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

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A serial slaughter experiment is described comparing 45 bulls and 44 implanted steers. Nine of each "sex" were slaughtered at the start of the trial and the remaining 71 were fed diets containing three roughage levels (20%, 50% and 80% alfalfa–brome hay) to two pen-average slaughter weights (450 kg or 580 kg). Cattle were about 12 mo old at the start of the trial, and bulls were heavier (290 kg vs. 269 kg) than steers. Increasing the level of roughage in the diet resulted in a significant decrease in average daily gain (ADG), and an increase in feed intake and feed per kilogram gained to both slaughter weights. Differences in digestible energy (DE) intake were not significant. Apparent digestibilities of dry matter, crude protein and DE were significantly decreased, and acid detergent fiber significantly increased, by increasing levels of roughage. Bulls grew faster than steers and required less feed per unit of gain to both slaughter weights. Increasing the level of roughage decreased warm carcass weight, dressing percent and all measures of carcass fatness to both slaughter weights. Cattle fed low levels of roughage reached an optimum grade (A1) at a lower carcass weight than those fed high levels of roughage, and remained in that grade for a shorter period of time. Fat-free body size tended to increase with roughage level. Steer carcasses were fatter than those of bulls and had lighter sample muscle weights and smaller sample muscle to bone ratios. Based on present feed costs the lowest roughage diet produced the cheapest liveweight gain.

Une expérience d'abattage en série a été réalisée sur 45 taurillons et 44 bouvillons traités avec un implant anabolisant. Neuf sujets de chaque type ont été abattus au début de l'expérience et les 71 autres ont reçu des régimes alimentaires contenant trois niveaux d'incorporation de fourrage grossier, soit 20, 50 et 80% de foin de luzerne-brome, jusqu'à deux poids moyens d'abattage, 450 ou 580 kg. Les bêtes avaient environ 12 mois au départ et les taurillons pesaient 290 kg en moyenne contre 269 pour les bouvillons. L'élèvement de la proportion de fourrage dans l'alimentation a entraîné une chute significative du GQM (gain quotidien moyen) et une augmentation du taux d'ingestion et de l'indice de consommation, et cela jusqu'aux deux poids d'abattage. Les différences d'ingestion d'ED (énergid digestible) n'étaient toutefois pas significatives. De même, l'accroissement de la proportion de fourrage a abaissé significativement la digestibilité apparente de la matière sèche, de la protéine brute (PB) et de l'ED mais augmenté la digestibilité de la cellulose (détergent acide). Les taurillons grandissaient plus vite que les bouvillons et ils se sont montrés de

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meilleurs valorisateurs des aliments. L'enrichissement en fourrage grossier a abaissé le poids à chaud des carcasses, le rendement à l'abattage ainsi que tous les paramètres de l'état d'engraissement. Les bêtes exposées à un régime à basse teneur en fourrage grossier ont atteint le niveau de qualité optimum (A1) à un moindre poids, et ont conservé cette catégorie moins longtemps que les bêtes recevant les régimes riches en fourrage. Le développement musculaire semble augmenter avec la proportion de fourrage grossier dans la ration. Les carcasses des bouvillons étaient plus grasses que celles des taurillons et accusaient un moindre poids des muscles repères et un plus faible rapport muscles repères/os repères. Au coût actuel des aliments, c'est le régime contenant le moins de fourrage grossier qui s'est révélé le plus rentable sur le plan de la production de viande.

The fattening of beef cattle in Western Canada is based on diets with a high content of grain and a minimal amount of roughage (Anonymous 1976). When the price of grain is high relative to that of roughage it may be advantageous to increase the roughage content of feedlot diets. However, this is likely to reduce average daily gain and increase feed requirement per unit of gain (Price et al. 1978). These factors will lead to greater overhead costs because of the extra length of time required in the feedlot, and an increased total feed requirement if cattle are marketed at similar weights. In addition to this, the amount of carcass fat at a given liveweight may be reduced if less grain is included in the diet which may, in turn, affect carcass grade. Price et al. (1978) reported that bulls fed diets containing 50% or more roughage graded underfat (insufficient fat for the A1 grade) when slaughtered at 500 kg. The following study was conducted to provide information on changes in slaughter weight required to compensate for the effects of increased dietary roughage in bulls and steers.

MATERIALS AND METHODS

Ninety crossbred commercial cattle were purchased from one herd a few weeks before weaning in October 1976, at which time half were castrated. The cattle were a mixed Charolais-British breed-type. The calves were fed grass hay ad libitum and supplementary grain during the 1976-77 winter and grew at an average of about 0.5 kg/day. On 25 Apr. 1977 the cattle were transported to the Beef Cattle Test Station, Ellerslie, Alta., and fed alfalfa-brome hay, trace mineralized salt and a mineral mixture on a free-choice basis for a 10-day adjustment period. They were weighed on 3 consecutive days and the average was recorded as initial weight. The 45 animals of each "sex" were ranked for initial weight and the ranks cut into equal thirds. One animal from each third was then allocated at random to each of 15 pens. This process resulted in 30 pens, each containing either three bulls or three steers. At random, three pens of each "sex" were designated for immediate slaughter at a local packing plant in order to provide an estimate of the initial relationship between fat depth and carcass weight. Each of the remaining 12 pens was randomly assigned to one of three dietary treatments, and one of two pen-average slaughter weights (450 or 580 kg). Thus, there were two pens of animals for each diet and "sex" treatment combination within a slaughter weight. The steers were all implanted with Synovex S (Syntex Agribusiness Inc.).

The three diets (Table 1) contained 20, 50 or 80% alfalfa-brome hay prepared with a hammer mill, equipped with a 3.8-cm screen. The hay was mixed with rolled barley, vitamins and minerals at the time of feeding. The alfalfa grass hay (85.0% dry matter (DM)) contained 10.8% crude protein, 38.0% acid detergent fibre (ADF), and 18.1 MJ gross energy/kg. Animals on all treatments received 5.0 kg feed/pen on the first day following allocation to treatment. The total feed offered was increased by 1 kg/pen daily, and all 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. Trace mineralized salt and a 1:1 mixture of salt and calcium phosphate were available free-choice. Shavings were used for bedding.

Pen feed consumption was recorded daily, and the cattle were weighed every second Tuesday. When the pen-average weight approached the designated slaughter weight, the cattle were weighed on 3 consecutive days and trucked 10 km

Table 1. Formulation and composition of experimental diets

	% roughage in diet		
	20	50	80
Ingredients (%)			
Alfalfa-grass hay, ground	20.00	50.00	80.00
Barley, dry rolled	79.00	49.25	18.90
Trace mineralized salt†	0.25	0.25	0.25
Calcium carbonate	0.5		
Calcium phosphate‡		0.25	0.60
Vitamin premix§	0.25	0.25	0.25
Analysis			
Dry matter (%)	84.9	85.6	85.6
Crude protein (% DM)	11.5	11.2	10.9
Acid detergent fibre (% DM)	12.5	22.5	31.8
Calcium (% DM)	0.51	0.68	1.06
Phosphorus (% DM)	0.34	0.35	0.36
Gross energy (MJ/kg DM)	18.0	18.1	18.0
Feed cost/kg as fed//	7.21	7.19	7.17

†Trace mineralized salt contained 96.5% salt, 0.900% Zn, 0.160% Fe, 0.120% Mn, 0.033% Cu, 0.007% I and 0.004% Co.
‡Biofos: a mixture of monocalcium phosphate and dicalcium phosphate which contained a minimum of 21% phorphorus and between 15 and 18% calcium.
§The premix provided the following in each kilogram of diet: vitamin A, 5000 IU; vitamin D, 825 IU; vitamin E, 5 IU.
//Assuming a cost of $68.90/tonne for rolled barley and $60.64/tonne for alfalfa-grass hay. Processing charge: $3.31/tonne for rolled barley and $11.02/tonne for alfalfa-grass hay.

to the packing plant immediately after the last weighing. Water was restricted for approximately 16 h before weighing, although feed was continuously available.

Digestibility measurements were made using a combined total collection and grab sampling technique (Mathison 1978). Total collection of excreta was accomplished by scraping the unbedded concrete pens daily over an 8-day period. The ADF in this material was determined and used as a marker in the grab samples, which were taken during the same period.

Most of the cattle remained healthy throughout their stay in the feedlot. One steer in the 20% roughage, 580-kg slaughter weight group was removed from the experiment because of ill health. The data for this animal were not used in the analysis of the results.

Following slaughter and overnight chilling, the carcasses were appraised 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 transformed to a numerical score, based on the assumpiton that the differences in grade within a slaughter weight 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 B1 (fat cover 0.25–0.51 cm) scored 1; A1 (fat cover 0.51–1.27 cm) scored 2; and A2 (fat cover 1.04–1.78 cm) scored 3.

The right front- and hindquarter from each carcass was weighed first in air and then completely submerged in water to obtain the density of the side. The half carcass muscle and bone content were estimated by partial dissection (Jones et al. 1978). Fat weight was estimated as the difference between carcass weight and the sum of the predicted muscle and bone weights.

The data were analyzed using a two-way analysis of variance within slaughter weights. The missing data (one steer) were replaced using the value of the appropriate pen mean along with the loss of one degree of freedom. The effects of roughage and castration were tested using the pens within roughages and sex component of variance for individual animal measurements. For pen measurements the animal component of variance was used for significance testing. Where a significant effect of roughage treatment was found ($P < 0.05$), means were separated using the Student-Newman-Keuls test (Steel and Torrie 1960) at $P = 0.05$.

RESULTS AND DISCUSSION

Feedlot Performance

Increasing the roughage level in the diet significantly reduced the apparent digestibilities of the dry matter (DM) ($P < 0.05$), crude protein (CP) ($P < 0.05$) and digestible energy (DE) ($P < 0.01$), but significantly increased acid detergent fibre (ADF) digestibility ($P < 0.001$) (Table 2). There were no significant differences between bulls and steers for apparent digestibility of nutrients.

Averages of daily gain (ADG), daily DM intake and DM per unit of gain to each slaughter weight are shown in Tables 3 and 4. Increasing the roughage level in the diet resulted in decreased liveweight gain ($P < 0.05$) which consequently increased the number of days on feed ($P < 0.05$). Daily DM intake increased with roughage level which resulted in a greater ($P < 0.001$) feed requirement per unit of gain in the 80% than the 50%, and in the 50% than the 20% roughage groups (Tables 3 and 4). These findings are similar to those reported by Agriculture Canada (1974) and Price et al. (1978). Daily DE intake was similar on all diets and showed no reduction with increased roughage level; Price et al. (1978) also found no differences in daily DE intake. Despite this, DE per kilogram of gain and feed cost per kilogram of gain increased with roughage level. In the previous trial (Price et al. 1978) this trend had also been noted but the effect was non-significant. The authors indicated that they believed the non-significance to be a type II statistical error. The present results confirm that belief. The explanation of similar DE intakes giving significantly different growth rates lies in the efficiency of DE and ME utilization in diets containing various levels of roughage. It is well established that high roughage diets increase the production of combustible gases in the rumen and that the ME is less efficiently utilized (Preston and Willis 1974).

The effects of castration became more apparent at the heavier slaughter weight (Tables 3 and 4). Bulls had a higher ADG than steers, spent less time on feed (31 days less to reach 450 kg, 75 days less to 580 kg), and required less feed per unit of gain. The results of many trials show conclusively that bulls are superior to steers in gain and feed conversion (Field 1971; Price and Yeates 1971; Preston and Willis 1974) and this study is no exception.

Roughage × "sex" interactions for days on feed and digestible energy per kilogram gain were found to be significant ($P < 0.05$)

Table 2. Apparent digestibilities of diets for bulls and steers

Treatments	n	% digestibility: Dry matter	Acid detergent fibre	Crude protein	Energy
Roughage level					
20%	8	72.75 *a*	31.49 *a*	63.44 *a*	71.24 *a*
50%	8	68.82 *a*	45.65 *b*	56.00 *b*	65.28 *ab*
80%	8	64.43 *b*	48.65 *b*	54.18 *b*	60.41 *b*
SE means		1.822	2.468	2.346	1.881
Sig.		*	***	*	**
Bulls	12	68.18	41.20	57.54	64.77
Steers	12	69.16	42.66	58.21	66.51
SE mean		1.488	2.015	1.915	1.536
Sig.		NS	NS	NS	NS

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

a,b Means in the same column bearing a different letter are significantly different ($P<0.05$).

Table 3. Treatment effects on feedlot performance up to 450 kg mean liveweight

Treatments		n	Initial wt (kg)	Final wt (kg)	Daily gain (kg)	Days on feed	Daily DM intake (kg)	Daily DE intake (MJ)	DM/kg gain (kg)	DE/kg gain (MJ)	Feed cost /kg gain (¢)
			Slaughter weight 450 kg								
Roughage level											
20%		12	278.8	450.9	1.59 *a*	108 *a*	8.80 *a*	113.09	5.55 *a*	71.25 *a*	46.1
50%		12	278.7	449.1	1.39 *b*	126 *ab*	9.40 *ab*	111.08	6.88 *b*	81.50 *b*	57.7
80%		12	280.7	446.8	1.26 *b*	133 *b*	9.92 *b*	112.17	8.24 *c*	89.75 *b*	68.9
SE means			5.55	2.95	0.045	5.4	0.196	2.975	0.204	2.477	
Sig.			NS	NS	*	*	*	NS	***	**	
Bulls		18	290.7	451.4	1.50	107	9.32	108.37	6.25	72.34	52.6
Steers		18	268.2	446.4	1.32	138	9.43	115.90	7.53	89.37	63.4
SE mean			4.53	2.41	0.037	3.1	0.160	2.385	0.167	2.021	
Sig.			*	NS	*	**	NS	NS	**	***	
Interactions											
Sex	*Roughage level*										
Bull	20%	6	291.2	458.0	1.59	105 *a*	8.53	110.081	5.37	69.25 *a*	45.5
Bull	50%	6	294.2	448.5	1.57	98 *a*	9.35	108.45	5.95	68.95 *a*	49.9
Bull	80%	6	286.7	447.8	1.36	119 *a*	10.06	106.48	7.44	78.74 *a*	62.3
Steer	20%	6	266.5	443.8	1.59	112 *a*	9.06	116.11	5.72	73.26 *a*	48.6
Steer	50%	6	263.3	449.7	1.21	154 *b*	9.44	113.72	7.81	94.10 *b*	65.5
Steer	80%	6	274.8	445.8	1.17	147 *b*	9.78	117.82	9.05	100.71 *b*	75.7
SE means			7.85	4.17	0.064	7.6	0.278	4.134	0.289	3.506	
Sig.			NS	NS	NS	*	NS	NS	NS	*	

*$P<0.05$; **$P<0.01$; ***$P<0.001$.
a-c Means in the same column bearing a different letter are significantly different ($P<0.05$).

Table 4. Treatment effects on feedlot performance up to 580 kg mean liveweight

Treatment		*n*	Initial wt (kg)	Final wt (kg)	Daily gain (kg)	Days on feed	Daily DM intake (kg)	Daily DE intake (MJ)	DM/kg gain (kg)	DE/kg gain (MJ)	Feed cost /kg gain (¢)
			Slaughter weight 580 kg								
Roughage level											
20%		11	283.3	590.9	1.46 *a*	215 *a*	9.30 *a*	119.49	6.44 *a*	82.72 *a*	54.7
50%		12	278.2	577.5	1.16 *b*	266 *b*	10.44 *b*	123.38	9.22 *b*	109.24 *b*	76.7
80%		12	276.7	572.8	1.03 *b*	292 *b*	11.78 *c*	127.86	11.56 *c*	125.73 *c*	96.7
SE means			4.51	5.14	0.049	11.2	0.192	2.192	0.320	3.535	
Sig.			NS	NS	**	**	***	NS	***	***	
Bulls		18	289.8	583.3	1.36	220	10.83	125.77	8.24	94.60	69.4
Steers		17	269.1	577.6	1.07	295	10.19	121.42	9.91	117.23	83.4
SE means			3.68	4.19	0.040	6.4	0.156	1.791	0.261	2.887	
Sig.			**	NS	**	**	*	NS	**	**	
Interactions											
Sex	*Roughage level*										
Bull	20%	6	297.8	601.7	1.62	189	9.86	127.11	6.12	78.87	51.9
Bull	50%	6	280.8	569.3	1.33	217	10.63	123.22	8.02	92.93	67.3
Bull	80%	6	290.7	578.8	1.14	255	11.99	126.94	10.58	111.96	88.5
Steer	20%	5	268.8	580.2	1.29	241	8.74	111.88	6.76	86.61	57.4
Steer	50%	6	275.7	585.7	0.99	315	10.25	123.55	10.42	124.56	87.4
Steer	80%	6	262.7	566.8	0.92	329	11.57	128.83	12.53	139.49	104.9
SE means			6.39	7.27	0.069	15.8	0.271	3.100	0.453	5.004	
Sig.			NS	NS	NS	NS	NS	NS	NS	NS	

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

a-c Means in the same column bearing a different letter are significantly different ($P<0.05$).

at the lower slaughter weight; the reason is not clear. However, no significant roughage × "sex" interactions were recorded at the heavier slaughter weight (Table 4); this agrees with the previous study (Price et al. 1978).

Carcass Characteristics

There were no signfiicant roughage × "sex" interaction effects on any of the carcass traits studied (Tables 5 and 6). Warm carcass weight and dressing percent decreased with increased roughage level in the diet, which is to be expected on the basis of increased gut fill and reduced amounts of carcass fat from the high roughage diet. However, there was little difference between animals fed the low and medium roughage diet in dressing percent; it would be expected that cattle in the 50% roughage group would be intermediate for dressing percent since their daily feed intake and fat levels were intermediate. A finding similar to the present one was reported by Price et al. (1978).

Bulls and steers had similar warm carcass weights and dressing percentages at the lower slaughter weight, but differed at the heavier weight where bulls had heavier warm carcass weights and higher dressing percentages (bulls were 5.7 kg heavier at slaughter than steers). Although steers are sometimes found to have higher dressing percentages than bulls (Preston and Willis 1974), this is by no means a universal finding, particularly when, as in this trial, kidney knob and channel fats are removed from the carcass.

The fat depth and marbling data (Tables 5 and 6) indicate an inverse relationship between dietary roughage level and carcass fatness, which was also found by Price et al. (1978). Bulls had less carcass fat than steers at both slaughter weights.

The bulls on low roughage diets all graded A1 (optimum fat) when slaughtered at a mean of 450 kg; at 580 kg the same diet produced slightly fatter but still acceptable carcasses. The bulls on the high roughage diets (50% and 80%) graded less than A1 at the lower slaughter weight, but all graded A1 at the higher weight. The steers on low roughage were slightly fatter (A1.2) at 450 kg, whereas the steers on high roughage diets (50% and 80%) graded A1.0. All steers at the heavier weight were graded fatter than A1.0.

Linear regressions of minimum fat depth (as defined for grading purposes) on warm carcass weight were calculated for each group using data from all 89 carcasses. The regression lines are shown in Figs. 1 and 2 superimposed on diagrams representing the Canadian grading system. The figures show clearly that as carcasses get heavier, grades change from C1 through B1 to A1 and A2. The average rate of accumulation of fat (regression) was greater in the 20% group (0.65 cm/100 kg increase in carcass weight) than in the 50% group (0.52 cm/100 kg), and greater in the 50% than the 80% group (0.43 cm/100 kg). As a result, cattle on the 20% roughage diet would begin to grade A1 at an average carcass weight of 221 kg, and reach A2 at an average carcass weight of 299 kg; a range in carcass weight of 78 kg. The corresponding ranges in A1 for the 50% roughage diets was 146 kg, and for the 80% group, 177 kg. The influence of dietary energy level on carcass grade is, therefore, twofold: if dietary energy level is reduced the animal will (a) be heavier when it reaches a particular carcass grade and (b) remain in that grade over a greater range of liveweight.

The effect of castration on grade performance is shown in Fig. 2. Steers achieve a particular grade sooner than bulls and pass through it more rapidly. To the producer this means that bulls would remain in the A1 grade over a greater range of carcass (or live) weight than steers, thus improving the chance of a large group of cattle all achieving the top grade simultaneously. However, it can be seen both in Fig. 1 and Fig. 2 that when an A2, A3, or A4 carcass surpasses 227 kg in warm carcass weight, it needs an extra 0.25 cm of fat to stay in the same grade. A similar situation occurs at 317 kg, and here both A1 and B1

Table 5. Treatment effects on carcass characteristics of animals slaughtered at 450 kg mean liveweight

Treatments		*n*	Slaughter weight 450 kg					
			Warm carcass wt (kg)	Dressing (%)	Fat depth (cm)	Grade†	Loin eye area (cm²)	Marbling‡
Roughage level								
20%		12	256.7 *a*	56.9	0.68 *a*	2.1	66.06	7.2
50%		12	255.9 *a*	56.9	0.57 *ab*	1.8	67.48	7.3
80%		12	246.5 *b*	55.1	0.49 *b*	1.7	61.16	7.6
SE means			2.28	0.52	0.040	0.11	1.928	0.13
Sig.			*	NS	*	NS	NS	NS
Bulls		18	254.6	56.3	0.42	1.7	69.53	7.5
Steers		18	251.4	56.4	0.73	2.1	60.27	7.2
SE means			1.86	0.42	0.032	0.09	1.574	0.10
Sig.			NS	NS	***	*	**	*
Interactions								
Sex	*Roughage level*							
Bull	20%	6	261.0	57.0	0.51	2.0	71.77	7.3
Bull	50%	6	255.8	56.9	0.38	1.7	74.47	7.5
Bull	80%	6	247.1	55.0	0.38	1.3	62.37	7.8
Steer	20%	6	252.4	56.9	0.85	2.2	60.35	7.0
Steer	50%	6	255.9	56.9	0.76	2.0	60.50	7.2
Steer	80%	6	245.9	55.1	0.59	2.0	59.95	7.3
SE means			3.23	0.73	0.055	0.15	2.726	0.18
Sig.			NS	NS	NS	NS	NS	NS

†B1=1; A1=2; A2=3.
‡1 (highly marbled); 8 (no marbling).
*$P<0.05$; **$P<0.01$; ***$P<0.001$.
a-b Means in the same column bearing a different letter are significantly different ($P<0.05$).

Table 6. Treatment effects on carcass characteristics of animals slaughtered at 580 kg mean liveweight

Treatments		n	Slaughter weight 580 kg: Warm carcass wt (kg)	Dressing (%)	Fat depth (cm)	Grade†	Loin eye area (cm²)	Marbling‡
Roughage level								
20%		11	356.8 *a*	60.3 *a*	1.30	2.5	78.82	6.6 *a*
50%		12	342.2 *b*	59.2 *a*	1.12	2.3	82.92	6.2 *a*
80%		12	327.6 *c*	57.2 *b*	0.87	2.2	76.20	7.3 *b*
SE means			3.22	0.35	0.103	0.17	1.853	0.19
Sig.			**	**	NS	NS	NS	*
Bulls		18	347.1	59.5	0.93	2.1	82.16	7.2
Steers		17	337.2	58.3	1.26	2.6	76.48	6.2
SE means			2.63	0.28	0.084	0.14	1.513	0.15
Sig.			*	*	*	NS	*	*
Interactions								
Sex	*Roughage level*							
Bull	20%	6	366.8	60.9	1.27	2.3	78.77	7.2
Bull	50%	6	341.5	59.9	0.80	2.0	85.20	7.0
Bull	80%	6	333.0	57.6	0.72	2.0	82.50	7.5
Steer	20%	5	346.8	59.7	1.33	2.7	78.88	6.0
Steer	50%	6	342.8	58.5	1.44	2.7	80.65	5.3
Steer	80%	6	322.1	56.8	1.02	2.3	69.90	7.2
SE means			4.55	0.49	0.146	0.24	2.620	0.26
Sig.			NS	NS	NS	NS	NS	NS

†B1=1; A1=2; A2=3.
‡1 (highly marbkled); 8 (no marbling).
*$P<0.05$; **$P<0.01$; ***$P<0.001$.
a-c Means in the same column bearing a different letter are significantly different ($P<0.05$).

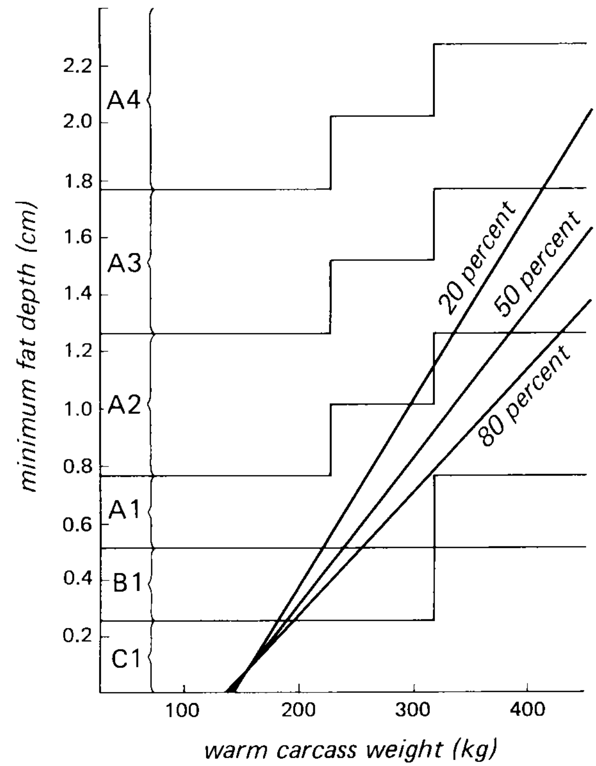

Fig. 1. The relationship of fat cover and carcass weight to grade in bulls and steers fed three levels of dietary roughage. *Regressions*: 20%: $y=-0.927+0.0065x$ ($n=41$; $R^2=0.80^{**}$); 50%: $y=-0.711+0.0052x$ ($n=42$; $R^2=0.70^{**}$); 80%: $y=-0.587+0.0043x$ ($n=42$; $R^2=0.77^{**}$). $^{**}P<0.01$.

carcasses are also affected. This can lead to a number of anomalous situations (Price 1978). In Fig. 1 for example, cattle fed a 20% roughage diet would be expected to grade A1, then A2, then A1 again and finally back again to A2 as carcass weight increased. Similar situations can be seen in Fig. 2 for steers. If the minimum fat level for a particular grade remained constant across all carcass weights, rapid, early fattening types would be more heavily penalized for overfatness, which would be more in keeping with current industry efforts to reduce excessive fatness.

Loin eye area was variable, but increased with slaughter weight and was larger for bulls than steers.

Carcasses were less dense at the heavier slaughter weights indicating an increase in carcass fatness with slaughter weight (Table 7). Density also increased with roughage level at both slaughter weights which agreed with the inverse relationship between dietary roughage level and carcass fatness already found for the fat depth data.

Sample muscle weights and sample muscle to bone ratios (Table 7) were greater for bulls than steers; there were no significant differences between "sexes" in sample bone weight.

Economic Considerations for Increasing the Amount of Roughage in Feedlot Diets

The level of roughage used in feed lot diets

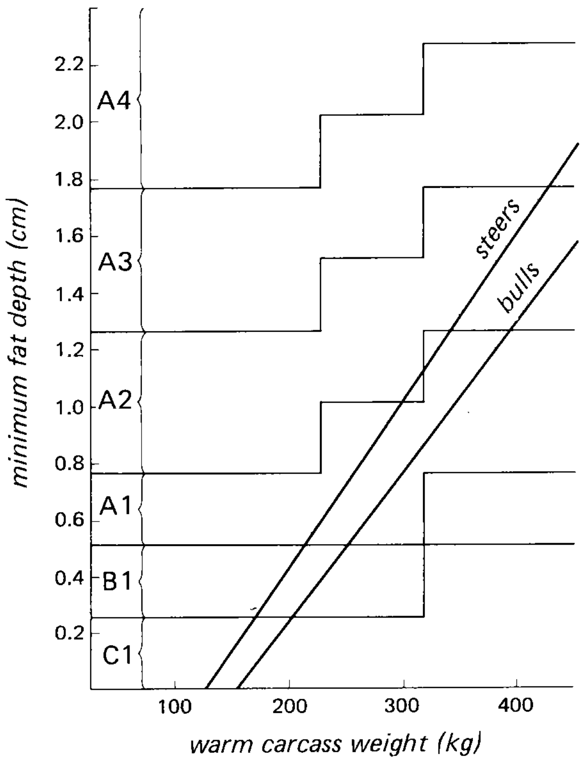

Fig. 2. The relationship of fat cover and carcass weight to grade in bulls and steers. *Regressions*: Steers: $y = -0.785 + 0.0060x$ ($n = 44$; $R^2 = 0.69$**); Bulls: $y = -0.805 + 0.0052x$ ($n = 45$; $R^2 = 0.66$**). **$P < 0.01$.

will depend mainly on the cost of grain relative to roughage, since most producers aim to finish cattle at the lowest feed cost per kilogram gained, which should ensure a maximum margin over costs. Figure 3 illustrates the feed cost per kilogram of grain for 20%, 50% and 80% roughage diets to both experimental slaughter weights, as grain price increases relative to that of roughage. When there is little difference between the price of grain and that of roughage, the data show that low levels of roughage inclusion promoted the cheapest liveweight gain. Once the grain price is close to 200% of the price of roughage, then an 80% roughage diet would give a lower cost of liveweight gain than a 20% roughage diet. However, this was only to 450 kg, and in the case of bulls a slaughter weight of at least 580 kg would be necessary to ensure an A1 carcass. These data strongly suggest that unless the price differential between grain and roughage is very large, then inclusions of roughage above 20% would not be economically feasible in feedlot rations.

Figure 4 shows the feed cost per kilogram gain for bulls and steers to both experimental slaughter weights. The clear superiority of bulls over steers in feed costs per kilogram of liveweight gain are obvious. It is also interesting to note that feed costs per kilogram of gain are similar for steers slaughtered at 450 kg to those for bulls slaughtered at 580 kg.

Increasing the level of roughage in feedlot diets not only influenced the liveweight performance, but also the carcass composition of the animals. For all levels of

Table 7. Treatment effects on carcass composition of animals slaughtered at 450 kg and 580 kg mean liveweight

			Slaughter weight 450 kg					Slaughter weight 580 kg			
Treatments		*n*	Density (g/cc)	Sample muscle wt (kg)	Sample bone wt (kg)	Sample muscle/kg bone (kg)	*n*	Density (g/cc)	Sample muscle wt (kg)	Sample bone wt (kg)	Sample muscle/kg bone (kg)
Roughage level											
20%		12	1.066 *a*	19.10 *a*	5.61	3.41	11	1.058 *a*	23.67	6.59	3.58
50%		12	1.073 *b*	19.74 *b*	5.69	3.48	12	1.056 *a*	22.59	6.13	3.71
80%		12	1.076 *b*	18.84 *a*	5.73	3.30	12	1.069 *b*	21.17	6.49	3.42
SE means			0.0019	0.176	0.009	0.051		0.0019	0.422	0.164	0.092
Sig.			*	*	NS	NS		**	NS	NS	NS
Bulls		18	1.078	20.04	5.69	3.53	18	1.070	24.02	6.41	3.75
Steers		18	1.066	18.41	5.66	3.26	17	1.052	21.59	6.40	3.39
SE means			0.0015	0.144	0.006	0.042		0.0016	0.344	0.134	0.075
Sig.			***	***	NS	**		***	**	NS	*
Interactions											
Sex	*Roughage level*										
Bulls	20%	6	1.071	20.58 *a*	5.60	3.69 *a*	6	1.062	24.59	6.50	3.79
Bulls	50%	6	1.080	20.43 *a*	5.76	3.56 *ab*	6	1.067	24.13	6.10	3.94
Bulls	80%	6	1.082	19.12 *b*	5.72	3.35 *abc*	6	1.081	23.34	6.63	3.52
Steers	20%	6	1.061	17.62 *c*	5.63	3.13 *c*	5	1.054	22.74	6.68	3.38
Steers	50%	6	1.065	19.06 *b*	5.61	3.41 *abc*	6	1.045	21.05	6.16	3.47
Steers	80%	6	1.071	18.56 *b*	5.73	3.25 *bc*	6	1.057	20.99	6.35	3.31
SE means			0.0027	0.250	0.139	0.072		0.0028	0.596	0.231	0.130
Sig.			NS	**	NS	*		NS	NS	NS	NS

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

a-c Means in the same column bearing a different letter are significantly different ($P<0.05$).

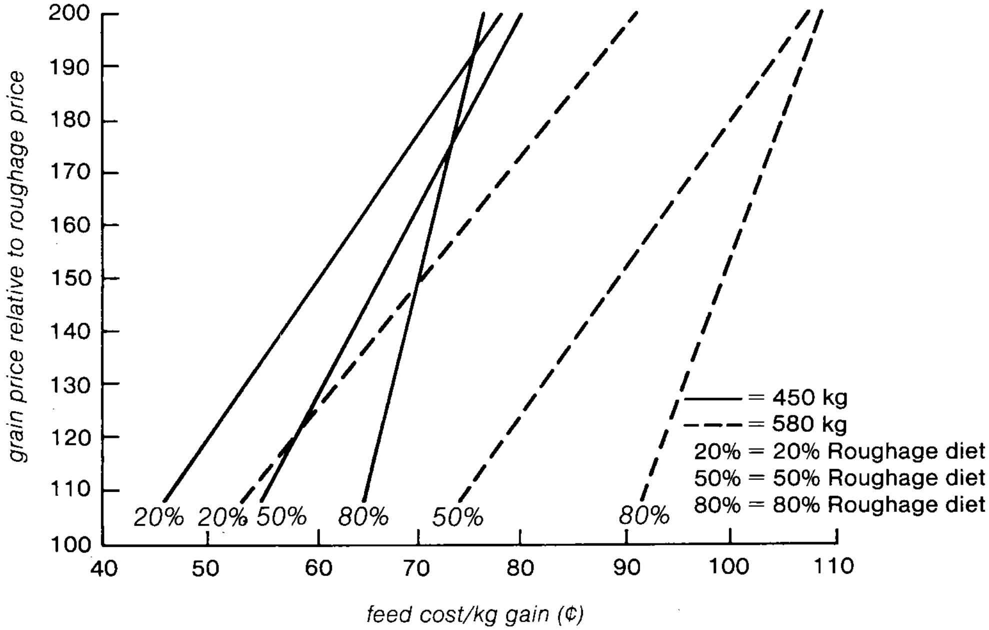

Fig. 3 Cost of liveweight gain for bulls and steers fed three levels of dietary roughage.

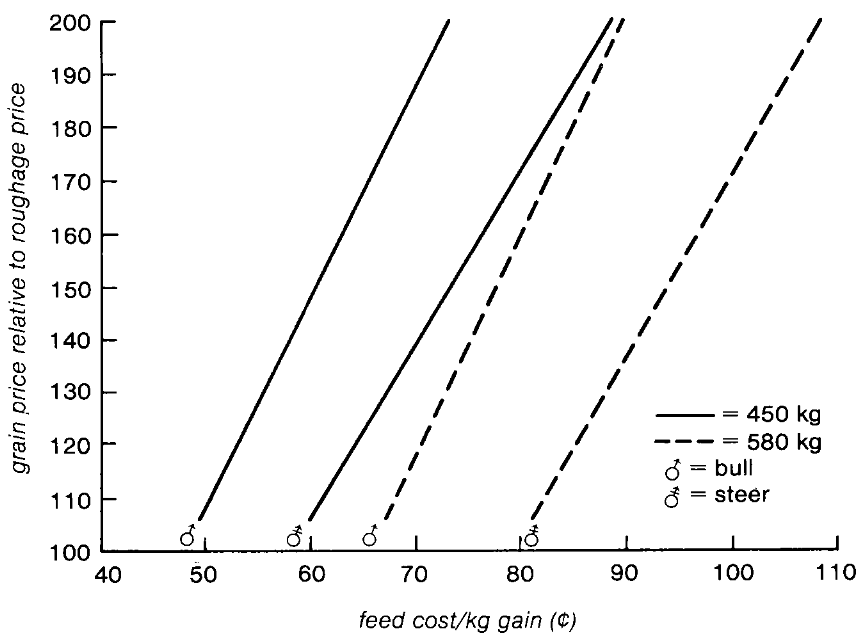

Fig. 4. Cost of liveweight gain in bulls and steers.

roughage, 450 kg was a satisfactory slaughter weight for steers of this type but only satisfactory for bulls fed 20% roughage. Bulls fed higher levels of roughage (50% and 80%) should be slaughtered at greater weights in order to achieve optimum grades. The decision to use roughage would depend on the actual price differential between roughage and grain. However, it is clear that unless the differential between grain and roughage prices are very great, the inclusion of roughage in the diet can only be justified as an aid to digestion and should be calculated on that basis.

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