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The influence of dietary energy concentration and feed intake level on feedlot steers
3. Carcass composition and tissue growth as influenced by rate of gain

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The effect of diets with three divergent concentrate to roughage (C : R) ratios (80:20, 55:45 and 30:70), fed at three feed intake levels (*ad libitum*, 90% *ad libitum* and 80% *ad libitum*), on carcass composition and tissue gain of implanted medium frame weaner steers was studied. Steers (initially 200 kg) were slaughtered at the same mean group live target mass of 380 kg. Each treatment consisted of 12 group-fed steers. Percentage carcass fat, based on the prime rib cut, for the three intake levels adjusted to the same carcass mass were respectively 21.7, 17.6 and 17.8% for the 80:20 diet, 20.1, 19.5 and 17.7% for the 55:45 diet and 14.5, 16.5 and 13.3% for the 30:70 diet. Carcass fat was reduced ($P \leq 0.01$) by both a decrease in the C:R ratio and feed intake level. Corresponding carcass muscle percentages were 61.4, 64.9 and 63.6; 62.8, 62.9 and 63.5; 66.2, 65.1 and 66.3%. Carcass muscle was increased ($P \leq 0.05$) by both a decrease in C:R ratio and feed intake level. Muscle gain (g/d) increased, but at a declining rate when carcass gain increased, while fat gain (g/d) increased at an accelerating rate. Fat gain of steers on the 80:20 diet when fed at 90% *ad libitum* was lower ($P \leq 0.05$) than when fed *ad libitum*, while protein gain was significantly higher ($P \leq 0.05$) and muscle gain ($P = 0.07$) tended to be higher. Maximum lean deposition, therefore, did not occur at maximum carcass gain and maximum energy intake. Efficiency with which metabolizable energy was utilized for carcass gain (MJ ME/g) improved with an increase in the C:R ratio. Steers fed sub-*ad libitum* feeding levels on the 80:20 and 55:45 diets tended not to differ from *ad libitum*-fed steers, while those fed the 30:70 diet was less efficient than *ad libitum*-fed steers. Diet and feed restriction influenced carcass composition primarily through the influence energy intake has on the rate of fat deposition.

Die invloed van drie kragvoer-tot-ruvoer(K:R)-verhoudings (80:20, 55:45 en 30:70) teen drie voedingspeile (*ad libitum*, 90% *ad libitum* en 80% *ad libitum*), op karkassamestelling en weefselgroei van geïmplanteerde mediumraam-speenkalfosse is ondersoek. Osse (aanvangsmassa ongeveer 200 kg) is by 'n groepgemiddelde teiken lewende massa van ongeveer 380 kg geslag. Twaalf groepgevoerde osse per behandeling is gebruik. Persentasie karkasvet, gebaseer op die primaribsnit, vir die drie voedingspeile was onderskeidelik 21.7, 17.6 en 17.8% vir die 80:20-dieet, 20.1, 19.5 en 17.7% vir die 55:45-dieet en 14.5, 16.5 en 13.3% vir die 30:70-dieet. Persentasie karkasvet het verlaag ($P \leq 0.01$) met 'n afname in die K:R-verhouding sowel as voedingspeil. Persentasie karkasspier was onderskeidelik 61.4, 64.9 en 63.6; 62.8, 62.9 en 63.5, 66.2, 65.1 en 66.3% en is verhoog ($P \leq 0.05$) deur beide 'n afnemende K:R-verhouding en voedingspeil. Spiertoename (g/d) het verhoog teen 'n afnemende tempo met toename in karkasmassa (KGDT), terwyl vettoename (g/d) toegeneem het teen 'n toenemende tempo. Vettoename van osse op die 80:20-dieet teen 90% van *ad libitum* was laer ($P \leq 0.05$) as by osse op die *ad libitum*-voedingspeil, terwyl proteïentoename hoër ($P \leq 0.05$) was en spiertoename hoër ($P = 0.07$) geneig het. Maksimum maerweefselneerlegging het nie by maksimum karkastoename en dus maksimum energie-inname voorgekom nie. Doeltreffendheid van metaboliseerbare energie-inname vir karkastoename (MJ ME/g) het verbeter met 'n toename in die K:R-verhouding. Doeltreffendheid van osse op die sub-*ad libitum*-voedingspeile van die 80:20- en 55:45-diëte het geneig om nie van dié van die osse op die *ad libitum*-voedingspeil te verskil nie, terwyl osse op die 30:70-dieet swakker was op die *ad libitum*-voedingspeil. Dieetsamestelling en voerbeperking het karkassamestelling primêr beïnvloed deur die invloed wat energie-inname op die tempo van vetneerlegging uitoefen.

Keywords: Carcass composition, dietary energy concentration, feeding level, steers, tissue gain.

Introduction

The consumer's changing demand for leaner beef focuses the attention on factors which influence growth and carcass composition (Slabbert, 1990). Mature size and genetic potential determine the pattern of daily protein (or muscle/lean) accretion; however, other factors, such as energy intake, stage of growth, sex and the use of anabolic agents, determine the rate of protein growth (Byers, 1982). Although a vast amount of research has been conducted to ascertain the role of energy intake on composition of growth and on body or carcass composition at a terminal mass, considerable uncertainty remains about the effect of energy intake on the composition of growth (Byers, 1982; Meissner, 1983b).

Results of several studies (Reid *et al.*, 1968; Old & Garrett, 1987) suggest that body or carcass composition is rigidly related to mass and cannot be altered by nutrition. In contrast,

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Byers (1982), Meissner (1983a) and Lemieux *et al.* (1988) indicated that nutrition can influence the composition of growth, primarily through accelerating growth rate so that the fraction of fat in growth increases as rate of growth increases.

Factors that have confused our understanding of responses in the composition of growth and hence the carcass, include associative effects of feeds and also effects of high feed intake levels. Both factors decrease the supply of utilizable energy from mixed diets so that the amount of energy available is less than assumed (Byers, 1982). Suggestions of effects of grains vs. forages on fat deposition (Smith *et al.*, 1984) and of specific carbon sources on lipogenesis (Prior & Scott, 1980) have also been reported. Furthermore, some disagreement may have been caused by difficulties in interpreting growth data from different experiments due to interactions between feed intake level and slaughter mass, feed intake level and breed or sex interactions, different methods used in determining body or carcass composition (Andersen, 1978; Meissner & Roux, 1983) and interactions between protein-energy intake and the physiological limit of protein accretion (Fox & Black, 1984).

For most breeds in South Africa, the optimum slaughter mass on a typical feedlot diet for non-implanted early, medium and late maturing genotypes (Naudé *et al.*, 1986) has been determined. Little information is available, however, on the extent to which carcass composition of steers may be nutritionally manipulated within the constraints of the South African beef carcass classification and grading system when slaughtered at a predetermined target mass (Slabbert, 1990).

This study was conducted to assess the effects of energy intake, by means of three different concentrate to roughage ratios fed at three feed intake levels, on growth rate, carcass composition and tissue gain of medium frame weaner steers.

Materials and Methods

Diets, carcasses and experimental methods were described by Slabbert *et al.* (1992a; 1992b). In South Africa, the prime rib cut (8, 9 and 10th rib) is a very practical joint from the fore quarter to estimate the carcass composition (percentage muscle, fat and bone) with a high degree of accuracy based on regression equations developed by Naudé (1972). These equations are similar to those developed by Hankins & Howe (1946), but their 9 to 11th rib cut is not comparable with our commercial cut-up techniques. Because rate of fat deposition tends to differ with anatomic site according to work of Belk *et al.* (1991), rib fat deposition may not be proportional to total carcass fat deposition. Nevertheless, prime rib cut composition remains a cheap and accurate method to determine relative differences in carcass composition.

Prime rib cuts (8, 9 and 10th rib) removed from the right side of each carcass from the initial slaughter group and for the different treatments, were weighed, dissected into subcutaneous fat, lean (lean = proportion of meat including intermuscular fat, but with subcutaneous fat removed) and bone. The masses of the three dissected components for each prime rib cut were recorded. Concurrently prime rib cuts also were removed from the left side to determine their dissected bone mass. The deboned components (subcutaneous fat and lean) of each cut were ground and subsampled for chemical analysis in order to determine the percentage protein, ash, fat and moisture (AOAC, 1970). Chemical fat was regarded as prime rib cut fat, while the total mass of protein, moisture and ash was considered to be prime rib cut muscle. Total fat, muscle and bone of the prime rib cuts were corrected for differences in the bone mass between the left and right vertebrae. Percentage carcass muscle, fat and bone were estimated from prime rib cut muscle, fat and bone percentages using the equations of Naudé (1972).

Accretion rates (g/d) of fat, muscle and protein (assuming that prime rib cut protein percentage was equal to carcass protein percentage), were calculated by difference, using final carcass composition and the composition of the initial slaughter group. The relationships between the composition of the prime rib cut of the initial slaughter group and their carcass masses were not significant ($R^2 < 0.50$). Initial carcass composition was calculated by multiplying initial carcass mass with the mean percentages of the different prime rib cut tissues or chemical composition of the initial slaughter group. The calculated percentage prime rib cut muscle, fat, bone and protein of the initial slaughter group was 75.2, 8.3, 16.6 and 16.2% respectively.

Statistical analyses

The data were subjected to analyses of variance according to the mixed model least squares and maximum likelihood computer program of Harvey (1988). Included in this model were dietary energy concentration, feed intake level and dietary energy concentration × feeding level interaction. The individual steer was used as experimental unit for all analyses except for efficiency of metabolizable energy utilization (MJ ME intake/g carcass gain), for which only treatment means were available. Using cold carcass mass as a covariate ($P \leq 0.05$), all variables were linearly adjusted to the same carcass mass, unless indicated otherwise.

Terminal carcass fat percentage ($P \leq 0.01$) and initial mass (before dietary adaptation) ($P \leq 0.01$), were simultaneously used as covariates to linearly adjust carcass mass to an equal carcass fatness. The obtained polynomial prediction equation (Harvey, 1988) was plotted (Figure 2). Relationships to relate the rate of carcass muscle, fat and protein gain to that of daily carcass gain were assessed through regression analyses using Statgraphics (1986), ignoring main effects.

Results and Discussion

The data in Table 1 illustrate the extent to which estimated terminal carcass composition of medium frame weaner steers, adjusted to a constant carcass mass, was influenced by dietary treatments. A significant C:R ratio × feed intake level interaction for percentage carcass fat and muscle was detected. A decrease in the C:R ratio (80:20 to 30:70) reduced ($P \leq 0.01$; linear, quadratic) percentage carcass fat from 19.1 to 14.8%. These findings agree with those of Bond *et al.* (1972), Byers (1982), Meissner *et al.* (1982), McCarthy *et al.* (1985) and Tatum *et al.* (1988), but are in contrast with the findings of Jesse *et al.* (1976), and Old & Garrett (1987). A decrease in C:R ratio also reduced percentage subcutaneous fat in the prime rib cut linearly ($P \leq 0.01$).

A decrease in feeding level (*ad libitum* to 80% *ad libitum*), linearly reduced ($P \leq 0.01$) carcass fat content from 18.8 to 16.3%. This is in agreement with results of Byers (1980) and Byers & Rompala (1980). However, percentage subcutaneous fat only tended ($P = 0.19$) to decrease when feed intake level was decreased. This can be explained by the large standard deviation as well as the smaller range in energy intake relative to that realized by the C:R ratio. A highly significant ($P \leq 0.01$) C:R ratio × feeding level interaction occurred for

Table 1 Least square means for percentage subcutaneous fat (SC) of the prime rib cut and the estimated carcass composition of steers group-fed various dietary treatments[d,e,f]

Concentrate : roughage ratio	Item	Feeding level†					Row mean
		AL	90 AL	80 AL			
80:20	SC fat (%)	7.58^{ax}	5.52^{y}	6.44^{axy}			6.51^{a}
	Fat (%)	21.7^{ax}	17.6^{ay}	17.8^{ay}			19.1^{a}
	Muscle (%)	61.4^{ax}	64.9^{ay}	63.6^{ay}			63.3^{a}
	Bone (%)	16.8^{ax}	17.1^{x}	18.3^{ay}			17.4^{a}
	Muscle : bone ratio	3.67^{xy}	3.80^{x}	3.49^{y}			3.66
55:45	SC fat (%)	6.18^{a}	6.24	5.80^{ab}			6.07^{a}
	Fat (%)	20.1^{bx}	19.5^{bx}	17.7^{ay}			19.1^{a}
	Muscle (%)	62.8^{a}	62.9^{b}	63.5^{a}			63.1^{a}
	Bone (%)	16.9^{ax}	17.3^{xy}	18.4^{ay}			17.5^{a}
	Muscle : bone ratio	3.76^{x}	3.67^{xy}	3.47^{y}			3.63
30:70	SC fat (%)	4.56^{b}	5.57	4.19^{b}			4.77^{b}
	Fat (%)	14.5^{cx}	16.5^{ay}	13.3^{bx}			14.8^{b}
	Muscle (%)	66.2^{b}	65.1^{a}	66.3^{b}			65.8^{b}
	Bone (%)	18.7^{bxy}	18.0^{x}	19.7^{by}			18.8^{b}
	Muscle : bone ratio	3.57	3.65	3.42			3.54
Column mean	SC fat (%)	6.10	5.78	5.48	$^{4}**\mathrm{L}$	$^{5}\mathrm{NS}$	$^{6}\mathrm{NS}$
	Fat (%)	18.8^{x}	17.9^{y}	16.3^{z}	$^{4}**\mathrm{L\&Q}$	$^{5}**\mathrm{L}$	$^{6}**$
	Muscle (%)	63.5^{x}	64.3^{xy}	64.4^{y}	$^{4}**\mathrm{L\&Q}$	$^{5}*\mathrm{L}$	$^{6}**$
	Bone (%)	17.5^{x}	17.5^{x}	18.8^{y}	$^{4}**\mathrm{L\&Q}$	$^{5}**\mathrm{L\&Q}$	$^{6}\mathrm{NS}$
	Muscle : bone ratio	3.67^{x}	3.71^{x}	3.46^{y}	$^{4}\mathrm{NS}$	$^{5}*\mathrm{L\&Q}$	$^{6}\mathrm{NS}$

† AL = *ad libitum*; 90AL = 90% of *ad libitum*; 80AL = 80% of *ad libitum*.

$^{x, y, z}$ Means in a row within diets with different alphabetic superscripts differ significantly 1 # 2 # 3 ($P \leqslant 0.05$).

$^{a, b, c}$ Means in a column within an intake level with different alphabetic superscripts differ significantly a # b # c ($P \leqslant 0.05$).

[d] Cold carcass mass (203 kg) as covariate ($P \leqslant 0.05$; linear), except for muscle % ($P \geqslant 0.10$).

[e] Respective error standard deviations of the mean were 1.42, 1.34, 1.42, 1.13 and 0.36 for SC fat, carcass fat, muscle and bone percentage, and muscle : bone ratio.

[f] Based on prime rib cut (Naudé, 1972).

[4] Diet effect.

[5] Feeding level effect.

[6] Diet × feeding level interaction.

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

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

percentage carcass fat, probably due to the differential effect of difference in ME intake on the composition of growth (Andersen, 1978; Byers, 1982). It is unknown, however, to what extent the different protein to ME ratios of the various C : R diets contributed to this interaction.

The effect of divergent dietary treatments on percentage carcass muscle (Table 1) was less pronounced than for carcass fat percentage. Nevertheless, a decrease in C:R ratio increased ($P \leqslant 0.01$; linear, quadratic) percentage carcass muscle from 63.3 to 65.8%. Bond *et al.* (1972) and Meissner *et al.* (1982) obtained similar results. A decrease in feeding level significantly ($P \leqslant 0.05$) increased the percentage carcass muscle linearly from 63.5 to 64.4%. Within the 80:20 diet, the mean muscle percentage of steers fed at 90% and 80% of *ad libitum* was 5.0% higher ($P \leqslant 0.05$) than for those fed at *ad libitum*.

Carcass bone percentage (Table 1) also was influenced by the nutritional treatments. A decrease in the C:R ratio and feeding level increased ($P \leqslant 0.01$; linear, quadratic) the percentage carcass bone. No C:R ratio × feeding level interaction ($P > 0.05$) was detected. A decrease in the C:R ratio had no significant effect ($P = 0.19$) on the carcass muscle to bone ratio. However, the carcass muscle to bone ratio was reduced ($P \leqslant 0.05$; linear, quadratic) by a decrease in feed intake. According to Berg & Butterfield (1976) different positive growth rates will not influence the muscle to bone ratio. However, results of Guenther *et al.* (1965), Murray *et al.* (1974) and Tatum *et al.* (1988) indicate that at a lower growth rate, muscle to bone ratio is lower. This is mainly due to a greater decrease in muscle gain than in bone growth with a decrease in energy intake.

Results in Table 1 and the discussion on carcass composition, indicated that varied feed intake within the same diet, will influence carcass composition in a similar way as dietary energy concentration does. This indicates that the effects of level of nutrition on carcass composition are more related to energy intake *per se* than to the specific feed ingredients included in the diet (Byers, 1982). However, additional effects of grains vs. forages on fat deposition (Smith *et al.*, 1984) and of specific carbon sources on lipogenesis (Prior & Scott, 1980) have been suggested. In the studies of Smith *et al.* (1984) and Lemieux *et al.* (1988), steers fed a high grain diet tended to have a higher fat gain at the same empty body gain than steers fed a forage diet, probably due to differences in substrate absorption. Studies of Martin *et al.* (1978) and Anderson *et al.* (1988) also indicate that a higher protein level in the diet, and thus a higher protein to ME ratio, may result in thicker subcutaneous fat. From Table 1 and substantiated by Reid *et al.* (1968), Byers (1980), Meissner (1983a), Old & Garrett (1987) and McCarthy *et al.* (1985), carcass composition is not always affected by the feeding level or the C:R ratio. One possible reason for this controversy is the correlation between rate and composition of growth (Byers, 1982; Rompala *et al.*, 1985).

The data in Table 2 illustrate the extent to which estimated tissue and protein gain, adjusted to a constant carcass mass, were influenced by dietary treatments. For fat, muscle and protein gain a significant C:R ratio × feeding level interaction was detected. Fat gain was reduced to a greater extent by a decrease in either the C:R ratio or feeding level than muscle or protein gain. This effect of the C:R ratio or feeding level on the proportional composition of tissue gain is in agreement with the findings of Béranger (1978), Byers (1980), Byers & Rompala (1980) and Rompala *et al.* (1985).

Rates of protein, muscle and fat gain were allometrically related to rate of carcass gain. The relationship between muscle gain and fat gain is shown in Figure 1. The allometric exponent (b) for protein (0.963) and muscle (0.914) gain is less than 1, but it is more than 1 for fat gain (1.425). This indicates that protein and muscle increased at a decreasing rate, while rate of fat gain increased at an accelerated rate as carcass gain increased. However, the exponent differs significantly ($P \leq 0.05$) from 1, only for muscle and fat gain. From Figure 1 it is also clear that muscle gain did not reach a plateau as Byers (1982), Campbell (1988) and Lemieux *et al.* (1988) have suggested for protein gain. In this study, an increased variability in composition of growth was observed when carcass gain exceeded 700 g/d. However, curvilinearity in previous studies have been drawn from very few points.

In this study, significantly ($P \leq 0.05$) more fat was deposited on the 80:20 diet at *ad libitum* intake than on 90% of *ad libitum* (44.6 vs. 35.7 kg), while muscle (124 vs. 132 kg) and protein mass (25.5 vs. 29.4 kg) were significantly less. This can be explained by results shown in Table 2 which indicate that the 80:20 diet, when fed *ad libitum*, resulted in a proportionally lower protein gain but a higher fat gain than at 90% of *ad libitum*. Maximum protein (87.2 g/d) and muscle gain (361.4 g/d) on the 80:20 diet at 90% of *ad libitum* (Table 2) occurred at a rate of carcass gain 8.7% lower than the maximum (723 vs. 792 g/d; Slabbert *et al.*, 1992b). This

Table 2 Least square means for rate of carcass tissue deposition in steers group-fed various dietary treatments[def]

Concentrate : roughage ratio	Item	Feeding level[†] AL	90 AL	80 AL	Row mean			
80:20	Fat gain (g/d)	330^{ax}	226^{ay}	157^{az}	238^{a}			
	Muscle gain (g/d)	330^{ax}	361^{ax}	264^{ay}	318^{a}			
	Protein gain (g/d)	59.8^{x}	87.2^{ay}	65.0^{ax}	70.6^{a}			
55:45	Fat gain (g/d)	202^{bx}	185^{bx}	140^{ay}	176^{b}			
	Muscle gain (g/d)	276^{b}	250^{b}	246^{a}	257^{b}			
	Protein gain (g/d)	61.5	59.4^{b}	52.7^{b}	57.9^{b}			
30:70	Fat gain (g/d)	102^{cx}	85^{cx}	57^{by}	81^{c}			
	Muscle gain (g/d)	244^{cx}	178^{cy}	159^{by}	194^{c}			
	Protein gain (g/d)	57.5^{x}	40.7^{cy}	31.7^{cz}	43.3^{c}			
Column mean	Fat gain (g/d)	212^{x}	165^{y}	118^{z}		^{4}**L&Q	^{5}**L	^{6}**
	Muscle gain (g/d)	283^{x}	263^{y}	223^{z}		^{4}**L	^{5}**L	^{6}**
	Protein gain (g/d)	59.6^{x}	62.4^{x}	49.8^{y}		^{4}**L	^{5}**L&Q	^{6}*

[†] AL = *ad libitum*; 90AL = 90% of *ad libitum*; 80AL = 80% of *ad libitum*.

[x, y, z] Means in a row within diets with different alphabetic superscripts differ significantly 1 # 2 # 3 ($P \leq 0.05$).

[a, b, c] Means in a column within an intake level with different alphabetic superscripts differ significantly a # b # c ($P \leq 0.05$).

[d] Cold carcass mass (203 kg) as covariate ($P \leq 0.01$; linear).

[e] Respective error standard deviations of the mean were 1.42, 1.34, 1.42, 1.13 and 0.36 for SC fat, carcass fat, muscle and bone percentage, and muscle : bone ratio.

[f] Based on prime rib cut (Naudé, 1972).

[4] Diet effect.

[5] Feeding level effect.

[6] Diet × feeding level interaction.

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

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

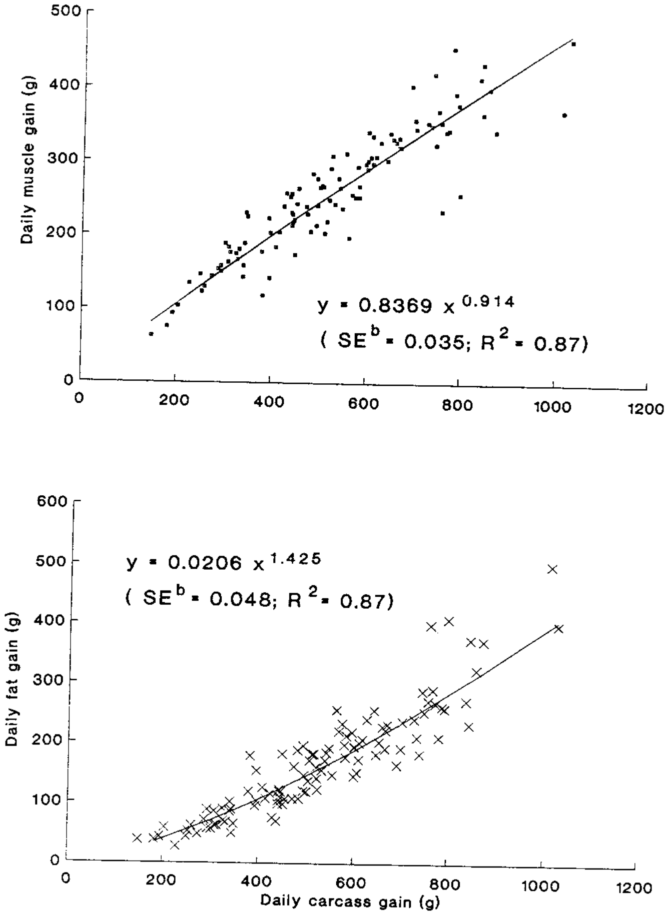

Figure 1 The relationship between tissue gain and carcass gain in medium frame weaner steers fed various dietary treatments.

suggested that when more energy is consumed than required for optimum protein accretion, the live mass-gain increment will decrease due to an increased fat deposition rate. On a wet tissue basis, more energy is needed for fat deposition than for muscle growth (Béranger, 1978). The net result is less protein, but more fat gain at a given mass when energy intake is maximized. Results of this study indicated that maximum lean (muscle) growth ($P = 0.07$) or protein accretion ($P \leqslant 0.05$) did not occur at maximum energy intake or rate of gain. These results support the findings of Anrique (1976) as quoted by the NRC (1985), who observed that protein accretion increases to a certain maximum, only to decrease during a subsequent increase in energy intake.

In contrast with the concept that protein accretion can reach a biological limit or plateau (Byers, 1982) at high levels of energy intake, the study of Mills *et al.* (1989) indicated that intake levels usually are too low to maximize lipogenesis in growing steers. The increase in fat gain with a simultaneous increase in carcass gain (Figure 1) supports this observation. Energy intake influences the composition of growth according to Byers (1982) and Lemieux *et al.* (1988), primarily through an acceleration of the growth rate above priorities for protein growth, so that the fraction of fat in growth increases with rate of growth. The higher the level of energy intake, and thus the growth rate, the greater the probability of obtaining a higher carcass fat percentage at a given mass. Fat is the most variable tissue in the carcass (Berg & Butterfield, 1976) and nutritional manipulation of carcass composition at lower growth rates can result in insignificant differences between treatments due to the small influence on fat deposition.

Carcass tissues (bone, muscle and fat) reach their maximum growth rate at different stages of maturity (Berg & Butterfield, 1976; Elsley, 1976). This, together with the concept that growth rate influences the composition of the carcass as discussed, create the opportunity to apply various nutritional (energy) strategies for growth manipulation. Figure 2 indicates the variation which may occur in estimated terminal carcass masses of medium frame weaner steers which managed to grow continuously at different rates to the same carcass fatness. The C:R ratio did not significantly ($P > 0.05$) influence this estimated carcass mass. However, an increase in carcass mass with a decrease in the C:R ratio at a constant percentage carcass fat as shown in Figure 2, seems realistic due to the significant decrease ($P \leqslant 0.01$) in percentage carcass fat, but an increase in percentage carcass muscle ($P \leqslant 0.05$) at a constant carcass mass (Table 1). Feeding level, however, significantly ($P \leqslant 0.05$) increased the final carcass mass linearly. No C:R ratio × feeding level interaction ($P = 0.14$) occurred. All periods of deferred, but positive growth, reduced fat deposition. An older animal has more time to deposit protein and accumulate more muscle (lean) tissue. The application of deferred feeding strategies to produce a Super A carcass may, however, be constrained by the age class in the grading system.

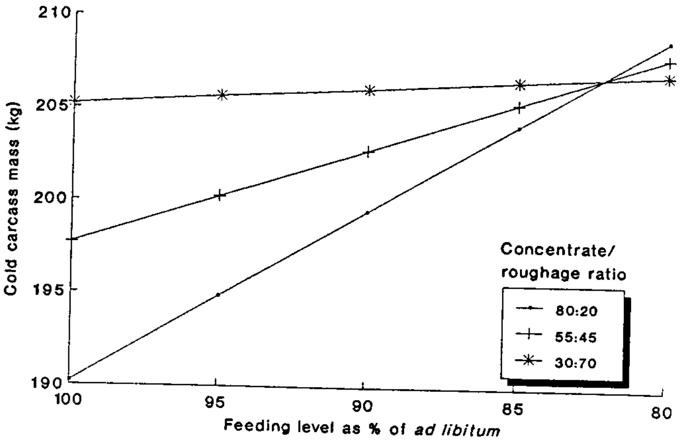

Figure 2 Estimated final carcass masses of medium frame weaner steers at a constant carcass fatness of 18%, when fed divergent dietary energy concentrations and feeding levels.

Group feeding did not allow analyses of variance to be done on the efficiency of ME utilization for carcass gain (MJ ME/g). Nevertheless, group means are shown in Figure 3 to illustrate trends. Efficiency improved with an increase in the C:R ratio on *ad libitum* feeding levels, probably due to an increase in energy intake and metabolizability (ARC, 1980). The efficiency response at sub-*ad libitum* feeding levels on the 55:45 and 80:20 diets varied from slightly better to slightly less than that found at *ad libitum* intake. For the 30:70 diet, however, a marked decrease in efficiency with sub-*ad libitum* feeding levels were obtained, probably due to an increased cost of maintenance. Although net energy equations (NRC, 1984) indicate that efficiency of feed utilization should be greater when feed intake is highest, several recent studies have challenged this assumption. Results discussed by Meissner (1983b), Hicks *et al.* (1987; 1988), Plegge (1987) and Zinn (1986) show that feed efficiency of feedlot cattle may be

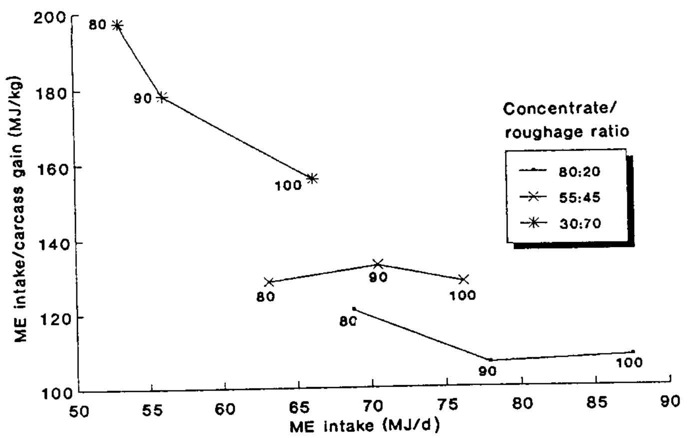

Figure 3 Efficiency of energy utilization of weaner steers on various nutritional management programmes, when slaughtered at the same live mass (80, 90 and 100 = feeding level as % of *ad libitum*).

improved by restricting or controlling feed intake. A review of research conducted on controlled feeding suggests that yearlings respond more favourably than weaner calves, as all studies with yearlings have shown that controlled feeding increases feed efficiency (Hicks *et al.*, 1987).

In conclusion, beef carcass composition may be manipulated through nutritional means within the fatness limits set by the South African classification and grading system, by varying the level of energy intake through either the C : R ratio or the feeding level. In accordance with Byers (1982) and Lemieux *et al.* (1988), energy intake influences the composition of growth primarily through altering the rate of growth of fat so that the fraction of fat in mass increases with the rate of gain. This concept, together with the concept that different carcass tissues reach their maximum growth rate at different stages of maturity, create the opportunity to strategically manipulate growth through nutritional means. The extent to which carcass mass at a constant carcass fatness, can be changed by divergent energy intake levels, needs further evaluation.

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