The influence of dietary energy concentration and feed intake level on feedlot steers 2. Feed intake, live mass-gain, gut fill, carcass gain and visual and physical carcass measurements

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A total of 108 medium frame weaner steers, divided into 9 groups of 12 each with mean group masses of 200 kg, were used to determine the effect of three concentrate to roughage (C:R) ratios (80:20, 55:45, and 30:70), fed at three feeding levels (*ad libitum*, 90% *ad libitum* and 80% *ad libitum*), on mass gain, dressing percentage and visual and physical carcass characteristics. Steers were slaughtered at a mean mass of 380 kg. Alimentary canal mass and contents, three subcutaneous fat thicknesses, carcass and buttock length, and cold carcass mass of each steer were measured. Carcasses were classified according to fatness and conformation scores into specific grades. Steers on the three feeding levels were respectively fed for 106, 114 and 174 days on the 80:20 diet, 156, 161 and 191 days on the 55:45 diet, and 197, 297 and 322 days on the 30:70 diet. Contrary to expectation, DM intake decreased and then increased as the C:R ratio increased. Respective carcass gains were 792, 723 and 530; 579, 535 and 489; and 448, 329 and 285 g/d. A decrease in C:R ratio reduced both dressing percentage and carcass gain linearly, while a decrease in feeding level did not significantly influence dressing percentage, but it reduced carcass gain linearly. Subcutaneous fat thickness measurements at different sites were divergently influenced by main effects, but they tended to be reduced by a decrease in either C:R ratio or feeding level. Carcass fatness score decreased with a decrease in either C:R ratio (linear, non-linear) or feeding level (linear). Carcass fatness can be nutritionally manipulated at the assumed target mass within the constraints of the South African beef carcass classification and grading system.

Nege groepe van 12 mediumraam-speenosse met 'n groepgemiddelde aanvangsmassa van ongeveer 200 kg elk, is gebruik om die invloed van drie voedingspeile (*ad libitum*, 90% *ad libitum* and 80% *ad libitum*) op massatoename, uitslagpersentasie sowel as visuele en fisiese karkaseienskappe by drie kragvoer-tot-ruvoer(K:R)-verhoudings (80:20, 55:45, en 30:70) te ondersoek. Na slagting by 'n groepgemiddelde massa van ongeveer 380 kg is die spysverteringskanaalmassa en -inhoud, drie onderhuidse vetdiktemates, karkas- en boudlengte asook koue karkasmassa van elke os bepaal. 'n Gradeerder het aan elke karkas 'n bouvorm- en vetheidskode asook 'n graad toegeken. Die voerperiodes vir die drie voedingspeile was onderskeidelik 106, 114 en 174 dae vir die 80:20-dieet, 156, 161 en 191 dae vir die 55:45-dieet en 197, 297 en 322 dae vir die 30:70-dieet. Droëmateriaal-inname het teen die verwagting in konveks toegeneem met 'n toename in die K:R-verhouding. Karkasmassatoename (KGDT) was onderskeidelik 792, 723 en 530; 579, 535 en 489; en 448, 329 en 285 g/d. 'n Afname in die K:R-verhouding het beide die uitslagpersentasie en KGDT lineêr verlaag, terwyl 'n daling in die voedingspeil geen invloed gehad het op die uitslagpersentasie nie, maar KGDT wel lineêr verlaag het. Onderhuidse vetdiktemate was differensiëel deur hoofeffekte beïnvloed, maar het geneig om met 'n verlaging in die K:R-verhouding sowel as voedingspeil te verminder. Karkasvethede het verlaag met 'n daling in die K:R-verhouding (lineêr, nie-lineêr) of voedingspeil (lineêr). Karkasvetheid by 'n bepaalde teikenmassa kan deur voeding gemanipuleer word binne die beperkinge van die Suid-Afrikaanse beeskarkasklassifikasie- en graderingstelsel.

Keywords: Beef steers, dietary energy concentration, feeding level, mass gain, visual and physical carcass measurements.

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Introduction

Both the semi-intensive and intensive beef industries in South Africa attempt to manipulate the growth pattern of beef cattle. This may be achieved by feed formulation and management practices to maximize feed margins from all available cattle types. Controversy exists regarding how much nutritional manipulation can vary the composition of growth and thus carcass mass at a desired composition (Byers, 1982; Meissner, 1983). If carcass composition can be manipulated by means of different energy intake strategies, an optimum level of subcutaneous fat at marketing can be attained by growing cattle along different growth curves or at different growth rates. Secondly, such strategies may contribute to maximize lean tissue accretion and defer fat deposition to increase the final carcass mass at which optimum fatness is obtained. Thirdly, strategies may enable producers to maintain cattle economically at a given carcass fatness when marketing problems are experienced to prevent over-fatness. Finally, such strategies will increase the flexibility in the marketing of cattle during periods of over-supply.

Carcass fatness, an indicator of meat yield, and age, an indicator of meat quality, are the two most important characteristics used in the beef carcass classification and grading system in South Africa. By this grading system, 18% carcass fat is considered to be the biological optimum amount of fat (Klingbiel, 1984) relative to the stage of protein maturity reached. This stage also corresponded with consumer preferences in the beginning of the 1980s (personal communication: R.T. Naudé, ADSRI, 1990). Visual evaluation of the amount and distribution of subcutaneous fat is an important component of the grading system with a subcutaneous fat thickness measurement of 7 mm as the maximum permitted to qualify for the optimum grades in each age group, namely Super A, Prime B or Top C (Government Notice, 1985). This places an upper limit on the range of carcass fatnesses within which growth may be manipulated (Slabbert, 1990a; 1990b). Although optimum slaughter masses on a typical feedlot diet for non-implanted early, medium and late maturing genotypes have been determined (Naudé *et al.*, 1986), little information is available on the extent that divergent dietary energy concentrations and feeding levels might influence the visual and physical carcass characteristics of steers (Slabbert, 1990a).

This study was conducted to determine the influence of continuously feeding three concentrate:roughage ratios at three feed intake levels on mass gain, dressing percentage and the variation in visual and physical carcass measurements of medium frame weaner steers.

Materials and Methods

Animals and diets

A total of 114 dehorned medium frame Bonsmara-crossbred weaner steers were obtained from one farm. Six steers were slaughtered upon arrival and used as an initial slaughter group. The other steers were stratified according to mass and allocated to nine groups of 12 animals each with a mean group live mass of 200 kg. These nine groups were randomly allocated to a 3 × 3 factorial arrangement of treatments. Steers received routine feedlot vaccinations, treatment for internal and external parasites, ear tags and 25 mg 17-β-oestradiol ear implants.

Steers were group fed on one of three experimental diets. These diets consisted of concentrate to roughage (C:R) ratios of 80:20, 55:45 or 30:70 fed at one of three feeding levels: *ad libitum* (AL), 90% of *ad libitum* (90AL), or 80% of *ad libitum* (80AL). Diet compositions used were described by Slabbert *et al.* (1992a). Animals were kept in an open-air facility with partial shelter. Adaptation to the respective dietary treatments lasted 21 days in which diets were fed in sequence of increasing dietary energy concentration. The daily feed allowances of the AL groups were based on the air-dry feed intake of the previous three days plus 10%. Feeding levels (% of AL) of the sub-AL fed groups were based on the feed intake of the respective AL fed groups at corresponding live masses. The feeding schedules for the sub-AL groups were updated on a weekly basis by means of a second-order polynomial regression between intake and weekly determined live mass. Steers were fed twice daily in equal amounts at 09:00 and 15:30.

Measurements and analyses

Daily intakes of the experimental diets were determined for each group while the dry-matter (DM) content of each diet was determined weekly. The steers, which had free access to feed and water, were weighed weekly and the groups were rotated between pens after each such weighing to minimize pen effects.

All steers in a particular group were slaughtered when the mean group live mass had reached 380 kg. During the slaughter process, the mass of the alimentary canal, both full and empty, was determined. Cold carcass mass was also recorded. After the carcasses were split, carcass and buttock lengths were measured on the right side of the carcass using the method of Naudé (1974). The right side of the carcass was quartered between the 10th and 11th ribs. The 2.5 and 5.0 cm fat thickness measurements, *i.e.* 2.5 and 5.0 cm from the midline of the carcass between the 10th and 11th ribs, as well as fat thickness measured opposite the widest point of the rib eye (F3) were determined with a calliper on the caudal surface of the prime rib. Fatness and conformation scores and consequent carcass grades of the carcasses (Government Notice, 1985) were determined by an official grader on a 18-, 15- and 4-point scale, respectively. Initial carcass mass was calculated to be 54.7% (mean cold dressing % of the initial slaughter group) of live mass. Age class was determined by checking for permanent incisors prior to dressing the carcass. Except for one steer on the 30:70 diet at 80AL, all other steers had no permanent incisors (class A-age).

Metabolizable energy (ME) values for the dietary treatments were calculated for each group of cattle, using NRC (1984) equations according to the method proposed by Hays *et al.* (1987), for comparison with ME values based on DM digestibility (Slabbert *et al.*, 1992a). For the application of net energy calculations for ME estimation, rate of gain was calculated from shrunk mass (96% of full mass). Daily live mass-gain was estimated from a second-order polynomial regression between weekly determined live mass and days in the feedlot.

Statistical analyses

Data were subjected to analyses of variance according to the mixed model least squares and maximum likelihood computer program of Harvey (1988). In this model, dietary energy concentration, feeding level and the dietary energy concentration × feeding level interaction were included. The experimental unit was the individual steer for all analyses except those for DM and calculated ME intakes, where only treatment means were available. Due to significant differences ($P \leq 0.05$) in final carcass mass between treatments, especially due to the changing C:R ratio, carcass mass was used as a covariate to linearly ($P \leq 0.05$) adjust all variables to the same carcass mass. Dry-matter intake of sub-AL feeding levels on the 80:20 and 55:45 diets deviated by not more than 2.5% from the planned intakes. However, on the 30:70 diet, the achieved feeding level was 9.6 and 6.7% lower, respectively, than the planned 90AL and 80AL. For statistical analyses, this deviation was ignored.

Results and Discussion

Feed intake

Contrary to the general postulate that the DM consumption of feed mixtures increases with level of concentrate until a peak is reached (Meissner *et al.*, 1982), DM intake in this instance (Table 1) tended to decrease and then to increase. A similar intake pattern was also observed in our concurrent digestibility trial (Slabbert *et al.*, 1992a). The achieved protein intakes of steers on the different treatments, as compared to factorial estimates (NRC, 1984), apparently were insufficient to meet growth requirements during the early stages of growth. However, based on results of Merchen *et al.* (1987) and Abdalla *et al.* (1988), this initial protein shortage should not significantly influence either the mean rate or the composition of gain over the feeding period due to compensation.

The estimated mean ME intake (Table 1), based on DM digestibility (Slabbert *et al.*, 1992a), was slightly higher than that calculated from production parameters and NRC equations (NRC, 1984) for the 80:20 diet, but slightly lower on the 55:45 and 30:70 diets. However, as expected, ME intake tended to increase as dietary energy concentration increased, irrespective of feeding level and method of ME estimation. For any given C:R ratio, the ME content at 80% of *ad libitum* (Table 1) tended to be higher than that at *ad libitum*. This tendency of ME content to increase with a restricted feeding level is in accordance with findings of Plegge (1987) and Hicks *et al.* (1987; 1990), suggesting that digestibility and / or utilization (Hays *et. al.*, 1987) was greater at sub-AL feeding levels.

Mass gain

Total energy intake (Table 1), altered by means of the C:R ratio and / or feeding level, undoubtedly was the main factor affecting growth rate in beef cattle; an increase in energy intake increased both daily gain and carcass gain (Table 2) as shown previously (Andersen, 1978). Carcass gain (Table 2) provides information that is more closely related to the saleable product than live mass-gain is, due to the differential effect of the C:R ratio and feeding conditions on alimentary canal contents. For carcass gain a significant ($P \leq 0.05$) C:R ratio × feeding level interaction was detected, probably due to differences in energy intake and their differential effects on the composition of growth (Andersen, 1978). As can be seen from Table 2, a decrease in the C:R ratio (80:20 to 30:70), as indicated by row means, significantly ($P \leq 0.01$) reduced carcass mass gain linearly (682 to 354 g/d). This agrees with the results of Danner *et al.* (1980) and Woody *et al.* (1983). Within the AL, 90AL and 80AL feeding levels, carcass gain decreased significantly ($P \leq 0.05$) as roughage inclusion level was increased. A decrease in feeding level (AL to 80AL) significantly ($P \leq 0.01$) decreased carcass gain (606 to 435 g/d) linearly, which agrees with the results of Geay (1976), Meissner (1983) and Hicks *et al.* (1987; 1990). Within the 80:20, 55:45 and 30:70 diets, carcass gain also decreased significantly ($P \leq 0.05$) with a decrease in feeding

Table 1 Mean daily DM and estimated ME intakes, initial and final live masses and feeding period of group-fed steers

Concentrate : roughage ratio	Item	Feeding level AL	90AL	80AL
80:20	DM intake[1] (kg/d)	8.20	7.53	6.47
	ME intake[1,3] (MJ/d)	90.9	83.8	74.3
	ME intake[1,4] (MJ/d)	87.4	77.9	68.8
	Initial live mass[2,5] (kg)	225[a]	224[a]	213
	Final live mass[2,5] (kg)	378	368	387
	Feeding period[1] (d)	106	114	174
55:45	DM intake[1] (kg/d)	7.65	7.07	6.13
	ME intake[1,3] (MJ/d)	74.9	69.3	60.2
	ME intake[1,4] (MJ/d)	76.2	70.5	63.1
	Initial live mass[2,5] (kg)	211[ab]	213[a]	201
	Final live mass[2,5] (kg)	390	383	377
	Feeding period[1] (d)	156	161	191
30:70	DM intake[1] (kg/d)	7.90	6.35	5.79
	ME intake[1,3] (MJ/d)	64.1	53.9	49.9
	ME intake[1,4] (MJ/d)	66.2	56.0	53.1
	Initial live mass[2,5] (kg)	205[b]	192[b]	204
	Final live mass[2,5] (kg)	377	384	386
	Feeding period[1] (d)	197	297	322

[a,b] Means in the same column (main effect) with different alphabetic superscripts differ significantly ($P \leq 0.05$).

[1] Group means.

[2] No significant ($P > 0.05$) differences in the same row (main effect).

[3] Based on DM digestibility and DM intake.

[4] Based on gain and intake data. The calculated ME content (MJ / kg DM) for the three feeding levels were respectively 10.59, 10.34 and 10.63 for the 80:20 diet, 9.96, 9.96 and 10.30 for the 55:45 diet and 8.62, 8.83 and 9.17 for the 30:70 diet.

[5] Respective error standard deviations of the mean were 20.3 and 36.7 for initial (after adaptation period) and final live mass.

Table 2 Least square means of average daily gain, alimentary canal contents and mass, dressing percentage and carcass gain of group-fed steers[de]

Concentrate : roughage ratio	Item	Feeding level AL	Feeding level 90 AL	Feeding level 80 AL				Row mean
80 : 20	Daily gain[7] (kg / d)	1.48^{ax}	1.35^{ay}	1.00^{az}				1.28^{a}
	Alimentary canal							
	contents (kg)	35.1^{a}	39.4^{a}	35.9^{a}				36.8^{a}
	mass (kg)	22.9^{ax}	17.7^{y}	19.1^{y}				19.9^{a}
	Dressing %	54.6^{a}	55.6^{a}	54.9^{a}				55.0^{a}
	Carcass gain (g / d)	792^{ax}	723^{ay}	530^{az}				682^{a}
55 : 45	Daily gain[7] (kg / d)	1.17^{bx}	1.13^{bx}	0.97^{ay}				1.09^{b}
	Alimentary canal							
	contents (kg)	42.7^{b}	45.9^{b}	43.4^{b}				44.0^{b}
	mass (kg)	18.6^{b}	19.1	18.6				18.8^{b}
	Dressing %	52.8^{bxy}	52.6^{bx}	53.6^{by}				53.0^{b}
	Carcass gain (g / d)	579^{bx}	535^{by}	489^{bz}				534^{b}
30 : 70	Daily gain[7] (kg / d)	0.92^{cx}	0.67^{cy}	0.60^{by}				0.73^{c}
	Alimentary canal							
	contents (kg)	56.0^{c}	60.1^{c}	57.6^{c}				57.9^{c}
	mass (kg)	17.6^{b}	17.9	18.3				17.9^{b}
	Dressing %	52.0^{c}	51.5^{b}	51.2^{c}				51.6^{c}
	Carcass gain (g / d)	448^{cx}	329^{cy}	285^{cz}				354^{c}
Column mean	Daily gain[7] (kg / d)	1.19^{x}	1.05^{y}	0.86^{z}	[4]**L&Q	[5]**L	[6]**	
	Alimentary canal							
	contents (kg)	44.6^{x}	48.5^{y}	45.6^{xy}	[4]*L&Q	[5]*Q	[6]NS	
	mass (kg)	19.7^{x}	18.3^{y}	18.7^{y}	[4]**L	[5]**L&Q	[6]**	
	Dressing %	53.1	53.2	53.3	[4]**L	[5]NS	[6]NS	
	Carcass gain (g / d)	606^{x}	529^{y}	435^{z}	[4]**L	[5]**L	[6]**	

^{x,y,z} Means in the same row (main effect) with different alphabetic superscripts differ significantly ($P \leqslant 0.05$).

^{a,b,c} Means in the same column (main effect) with different alphabetic superscripts differ significantly ($P \leqslant 0.05$).

^{d} Final cold carcass mass (202 kg) as covariate ($P \leqslant 0.01$; linear).

^{e} Respective error standard deviations of the mean were 0.14, 2.58, 1.80, 1.08 and 1.45 for gain, alimentary canal contents and mass, dressing percentage and carcass gain.

[4] Diet effect

[5] Feeding level effect.

[6] Diet × feeding level interaction.

[7] Based on second-order polynomial regressions.

L = linear; Q = quadratic, NS = not significant ($P > 0.05$).

* $P \leqslant 0.05$; ** $P \leqslant 0.01$.

level. Restricting intake usually reduces mass gain to a smaller degree than feed intake (Andersen, 1978; Plegge, 1987; Hicks *et al.*, 1987; 1990). Such results were observed for the sub-AL treatments on the 55:45 diet and 90AL on the 80:20 diet. However, for the 80AL treatment on the 80:20 diet and both sub-AL treatments on the 30:70 diet, carcass gain tended to be reduced by a higher percentage than feed intake was.

Dressing percentage

A decrease in C:R ratio reduced ($P \leqslant 0.01$) dressing percentage (55.0 to 51.6; Table 2) linearly. This may primarily be attributed to the influence of the roughage level on the mass of alimentary canal contents (Berg & Butterfield, 1976; McCarthy *et al.*, 1985) which increased (36.8 to 57.9 kg) ($P \leqslant 0.05$) as C:R ratio decreased. This decrease in dressing percentage occurred in spite of the corresponding linear ($P \leqslant 0.01$) decrease in wet mass of the alimentary canal (19.9 to 17.9 kg). Differences in the carcass fat percentage (Slabbert *et al.*, 1992b) at the same slaughter mass could also contribute to the observed differences in dressing percentage (Berg & Butterfield, 1976). Dressing percentage usually decreases as feed intake is decreased (Andersen, 1978) but, in our study, no effect of feed intake level on dressing percentage ($P > 0.05$) was observed. In addition, no significant ($P = 0.07$) C:R ratio × feeding level interaction occurred. Non-significance of the main effect of feeding level on dressing percentage probably is due to a significant interaction, C:R by feeding level, which occurred for both alimentary canal mass (Table 2) and carcass fat percentage (Slabbert *et al.*, 1992b). The decrease in alimentary canal mass with a corresponding decrease in the C:R ratio contrasts with the results of Bailey (1986) who concluded that the C:R ratio of the diet has no effect on alimentary tract mass. However, the decrease in alimentary canal mass with a reduction in feeding level agrees with results of Koong *et al.* (1985) and Burrin *et al.* (1989). Results of Koong *et al.* (1985) indicate that the decrease in the mass of metabolically active organs with a decrease in feed intake, and the associated decrease in gain, depends primarily on the level of energy intake, not on diet composition *per se.* This also may explain why Bailey (1986) observed no difference in alimentary canal mass between roughage and concentrate diets at approximately the same DE intake.

Carcass conformation characteristics

Although conformation is responsible for approximately only 11% of estimated meat yield, it still forms part of the grading system in South Africa; it helps exclude extremely poor conformation types from the higher grades (Klingbiel, 1984; Government Notice, 1985). Both carcass compactness (conformation ratio) and buttock compactness (kg/cm; Table 3) decreased ($P \leq 0.01$) linearly with a decrease in either the C:R ratio (1.76 to 1.68 and 0.71 to 0.70, respectively) or feeding level (1.73 to 1.71 and 0.72 to 0.70, respectively). This decrease in 'blocky' appearance associated with a reduced gain (Table 2) and ME intake (Table 1), is primarily due to the lack of fat accumulation in the carcass (Klingbiel, 1984; Bruwer *et al.*, 1987) as indicated by the trend in subcutaneous fat measurements (Table 4). The influence of main effects on conformation disappeared when percentage carcass fat (Slabbert *et al.*, 1992b) was used as covariate, which confirms the influence of carcass fatness on conformation. For the visual allocated conformation score a significant diet × feed intake level interaction was detected. Conformation score decreased (linear, non-linear; $P \leq 0.05$) when the

Table 3 Least square means of visual and physical conformation characteristics of group-fed steers adjusted to an equal carcass mass[de]

Concentrate : roughage ratio	Item	Feeding level AL	Feeding level 90 AL	Feeding level 80 AL				Row mean
80:20	Conformation score[9] (1—15)	10.5^{ax}	9.45^{ay}	11.4^{az}				10.5^{a}
	Hind/fore quarter mass ratio (kg/kg)	1.07	1.06	1.05				1.06
	Carcass compactness[7] (kg/cm)	1.76^{a}	1.76^{a}	1.75^{a}				1.76^{a}
	Buttock compactness[8] (kg/cm)	0.73^{ax}	0.71^{y}	0.70^{y}				0.71^{a}
55:45	Conformation score[9] (1—15)	8.96^{bx}	8.26^{bx}	10.0^{by}				9.09^{b}
	Hind/fore quarter mass ratio (kg/kg)	1.06	1.07	1.05				1.06
	Carcass compactness[7] (kg/cm)	1.75^{ax}	1.71^{by}	1.72^{axy}				1.73^{b}
	Buttock compactness[8] (kg/cm)	0.73^{ax}	0.70^{y}	0.70^{y}				0.71^{a}
30:70	Conformation score[9] (1—15)	8.41^{b}	9.14^{a}	8.57^{a}				8.71^{b}
	Hind/fore quarter mass ratio (kg/kg)	1.05	1.06	1.05				1.05
	Carcass compactness[7] (kg/cm)	1.70^{cx}	1.68^{bxy}	1.66^{by}				1.68^{c}
	Buttock compactness[8] (kg/cm)	0.71^{bx}	0.70^{xy}	0.69^{y}				0.70^{b}
Column mean	Conformation score[9] (1—15)	9.30^{x}	8.95^{x}	10.0^{y}	[4]*L&Q	[5]*L&Q	[6]**	
	Hind/fore quarter mass ratio (kg/kg)	1.06	1.06	1.05	[4]NS	[5]NS	[6]NS	
	Carcass compactness[7] (kg/cm)	1.73^{x}	1.72^{y}	1.71^{y}	[4]**L	[5]**L	[6]NS	
	Buttock compactness[8] (kg/cm)	0.72^{x}	0.70^{y}	0.70^{y}	[4]**L	[5]**L	[6]NS	

[x, y, z] Means in the same row (main effect) with different alphabetic superscripts differ significantly ($P \leq 0.05$).

[a, b, c] Means in the same column (main effect) with different alphabetic superscripts differ significantly ($P \leq 0.05$).

[d] Final cold carcass mass (202 kg) as covariate ($P \leq 0.01$; linear).

[e] Respective error standard deviations of the mean were 0.86, 0.04, 0.03 and 0.02 for conformation score, hind/fore-quarter mass ratio, carcass- and buttock compactness.

[4] Diet effect

[5] Feeding level effect.

[6] Diet × feeding level interaction.

[7] Carcass mass / carcass length = conformation ratio. Presently used as guideline for conformation in the grading regulations.

[8] Hind quarter mass / buttock length.

[9] Carcasses were scored in 1/3 units within five different conformation classes: 1-emaciated = 2; 2-flat = 5; 3-medium = 8; 4-round = 11; 5-very round = 14.

L = linear; Q = quadratic, NS = not significant ($P > 0.05$).

* $P \leq 0.05$; ** $P \leq 0.01$.

Table 4 Least square means of visual and physical carcass fatness characteristics and grade code of group-fed steers adjusted to an equal carcass mass[de]

Concentrate : roughage ratio	Item	Feeding level AL	Feeding level 90 AL	Feeding level 80 AL		Row mean	
80:20	2.5 cm fat thickness (mm)	6.39^{a}	5.39	4.88		5.56^{ab}	
	5 cm fat thickness[7] (mm)	4.46^{ab}	3.52	4.25		4.08^{ab}	
	F3-fat thickness (mm)	3.18	3.52	3.20		3.30	
	Fatness score[8] (1—18)	9.65^{ax}	7.46^{ay}	7.76^{ay}		8.29^{a}	
	Grade score[9] (1—4)	3.13^{ax}	2.65^{ay}	2.83^{ay}		2.87^{a}	
55:45	2.5 cm fat thickness (mm)	9.22^{bx}	5.03^{y}	4.10^{y}		6.12^{a}	
	5 cm fat thickness[7] (mm)	5.67^{ax}	5.14^{x}	3.27^{y}		4.69^{a}	
	F3-fat thickness (mm)	4.69^{x}	2.90^{y}	2.58^{y}		3.39	
	Fatness score[8] (1—18)	7.51^{b}	6.96^{a}	7.02^{a}		7.16^{b}	
	Grade score[9] (1—4)	2.81^{b}	2.60^{a}	2.59^{a}		2.67^{b}	
30:70	2.5 cm fat thickness (mm)	4.97^{a}	5.71	4.33		5.00^{b}	
	5 cm fat thickness[7] (mm)	2.94^{b}	3.32	3.27		3.18^{b}	
	F3-fat thickness (mm)	3.88	3.62	2.88		3.46	
	Fatness score[8] (1—18)	4.85^{c}	5.16^{b}	5.04^{b}		5.00^{c}	
	Grade score[9] (1—4)	1.98^{c}	2.04^{b}	2.04^{b}		2.02^{c}	
Column mean	2.5 cm fat thickness (mm)	6.861^{x}	5.38^{y}	4.44^{y}	[4]NS	[5]**L	[6]*
	5 cm fat thickness[7] (mm)	4.36	3.99	3.60	[4]*L&Q	[5]NS	[6]NS
	F3-fat thickness (mm)	3.92^{x}	3.35^{xx}	2.89^{y}	[4]NS	[5]*L	[6]NS
	Fatness score[8] (1—18)	7.33^{x}	6.51^{y}	6.61^{y}	[4]*L&Q	[5]*L	[6]*
	Grade score[9] (1—4)	2.64^{x}	2.43^{y}	2.49^{xy}	[4]*L&Q	[5]NS	[6]NS

[x,y,z] Means in the same row (main effect) with different alphabetic superscripts differ significantly ($P \leq 0.05$).

[a,b,c] Means in the same column (main effect) with different alphabetic superscripts differ significantly ($P \leq 0.05$).

[d] Final cold carcass mass (202 kg) as covariate ($P \leq 0.01$; linear).

[e] Respective error standard deviations of the mean were 1.45, 1.43, 1.46, 1.11 and 0.62 for the 2.5 cm, 5 cm and F3-fat thickness measurements, fatness score and grade score respectively.

[4] Diet effect

[5] Feeding level effect.

[6] Diet × feeding level interaction.

[7] Presently used as guideline for fatness in the grading regulations.

[8] Carcasses were scored in 1/3 units within six different fatness classes: 1-very lean = 2; 2-lean = 5; 3-medium = 8; 4-fat = 11; 5-slightly overfat = 14; 6-excessively overfat = 17.

[9] Scores allocated to grades: grade 3 = 1; grade 1 = 2; super = 3; grade 2 = 4.

L = linear; Q = quadratic, NS = not significant ($P > 0.05$).

* $P \leq 0.05$; ** $P \leq 0.01$.

C:R ratio was decreased, but in contrast with carcass or buttock compactness, it increased (linear, non-linear; $P < 0.05$) when the feeding level decreased. Although visual and physical conformation characteristics were influenced by the main effects, changes were relatively small and the mean conformation score of carcasses on all treatments were within the limits (conformation classes 3 to 5) of the Super A grade. An increase in the feeding period (Table 1) due to a decrease in either the C:R ratio or feeding level, had no significant influence ($P > 0.05$) on the hind to fore quarter mass ratio (Table 3).

Carcass fatness characteristics

The various subcutaneous fat thickness measurements (see Table 4) were divergently influenced by a change in the C:R ratio and or feeding level as indicated by differences in significance within main effects and interactions. For instance, a decrease in the C:R ratio reduced ($P \leq 0.05$) the 5.0 cm fat measurement (linear; non-linear), while the 2.5 cm and F3 fat measurements were not significantly ($P > 0.05$) influenced. However, the latter two fat measurements were linearly reduced ($P \leq 0.05$) with a decrease in feeding level, while the 5.0 cm fat measurement was not altered ($P > 0.05$). Studies of Martin *et al.* (1978) and Anderson *et al.* (1988) indicate that a higher protein level, and thus a higher protein:ME ratio, may increase fat thickness. It is not known to what extent the higher protein:ME ratio of the 30:70 diet relative to that of the 80:20 diet (14.1 vs. 11.3; Slabbert *et al.*, 1992a) contributed to the non-significant dietary effect, which occurred with the 2.5 cm and F3 fat measurements. In general, a decrease in either C:R ratio or feeding level decreased fat thickness at a constant carcass mass. This indicates that carcass composition and thus the optimum carcass mass may be manipulated through the nutritional regime applied. This decrease in carcass fat thickness measurements with an increase in the roughage inclusion level, matches the results of Danner *et al.* (1980), Woody *et al.* (1983), McCarthy *et al.* (1985) and Merchen *et al.* (1987). Sub-AL feeding levels apparently also reduce fat measurements, but results seldom are significant (Hicks *et al.*, 1990).

A significant ($P < 0.05$) C:R × feed intake level interaction for fatness score was detected (Table 4). Fatness score allocated during the visual assessment of the carcass subcutaneous fat yield is in general agreement with trends observed for fat measurements. Mean grade scores (Table 4) are also in general agreement with the trends observed for fat measurements and fatness score, although only the effect of dietary energy concentration ($P \leqslant 0.05$) was significant. An evaluation of the percentage distribution of carcass grades within C:R ratios and feeding levels (Table 5) indicates that carcass fatness decreased (higher proportion leaner A1 and A3 grades) when the C:R ratio and feeding level decreased. Hicks *et al.* (1990) found that a restricted feeding level significantly reduced the number of carcasses in the highest grade due to a reduction in fat deposition.

Table 5 Percentage distribution of carcass grades

Concentrate: roughage ratio	Grade[1]	Feeding level AL	90AL	80AL
80:20	A3	–	–	–
	A1	–	33	8
	Super A	83	67	92
	A2	17	–	–
55:45	A3	–	–	–
	A1	17	42	42
	Super A	83	58	58
	A2	–	–	–
30:70	A3	8	17	8
	A1	92	58	75
	Super A	–	25	17
	A2	–	–	–

[1] A3 – very lean (fatness class 1); A1 – lean (fatness class 2); Super A – medium fat (fatness classes 3 & 4); A2 – slightly to excessively overfat (fatness classes 5 & 6).

In conclusion, a reduction in the level of energy intake, by either decreasing the C:R ratio or feed intake, decreased carcass gain and significantly influenced most of the visual and physical carcass measurements of steers slaughtered at a predetermined optimum target mass. General trends indicate that subcutaneous fat deposition of steers adjusted to the same carcass mass were reduced as energy intake decreased, suggesting that carcass fatness and carcass mass can be manipulated by energy restriction. Nutritional strategies thus may be important to optimize the marketing of cattle within the fatness constraints of the South African beef carcass classification and grading system. The application of restricted feeding under feedlot conditions has potential for the growing and finishing of steers and needs further evaluation.

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