229.6	494.5	1.40	188.2	527.3	10.08	31.3	7.18	24.8	69.4
Steer	80%	7	231.6	503.5	1.25	216.2	561.1	10.76	30.2	8.56	26.7	69.1
SEM†			4.10	2.62	0.438	5.87	13.15	0.284	0.86	0.313	1.05	2.84
Sig			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

†Standard error of means
$*P<0.05$ $**P<0.01$.
a-c Means in the same column (within main effect) bearing the same letter are not significantly different ($P<0.05$).

cattle on ad libitum feeding will attempt to equalize their DE consumption. The intake of the 80% roughage group, however, while not significantly less than the others, did suggest that on high forage rations, rumen capacity may restrict the animal's ability to maximize its digestible energy (DE) intake. No significant difference in consumption of DE per unit of liveweight gain was found among the roughage levels.

Feed cost per unit of gain decreased (though not significantly) with increasing levels of roughage in the ration. Naturally, this is a function of the costs of grain and forage relative to each other.

As expected, the bulls grew faster ($P<0.05$), and required less feed per unit of gain than the steers. They also required less DE and had a lower feed cost per unit of weight gain but the differences were not statistically significant over the first 97 days of feeding.

Day 1 to Slaughter (500 kg)

In general, the effects of dietary roughage level over the period from day 1 to slaughter (Table 3) were similar to those found during the shorter period, days 1–97 (Table 2). However, the growth rates were lower and feed consumption and conversion figures were higher during the longer period. These are changes that are normally expected as cattle mature (Preston and Willis 1974), and they explain the notable increase in feed cost per unit of gain when measured to slaughter (Table 3) rather than only over the first 97 days (Table 2).

Increasing roughage level lowered average daily gain ($P<0.01$) and increased time to reach 500 kg ($P<0.01$) (Table 3). The 80% roughage group took an average of 27.8 days longer on feed than the 20% roughage group.

Digestible energy and feed cost per kilogram gain were higher to the 500-kg endpoint than they had been to day 97, but the effect of roughage level remained nonsignificant. This may, however, result from a Type II statistical error because of the limited number of cattle.

The effects of castration became more apparent over the longer period from day 1 to the 500 kg endpoint than they had been over the period up to day 97. Bulls had greater rates of gain ($P<0.01$) than steers, and required 19.5 days less on feed ($P<0.01$) to reach the target weight. However, bulls and steers required an almost identical amount of feed (kg of DM or Mcal of DE) per day. The superiority of bulls over steers in feed trials is well-established (Turton 1969), particularly at rapid growth rates (Price and Yeates 1971).

Although the effect of castration on feed and cost per unit of gain was not found to be significant during the first 97 days of the feed period (Table 2), the results for the whole period from day 1 to 500 kg (Table 3) indicate that the bulls required significantly less feed ($P<0.05$) and digestible energy ($P<0.05$) per kilogram of gain, and that their feed cost per unit of gain was also considerably lower ($P<0.01$). The feedlot performance results, therefore, indicate a clear superiority of bulls over steers in terms of both variable costs (less feed per unit of gain) and fixed costs (less time on feed to reach a target slaughter weight). However, cattle are normally marketed at a fixed fat level (grade) rather than liveweight, and this experiment was not designed to investigate the effects to a constant fatness (or fat-corrected) endpoint.

The results from Tables 2 and 3 indicate that increasing dietary roughage significantly reduced rate of gain ($P<0.01$) and increased dry matter consumption per unit of gain ($P<0.01$). Thus, lowered levels of dietary roughage would be expected to result in reduced fixed costs. However, these comparisons were not made to a constant fat level. The feed or variable cost for each group is a function of the costs of grain and roughage relative to each other, as well as the biological efficiency of utilization. It should be noted for example that a 1¢/kg increase in the cost of the grain portion of the ration (Table 1) would alter feed cost per kilogram gained (Table 3) from 65.7, 64.8, 64.8¢/kg gained for the 20, 50 and 80% roughage groups to 70.7, 68.3, 64.8¢/kg gained, respectively. Feedlot management decisions on level of dietary roughage must therefore pay particular attention to the relationship between the cost of grain and the cost of roughage.

Carcass Characteristics

There were no significant roughage × castration interaction effects on any of the traits studied (Table 4). Although the differences attributable to diet in liveweight were small and not significant, the differences in carcass weight and dressing percent were significant, with the 80% roughage group being significantly ($P<0.05$) lighter than the other groups. This is expected on the basis of both increased gut fill and reduced amounts of carcass fat on the high roughage diet (Preston and Willis 1974). On the same basis it would be expected that cattle in the 50% roughage group would be intermediate for dressing percent. It is not clear why they were not, since their daily feed intake and carcass fat levels were intermediate.

The carcass composition results indicate an inverse relationship between dietary roughage level and carcass fatness. This was manifested in significant dietary effects ($P<0.01$) on grade and carcass fat depth (Table 4). It is well established that as daily energy intake increases, the rate of fattening

Table 4. Treatment and interaction effects on carcass characteristics

		n	Warm carcass wt (kg)	Dressing %	Grade†	Fat depth (mm)	L. dorsi area (sq cm)	Partial dissection: Sample muscle‡	Sample bone§	Sample M/B ratio
					Treatments					
Roughage level										
20%		15	288.0*a*	57.2*a*	3.4*a*	12.9*a*	73.7	20.8	5.7*a*	3.7
50%		15	288.0*a*	57.5*a*	3.1*a*	10.0*b*	75.9	21.7	6.1*b*	3.6
80%		15	275.5*b*	54.8*b*	2.5*b*	7.5*c*	7.43	21.8	6.2*b*	3.5
SEM//			2.67	0.40	0.16	0.75	1.93	0.42	0.12	0.07
Sig			**	**	**	**	NS	NS	*	NS
Bulls		24	287.3	56.9	2.6	7.9	76.5	22.1	5.9	3.7
Steers		21	280.3	56.2	3.4	12.4	72.7	20.7	6.0	3.4
SEM//			2.18	0.32	0.13	0.61	1.58	0.34	0.09	0.06
Sig			*	NS	**	**	NS	**	NS	**
					Interactions					
Sex	Roughage level									
Bull	20%	8	291.2	57.5	3.1	10.4	74.4	21.4	5.6	3.8
Bull	50%	8	294.6	58.2	2.8	8.3	77.8	22.7	6.0	3.8
Bull	80%	8	276.1	55.1	2.0	4.9	77.4	22.3	6.2	3.6
Steer	20%	7	284.7	57.0	3.7	15.5	73.0	20.1	5.8	3.5
Steer	50%	7	281.4	56.9	3.4	11.7	73.9	20.7	6.2	3.4
Steer	80%	7	274.9	54.6	3.0	10.2	71.2	21.3	6.1	3.5
SEM//			3.78	0.55	0.23	1.06	2.74	0.59	0.16	0.10
Sig			NS	NS	NS	NS	NS	NS	NS	NS

//Standard error of the means.
†C1=1; B1=2; A1=3; A2=4; A3=5.
‡Sum of the individual weights of Mm. tensor fasciae latae, biceps femoris, gluteus medius, vastus lateralis, rectus femoris, semitendinosus, gracilis and semimembranosus from one side (Price and Berg 1976).
§Sum of the individual weights of humerus, radius/ulna, femur and tibia from one side (Price and Berg 1977).

will also increase (Fowler 1974). This applies particularly to what Fowler (1974) termed the "variable" portion of body fat, i.e. that deposited primarily as an energy sink after all other growth and maintenance needs have been met.

Since the cattle were slaughtered at a common liveweight (500 kg), those on the higher roughage rations would be expected to have larger "fat-free bodies." The sample muscle and bone dissection results confirm this. The 20% roughage group had significantly less sample bone than the other groups, and less, though not significantly, sample muscle. There was no significant effect of roughage level on sample muscle to bone ratio, or on the area of longissimus muscle exposed at the quartering cut.

The mean carcass weight of the bulls was 7.0 kg greater ($P<0.01$) than of the steers, since their liveweight was greater and their dressing percent was almost 1 percentage point higher. The difference in dressing percent was, however, not significant.

Steer carcasses were fatter than bull carcasses, resulting in significantly higher average grade score ($P<0.01$) and fat depth ($P<0.01$). Under the scoring system used, the average bull failed to achieve an A grade, while the average steer graded between A1 and A2. Steers commonly grade "fatter" than bulls (Turton 1969; Field 1971).

In terms of the non-fat carcass, bulls had nonsignificantly larger longissimus muscle areas, and significantly heavier sample muscle weights ($P<0.01$) and sample muscle:bone ratios ($P<0.01$). There was no significant difference in sample bone weights. This corresponds to the general results reviewed by Field (1971) who cited many papers showing bulls to have greater separable muscle than, and similar separable bone to, steers.

It is concluded that the use of bulls rather than implanted steers would result in faster growth rates at all levels of dietary roughage, but would also result in reduced carcass fat content in 500-kg animals on all roughage levels. Increasing the level of roughage in the diet was found to reduce growth rates and carcass fat levels in bulls and implanted steers.

Both roughage level and castration would therefore be expected to have an influence on carcass grade, and further work is needed to identify changes in liveweight needed to compensate for this. An important finding from the present work is the lack of any significant interaction between dietary roughage level and castration followed by implantation for any of the beef production characteristics studied.

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