INFLUENCE OF AGE AND BIOLOGICAL TYPE ON GROWTH AND DEVELOPMENT OF STEERS DURING A GROWING PERIOD OF RESTRICTED OR OPTIMUM NUTRITION AND THE SUBSEQUENT FINISHING PERIOD

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INTRODUCTION

During recent years, the need for more efficient and economical beef production has become increasingly apparent to the beef cattle industry. When cereal grain prices increase, the producer seeks alternative methods of feeding cattle and often looks toward higher roughage feeding programs. This means of diverting his costs must be weighed, however, against the increased inventory time necessary for the cattle to reach the final end-point. In the post weaning segment of production it is believed that calves which enter the feedlot after being grown on a relatively low plane of nutrition, will gain faster than calves reared on a high plane of nutrition, other factors being equal.

Data from many experiments support the phenomenon of compensatory growth. However, the physiological cause of the accelerated growth has not been satisfactorily explained since the conditions under which the animal is subjected to the nutrient restriction (age, severity and duration of the restriction, genetic type, etc.) influence the animal's ability to compensate.

The objective of this study was to determine the effect of a low vs high energy growing ration on rate of gain, composition of gain and nutrient efficiency of steers during the subsequent finishing period. The design allowed for the evaluation of animal age and animal weight at the end of this period on successive performance. Steers entering the finishing phase were either of equal weight but different ages, or of different weight but the same age. Further, two breeds were used to evaluate the effect of frame size (large frame, late maturing vs small frame, early maturing steers) in conjunction with age and size on steer performance.

CHAPTER II

REVIEW OF LITERATURE

Compensatory growth is defined as growth, following a period of undernutrition, which is more rapid than is normal for adequately fed animals. It is well documented that following a period of restricted nutrient intake, an animal is able to fully recover and attain comparable mature sizes and weights as animals which were not restricted (Wilson and Osbourn, 1960; Allden, 1970; Moran and Holmes, 1978). As early as 1915, Osborne and Mendel observed that when rats were subjected to very long periods of undernutrition, they were able to attain full mature size when refed adequate diets. They further found that the rates of gain of previously undernourished rats were greater than those for normal rats.

Cattle wintered on a low plane of nutrition have shown accelerated rates of gain both on subsequent summer pastures (Bohman and Torell, 1956; Heinemann and Van Keuren, 1956; Carroll _et_ _al_., 1964) and on high concentrate feedlot rations (Perry _et_ _al_., 1971; Fox _et_ _al_., 1972; Hinks and Prescott, 1972; Perry _et_ _al_., 1972; Diori _et_ _al_., 1974; Smith _et_ _al_., 1976). However, other research has shown that the rate of gain of steers in the feedlot is independent of previous levels of nutrition and that previously restricted steers gained at similar rates as their unrestricted counterparts (Steudemann _et_ _al_., 1968; Lake _et_ _al_., 1974; Coleman _et_ _al_., 1976). Furthermore, Holstein-Fresian bulls which were restricted in energy intake actually gained at a slower rate than their unrestricted controls once the restriction was removed (Levy et al., 1971). These conflicting results suggest that compensatory growth is not a simple phenomenon and that factors other than previous nutrition may influence subsequent growth rate. For this reason various explanations are found in the literature as to the physiological basis for compensatory growth (Winchester and Ellis, 1957; Graham and Searle, 1975; Ledger and Sayre, 1977), which may be due to the wide range of conditions under which the compensatory growth response was observed. For example, in several of the studies where compensatory gains were observed, the previously restricted animals entered the realimentation period at lighter weights than their unrestricted counterparts (Bohman, 1955; Carroll et al., 1963), but when steers entered the regrowth period at equal weights, no compensatory growth was observed (Coleman et al., 1976). Further, steers restricted in early life (0-8 months) did not exhibit accelerated rates of gain during refeeding (Stuedemann et al., 1968), while steers restricted at post-weaning ages did show increased rates of gain as compared with continuously fed steers (Fox et al., 1972).

This literature review has been divided into three parts: 1) body composition and skeletal changes during and following a period of restriction; 2) factors influencing growth after the restriction is removed; and 3) factors influencing the animal's ability to compensate.

Body Composition and Skeletal Changes

During normal animal growth, various body tissues exhibit a differential pattern of development as the animal matures physiologically. This order of development has been described by Berg and Butterfield

(1976) as (1) vital organs (central nervous system, viscera); (2) bone and muscle; and (3) fat. Further, they indicated that as long as the animal consumes an adequate diet, bone and muscle increase at a rate proportional to one another, while during a period of nutrient restriction, bone continues to increase while lean growth is retarded. The growth of fat, however, increases in a manner directly proportional to the level of energy intake. Byers and Rompala (1979) observed that rate of protein and fat deposition was dependent on rate of gain in steers. Protein deposition rate increased with increased rate of gain, but at a decreasing rate. Fat deposition, however, increased at an increasing rate with an increase in average daily gain.

During periods of restricted growth, Berg and Butterfield (1976) suggested that tissues which have already reached their mature size are least affected and that body tissues developing most rapidly at the time of the restriction take priority for available nutrients over later maturing tissues. In contrast, when sheep were fed to lose 25% of their empty body weight, no loss of body fat occured during the first half of the restriction and body fat did not increase during the first part of the refeeding period (Drew and Reid, 1975a).

Skeletal Diminsions

Skeletal growth continues during a period of weight stasis but at a rate less than that for continuously growing animals (Lawrence and Pearce, 1964; Levy et al., 1971; Dockerty et al., 1973). There is also a differential growth pattern for skeletal development where height measurements are least affected by a nutrient restriction, length from hooks to pins and depth of chest measurements are intermediate, and width measurements at the hooks and girth measurement being most severely restricted (Lawrence and Pearce, 1964). During the refeeding period, the skeletal dimensions compensate in a reverse order; that is, the dimensions most severely restricted compensate the most and are not different in magnitude from continuously grown animals by the end of the refeeding period (Winchester and Howe, 1955; Lawrence and Pearce, 1964; Stuedemann *et al.*, 1968; Folman *et al.*, 1974). Skeletal growth as determined by bone maturity scores, progresses at a slower rate for restricted than for control steers during the refeeding period. As a result, the previously restricted steers had more youthful carcasses at slaughter (Dockerty *et al.*, 1973). It was concluded that during realimentation, body tissue growth was emphasized at the expense of skeletal development. Drew and Reid (1975b) observed that bone greatly decreased in water content but not in lipid content during a restricted period. After the restriction was removed, the bone quickly rehydrated and the fat was mobilized.

Body Composition

Previous research is not conclusive concerning the effect of undernutrition on body composition. When animals are subjected to submaintenance rations, body compositional changes are not a simple reversal of growth. Instead of a differential loss of fat which might be expected since it is the latest body tissue to develop, body weight loss resulted from a combination of water, lean and fat losses (Meyer, *et al.*, 1962; Butterfield, 1966; Drew and Reid, 1975a). During realimentation, restricted animals may yield carcasses with higher water and protein content and depressed fat content when compared to carcasses of continuously fed animals (Keenen *et al.*, 1969; Levy *et al.*, 1971; McManus *et al.*, 1972; Little and Sandland, 1975). However, this is not always the case. Meyer and Clawson (1964) observed increased fat and decreased protein deposition in the carcasses of sheep and rats that had been realimented following a period of retarded growth. Furthermore, Thornton *et al.* (1979) reported that sheep previously restricted did not differ from controls in body composition when slaughtered at equal body weights. Similar results were observed for cattle by Fox *et al.* (1972) and Winter *et al.* (1976). In addition, carcass quality grade was similar for restricted and unrestricted steers when fed to an equal final slaughter weight (Winchester and Howe, 1955; Winchester *et al.*, 1957; Dockerty *et al.*, 1973).

During the realimentation period, Fox *et al.* (1972) observed that steers deposited relatively more protein during the first part of the feeding period and more fat during the latter part to yield steers of approximately equal final body composition as the continuously fed animals. Similarly, Drew and Reid (1975a) concluded that during early regrowth lean synthesis was increased and fat synthesis was decreased, but beyond this initial period, the rate of tissue growth is very similar to continuously grown animals. Byers and Rompala (1979) reported that composition of gain changed with rate of gain. They indicated that as rate of gain increased, fat content of gain increased and protein content decreased.

Factors Influencing Growth During Refeeding

Period of Increased Growth Rate

Animals previously restricted and then realimented will usually continue to grow for a longer period of time than their controls in order to reach the same end point. Therefore, even if compensatory growth is exhibited during refeeding, restricted animals attain final slaughter weight at an older chronological age (Osborne and Mendle, 1915; Winchester and Howe, 1955; Steudemann *et al.*, 1968; Levy *et al.*, 1971; Fox *et al.*, 1972; Morgan, 1972; Folman *et al.*, 1974). This suggests that the compensatory response may not be adequate to compensate for the period of time on the restricted diet and the growth rate will remain less than that of unrestricted counterparts when both the restricted and realimentation periods are considered.

Increased Intake

Following a period of restricted feeding, dietary intake is normally increased when compared to animals at the same weight that were full-fed (Meyer and Clawson, 1964; McManus, Reid and Donaldson, 1972; Graham and Searle, 1975). In some cases, the increase in intake was determined as the primary cause for the compensatory growth response (Graham and Searle, 1975). But when previously restricted sheep and rats were allowed to eat *ad libitum* or were fed the same amount as the controls, the *ad libitum* group ate more than the second group yet both groups exhibited compensatory growth (Myer and Clawson, 1964). Winchester and Howe (1955) observed that restricted steers were able to make the same amount of weight gains during recovery without an increase in intake as compared to unrestricted controls.

Decreased Maintenance Requirement

Ledger and Sayre (1977) fed groups of steers to maintain 185, 275 or 450 kg body weight for periods up to 24 weeks. As time passed, less feed was required to maintain the weights and slaughter analysis showed that there were no differences among groups in the energy values of the boneless retail carcass meat. They concluded that there was a progressive increase in efficiency of energy utilization during the maintenance period. This conclusion was further supported by Graham and Searle (1975) with sheep maintained at a constant weight for 4-6 months. Conversely, sheep and rats maintained for a shorter period (42 and 21 days, respectively), showed no change in their maintenance requirement (Meyer and Clawson, 1964). This suggests that long term periods of restriction may be necessary to significantly affect the maintenance energy requirements.

Increased Energy and Protein Utilization

Energy, and often protein, is utilized more efficiently during the full-feeding period by animals previously restricted than by their control counterparts. Winchester and Howe (1955) and Winchester and Ellis (1957) reported that steers which had been previously restricted (3-4 months) required the same amount of feed to reach 1000 pounds as the control steers; thus energetic efficiency was increased during the realimentation period. Other research also indicated an increase in energetic efficiency during the refeeding period, but because of the increased age of these animals as a direct result of the length of the period of undernutrition, the overall efficiency favored the continuously grown steers (Meyer and Clawson, 1964; Levy et al., 1971; Fox et al., 1972; Folman et al., 1974). An increase in protein utilization above maintenance was observed in sheep (Asplund et al., 1975) and in steers (Fox _et al._, 1972) as compared to their respective control animals. Fox _et al._ (1972) concluded that the net energy values for maintenance and for gain for a ration and the efficiency of dietary protein utilization is higher for steers exhibiting compensatory growth than for previously full-fed steers.

Hormones

Relatively little information is available on the relationship between endocrine secretions and changes that occur during compensatory growth in cattle. Steers exhibiting accelerated gain following a period of restriction, had lower plasma growth hormone (GH) concentrations than did their continuously fed controls (Fox _et al._, 1974). This negative relationship between GH and growth rates was also observed in finishing cattle (Trenkle, 1970). Conversely, Holstein heifers grown on a continuous plane of nutrition had a decrease in pituitary GH concentration as they matured (from 1-80 weeks of age) and their growth rates declined (Armstrong and Hansel, 1956). This may suggest that GH has a positive effect on lean tissue growth but a negative effect on fat synthesis (Trenkle, 1970; Trenkle and Topel, 1978). Nalbandov (1963) suggested a dilution by body mass of available GH as the mechanism for decline in GH and protein synthesis. Comparisons at different levels of nutrition indicate that pituitary GH concentration (Armstrong and Hansel, 1956) and plasma GH concentration (Trenkle, 1970; Trenkle and Topel, 1978) are not affected by level of nutrition. Daily fluctuations in plasma GH concentrations (Fox _et al._, 1974) and the infrequency of sampling may make reliable estimates of average concentrations difficult to obtain.

Pituitary thyrotropin concentrations declined as growth rate decreased in Holstein heifers (Armstrong and Hansel, 1956) and in beef steers (Curl et al., 1968) as these cattle increased in age. Compensating steers had a decreased thyroid secretion rate during their restricted phase and during the early part of their realimentation period as compared to controls (Fox et al., 1974). By the end of the finishing period the thyroid secretion rate equaled or exceeded those of control animals. This suggests a lower maintenance requirement for previously restricted cattle during the period which coincides with increased protein and energy utilization of compensatory gain.

Factors Influencing the Ability to Compensate

Age at Beginning of Restriction

Bohman (1955) wintered both weanling and yearling steers on a restricted or adequate level of feeding (2 x 2 factorial). The steers subsequently grazed spring and summer pastures. The following fall, the yearling steers wintered on a restricted level of feeding had completely compensated whereas the weanling steers wintered on the restricted level were still at a lighter weight than the control steers. Restricting animals at a younger age while their potential for growth is greater tends to have more serious and longer term effects. Steers that were restricted from either 0-16 or 16-30 weeks of age were both able to attain their full mature size and weight but compensatory growth was observed only in the group restricted from 16-32 weeks of age (Morgan, 1972). Furthermore, steers undergoing various degrees of restriction from 0-8 months of age failed to have compensatory growth during the subsequent finishing period (Stuedemann et al., 1968).

Allden (1968) imposed a restriction on sheep during the first or second 6 months of age and observed that the group restricted the first 6 months did not fully recover until 5 1/2 years of age whereas the sheep restricted at the later age required less than 1 year. These results would indicate that at very young ages, the stimulatory response for compensatory growth does not exist to the same extent as in older animals. Lawrence and Pearce (1964) concluded that a restriction imposed at less than 3 months of age may permanently stunt the animal's ability to recover.

Severity and Duration

Following periods of restriction resulting in body weight changes ranging from small weight losses to slight gains, sheep (Winchester and Ellis, 1957; Winter *et al*., 1976) and cattle (Bohman, 1955; Butterfield, 1966; Allden, 1968; Perry *et al*., 1972), are able to resume growth and reach mature size once the restriction is removed. In more severe cases, Osborne and Mendle (1915) observed that when rats were undernourished for very long periods of time (500 days) they were able to grow and attain their mature size when refed. Sheep restricted for up to 400 days at different stages of post-natal life resumed normal growth, although in the most extreme cases, mature size was not attained until 5 1/2 years of age (Allden, 1968). This suggests that even in cases of very severe restrictions, the stimulus for growth is not impaired and normal mature weights will be attained by the restricted animals.

Wilson and Osborn (1960) concluded that the more severe the restriction imposed, the greater the initial response when the restriction is removed. In addition, the severity of the restriction (loss of weight, maintenance or slight gains) may affect animal performance during the realimentation period and if the restriction period is for a very long time, however, the animal may not be able to totally recover and if the restriction is severe enough, permanent stunting may result.

Nature of the Restriction

When the energy content in the ration (otherwise normal) is limited, animals can be maintained for long periods of time without adverse affects on their ability to recover (Winchester and Howe, 1955; Lawrence and Pearce, 1964; Levy et al., 1971). Denham (1977) observed that energy supplementation prior to entering the feedlot had a negative affect on feedlot gains while protein supplementation increased subsequent gains. Bohman and Torell (1956) observed similar results with protein supplementation for pasture gains. When protein intake of rats was restricted, they failed to respond to realimentation on a high protein diet to the extent of their counterparts which had been restricted in energy intake (Cabek et al., 1963). These results suggest that the recovery response of an animal to a period of undernutrition is influenced by the type of restriction and that limiting protein in the diet may have a more serious effect on the animal's recovery than an energy deficiency.

Biological Type

In continuously grown cattle, Byers et al. (1977) and Byers and Rompala (1979) observed that large frame steers (Charolais) deposit fat at a rate directly and positively related to rate of gain. In small frame steers (Angus-cross) a similar relationship was observed but the magnitude of the differences in fat deposition was much smaller.

Rompala and Byers (1978) compared large and small frame steers fed ad libitum or 70% ad libitum energy levels to a 30% carcass fat (low choice) endpoint. They concluded that only small frame steers were able to reach this endpoint at a reasonable market weight on the lower energy ration. These results indicate that body composition at low choice is less affected by level of nutrition for small frame steers.

Beranger (1978) stated that feed efficiency decreased for larger frame animals with a high potential for lean tissue growth when energy was below ad libitum since their growth rate was decreased but no change occurred in the composition of the gain. With smaller frame steers which mature and therefore fatten at lighter weights, feed efficiency increased by limiting the level of energy intake. The increase in efficiency was attributed to a decrease in fat deposition and energy content of the gain. Folman et al. (1974) restricted large and small type bulls for a 90 day maintenance period beginning at 180 or 270 days of age. For the restricted smaller frame bulls, feed efficiency was improved without decreasing average daily gains. In contrast, the slight increase in feed efficiency for the restricted larger frame bulls was accompanied by a decrease in average daily gains. These differences indicate that a period of restricted feeding favors small frame breeds of cattle but acts as a detriment to larger breeds.

Liveweight at the Begining of the Realimentation Period

In studies reporting a compensatory growth response subsequent to a period of undernutrition, the restricted animals often enter the realimentation period at lighter weights than their control counterparts. Coleman et al. (1976) did not observe compensatory growth in cattle reared on different levels of nutrition when the finishing period was begun at a constant weight. Similar results were reported by Lake _et al_. (1974). Therefore, feedlot gains may be more a function of initial weight than previous level of nutrition. Moran and Holmes (1978) concluded that the degree to which animals compensate may depend on the live weights of the control and the restricted cattle at the onset of the realimentation period.

Quality of the Realimentation Diet

The available energy during recovery from undernutrition is an important factor influencing an animal's ability to compensate. Bohman (1955) indicated that a higher plane of nutrition during realimentation will allow for the greater and faster weight gains of previously restricted animals. The data of Fox _et al_. (1972) supports this conclusion in which a greater compensatory growth response was observed in restricted cattle refed a diet with greater metabolizable energy content. Therefore, high energy diets may be a necessary requirement if animals are to fully express their potential for compensatory growth (Moran and Holmes, 1978).

CHAPTER III

MATERIALS AND METHODS

Experimental Design

A 2 x 2 x 2 factorial design which included age, resulting from the duration of the growing phase, (older vs younger), biological type (large frame vs small frame), and plane of nutrition during the growing phase (control vs restricted) was used. Thirty-four spring-born weanling Angus steers and thirty-four Charolais steers purchased in November, 1978 represented the older steers. An equal number of fall-born steers of each breed were purchased from the same producers in June, 1979 and represented the younger steers. The Angus steers were representative of the small frame, early maturing biological type and the Charolais steers were representative of the large frame, late maturing type. All steers were maintained in confinement pens (2 animals per pen) at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma.

Within each age and biological type, six steers were slaughtered initially to determine body composition at the onset of the study; twenty-four steers were randomly assigned to either the control or the restricted growing ration; and the remaining four steers were assigned to one of the two nutritional levels but were designated for use in the three metabolism studies used to characterize the rations.

Growing Phase

Twelve older and twelve younger steers of each biological type were stratified based on weight, height at the withers, and ultrasonic backfat thickness to one of three reps. Within each rep, the calves were randomly allotted to either the control or the restricted growing ration. Those calves on the control ration were fed pelleted dehydrated alfalfa *ad libitum*. Gains of approximately .75 kg per day were expected. The restricted steers were limit fed a ration which had a digestible energy content of 81.8 Mcal/kg. Adjustements were made in the amount of the ration fed until average daily gains of approximately .2 kg per day were attained. Ration composition, chemical analyses and nutrient values are described in Table I.

The steers were weighed on to trial and at 28-day intervals following a 16-hour shrink without feed and water. The growing phase was terminated for each rep when the younger steers fed the control growing ration reached approximately the same weight as the older steers fed the restricted ration. At this point, half of the steers (six animals) of each treatment were slaughtered and the remaining steers were switched to a high concentrate finishing ration (Table II). A schematic drawing of the design of the experiment is in Figure 1.

Finishing Phase

During the first, second and third weeks of the finishing phase, the steers were fed a 50:50, 60:40 and 70:30 concentrate:roughage ration, respectively. Begining the fourth week and for the remainder of the experiment, all steers received a typical 80% concentrate ration (Table I), fed *ad libitum*.

TABLE I

INGREDIENTS AND CHEMICAL ANALYSIS OF THE RATIONS

Item	IRN[a]	Growing ration		Finishing ration[b]
		Control	Restricted	
		% of the diet		
Ingredients				
Alfalfa hay	1-00-059	....	13.0	10.0
Dehydrated alfalfa pellets	1-00-023	100.0	....	....
Cracked shelled corn	4-02-931	....	....	70.3
Soybean meal	5-04-604	....	10.0	3.9
Cottonseed hulls	1-01-599	....	45.0	10.0
Mixed grass hay	1-02-244	....	19.0	....
Wheat straw	1-05-175	....	13.0	....
Molasses	4-04-696	....	....	5.0
Salt	....	....	....	0.6
Calcium carbonate	....	....	....	0.2
Proximate analysis[c]				
Dry matter, %		92.6	93.5	87.6
Organic matter, %		89.5	93.6	95.3
Crude protein, %		17.2	10.1	10.8
Neutral detergent fiber, %		50.5	75.4	30.1
Energy, Mcal/kg		4.8	3.9	4.5
Digestible protein, %		9.4	4.7	7.4
Digestible energy, Mcal/kg		2.7	1.8	3.3
Metabolizable energy, Mcal/kg		2.1	1.5	2.9

[a] International reference number.

[b] Finishing ration contains 250 mg monensin per ton.

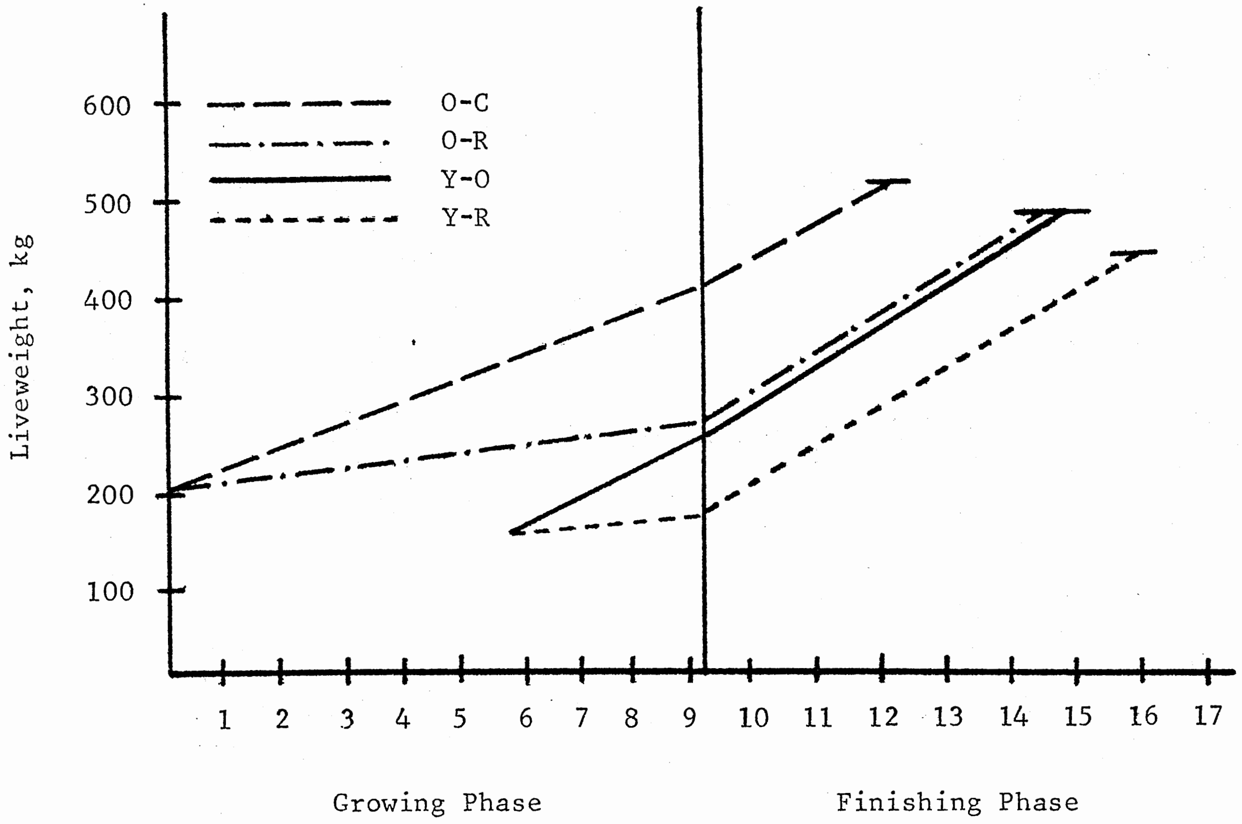
[c] All components except % dry matter are expressed on a dry matter basis.

TABLE II

EXPERIMENTAL DESIGN

	Angus				Charolais			
	Older		Younger		Older		Younger	
Initial slaughter	6		6		6		6	
Treatment level	C[a]	R[a]	C	R	C	R	C	R
Start of growing phase: Twelve steers/subgroup	12	12	12	12	12	12	12	12
End of growing phase: Six steers/subgroup to slaughter	6	6	6	6	6	6	6	6
Six steers/subgroup enter finishing phase								
End of finishing phase: Remaining six steers/subgroup to slaughter	6	6	6	6	6	6	6	6

[a] C = Control growing ration; R = restricted growing ration.



Time, months from onset of the experiment

Figure 1. Basic Design of the Experiment with Regard to Energy Level, Animal Age and Duration of the Growing and Finishing Phases

Steers were shrunk and weighed at 28-day intervals. The final slaughter point was determined by ultrasonic measurement of backfat thickness. Angus steers were slaughtered at 12 mm backfat and Charolais steers at 8 mm backfat.

Metabolism Trials

During the growing phase, two metabolism trials were conducted. The first trial was begun approximately six weeks after the arrival of the older steers. Eight steers were used, two for each biological type and treatment sub-group. The second trial, conducted in July, 1979, included steers from both age groups. Four steers were fed the control growing ration (one steer per biological type and age) and the remaining eight steers represented both biological types and ages on the restricted ration. A third metabolism trial was conducted during the finishing phase and utilized 16 steers, four per biological type and age. Six steers were randomly selected to characterize the three warm-up rations fed at the beginning of the finishing phase. The other 10 steers were fed the 80% concentrate ration. Steers were fed at 90% ad libitum. Each metabolism study was conducted following a 10-day preliminary adjustment period with feed, refusals, fecal samples and urine being collected for seven days thereafter.

All feed, refusal, and fecal samples from the metabolism studies were analyzed for dry matter, organic matter, crude protein, gross energy (A.O.A.C., 1975) and neutral-detergent fiber (Goering and Van Soest, 1970). Apparent digestibilities were calculated. Urine was analyzed for nitrogen content and gross energy was calculated (Street et al., 1964). Energy losses due to methane production were estimated at 8% of gross energy consumed for the growing rations and 6% for the finishing ration (Blaxter, 1962). Metabolizable energy was determined by subtracting energy losses due to the feces, urine and methane production. The conversion of digestible protein intake for protein gain was determined by a modification of the equation by Fox et al (1973):

$$\frac{\text{daily protein gain, g}}{\text{daily digestible protein intake, g} - (\text{digestible protein required daily for maintenance})} \times 100$$

Daily maintenance requirement for g protein was calculated by the following equation:

$$.88\ \text{weight}_{\text{kg}}^{0.75} + 25.0\ \text{dry matter intake, kg}$$

Values were obtained from factorial metabolic losses listed in NRC (1976).

Aside from the time during the metabolism trials, the steers were maintained in a manner identical to those steers of the sub-group they represented.

Live Animal Measurements

Animal height at the withers, body length (point of the shoulder to the hip bone), and backfat thickness (measured ultrasonically) were measured at the onset of the growing phase. These same measurements plus height at the hooks were taken at the end of the growing and finishing phases. In addition, ultrasonic backfat thickness was measured at 28-day intervals towards the end of the finishing phase, as the animals neared the slaughter point.

Slaughter Data and Carcass Measurements

All steers were weighed (after a 16-hour shrink) and transported to the Oklahoma State University Meat Laboratory where they were penned overnight without feed and water and slaughtered the following morning. Each steer was weighed immediately prior to slaughter. Reticulo-rumen and omasum contents were weighed and subtracted from live weight prior to slaughter to determine empty body weight. Following a 24-48 hour chill, the following carcass measurements were taken: rib eye area, fat thickness over the rib eye, bone maturity, marbling score and quality grade.

Carcass Chemical Analyses

The right side of each carcass was physically separated into bone, soft tissue, and kidney and pelvic fat. The soft tissue was ground, mixed and two 5 kg samples were removed. These samples were again ground and mixed. Four samples (.25 kg) were then taken, homogenized using a Sorvall Omnimixer, frozen and stored at $-20^{\circ}C$ while awaiting chemical analysis. Proximate analysis procedures (A.O.A.C., 1975), were used to determine percent moisture, protein, ether extract and ash of the carcass soft tissue. Gross energy was calculated using equations reported by Garett and Hinman (1969).

Statistical Analyses

The general linear models procedure of the Statistical Analysis System (SAS) of North Carolina State University was used to determine estimates of variance and least squares means. The data obtained from the growing phase were analyzed using the model:

$$Y_{ijkl} = u + B_i + T_j + A_k + (BT)_{ij} + (BA)_{ik} + (TA)_{jk} + (BTA)_{ijk} + IWT\,(BA) + E_{ijkl}$$

where Y_{ijkl} was the lth observation of the response variable for liveweight, skeletal and carcass measurements and efficiency of nutrient utilization and where u was the theoretical population mean, B was the ith effect of biological type (large frame vs small frame), T was the jth treatment level during the growing phase (control vs restricted), and A was the kth effect of animal age (older vs younger). BT was biological type by treatment interaction, BA was biological type by age interaction, TA was treatment by age interaction, BTA was biological type by treatment by age interaction and IWT (BA) was deviation in individual initial weight within a biological type and age at the beginning of the growing phase from the mean of its sub-group. The components u, B_i, T_j, A_k, $(BT)_{ij}$, $(BA)_{ik}$, $(TA)_{jk}$ and $(BTA)_{ijk}$ were treated as fixed effects of biological type_i, treatment_j and age_k. Initial weight within breed and age (IWT[BA]) was a continuous variable and E_{ijkl} was the random error effect.

Data from the finishing phase were analyzed using the model:

$$Y_{ijkl} = u + B_i + T_j + A_k + (BT)_{ij} + (BA)_{ik} + (TA)_{jk} +$$
$$(BTA)_{ijk} + IWT(BTA) + SBF + E_{ijkl}$$

where Y_{ijkl}, u, B_i, T_j, A_k, $(BT)_{ij}$, $(BA)_{ik}$, $(TA)_{jk}$, $(BTA)_{ijk}$ and E_{ijkl} were the same response variables as described in the previous model. Deviation in individual initial weight within a biological type, treatment, and age sub-group (IWT[BTA]) at the beginning of the finishing phase from the sub-group mean and backfat thickness at slaughter (SBF) were continuous variables.

Data from the growing and finishing phases combined can be described by:

$$Y_{ijkl} = u + B_i + T_j + A_k + (BT)_{ij} + (BA)_{ik} =$$
$$(TA)_{jk} + (BTA)_{ijk} + IWT(BA) + SBA + E_{ijkl}$$

where each component of the response variable is as previously defined.

Least square means for significant interactions were separated by least significant differences based on the planned non-orthogonal comparisons of treatment differences within each level of biological type and age effects. The standard error may appear small due to the inclusion of the continuous variables in the models. These variables tend to reduce the error term, from which the standard error is calculated.

CHAPTER IV

RESULTS AND DISCUSSION

Growing Phase

The objective of the growing phase was to create differences due to breed, treatment and age in order to determine their effect on steer performance during the subsequent finishing phase (Tables III and IV).

Liveweight Parameters

Average daily gains (ADG) during this period directly reflect the energy level of the diets as the control steers gained significantly faster than the restricted steers within their respective breed/age subgroup. Final weight was greater ($P<.05$) for the older control steers within both breeds (Angus, 361.8; Charolais, 471.7 kg) but weight was similar for the older restricted and younger control steers ($P>.05$) as was predetermined in the design of the experiment. The younger restricted steers were the lightest groups within breed. The Charolais steers remained in the growing phase longer than the Angus steers (215 vs 186 days) and the older steers were on trial longer than the younger steers (306 vs 95 days).

Nutrient Efficiency and Body Compositional Changes

Dry matter and metabolizable energy efficiency for liveweight gain

TABLE III

EFFECT OF BREED, TREATMENT AND AGE ON WEIGHT GAIN AND COMPONENTS OF CARCASS GAIN OF STEERS DURING THE GROWING PHASE

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial weight, kg	172.1	162.0	146.0	144.0	230.6	224.7	244.2	276.5	12.1
Final weight, kg	361.8	223.4	213.9	171.7	471.7	313.8	316.4	280.3	7.5
Number of days on feed	314	330	108	108	291	289	82	83	8
Average daily gain, kg	0.62	0.16	0.58	0.23	0.84	0.30	0.62	0.16	0.04
Protein gain[d], g/day	57.4	24.0	87.7	42.5	94.8	32.8	68.7	3.8	4.64
Fat gain[d], g/day	132.1	15.9	62.5	32.4	110.4	10.2	78.9	18.4	2.79
Energy gain[d], Mcal/day	1.557	0.281	1.072	0.539	1.561	0.276	1.121	0.193	0.048

[a] Least square means; number of observations/mean = 12.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] Carcass compositional changes are based on hot carcass weight.

TABLE IV

EFFECT OF BREED, TREATMENT AND AGE ON FEED, ENERGY AND PROTEIN EFFICIENCY OF STEERS DURING THE GROWING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
DMI[d], kg/day	8.52	5.45	5.63	3.85	9.70	7.27	7.77	5.38	.20
DMI, g/weight $_{kg}^{.75}$/day	131.4	105.6	115.3	86.8	120.1	109.6	111.4	80.3	2.50
DMI, kg/liveweight gain, kg	9.94	40.23	7.22	33.82	7.79	23.23	9.06	29.50	.50
MEI[e], Mcal	17.71	9.45	11.71	5.86	20.18	12.54	16.15	8.19	.39
MEI, Mcal/liveweight gain, kg	22.82	70.36	17.17	51.38	18.35	40.85	21.00	43.84	25.07
MEI, Mcal/carcass gain, gain, Mcal	10.01	33.74	11.26	10.14	11.54	48.79	13.29	49.41	14.77
DPI[f], g/day	795.2	223.3	525.5	173.4	905.8	292.7	725.2	235.3	15.15
DPI, g/carcass protein gain, g	12.83	9.33	4.96	3.28	8.68	9.36	10.04	13.20	2.58

[a] Least square means; number of observations/mean = 12.
[b] C = control growing ration; R = restricted growing ration.
[c] SEM = standard error of the mean.
[d] DMI = dry matter intake.
[e] MEI = metabolizable energy intake.
[f] DPI = digestible protein intake.

indicate more efficient utilization by the control steers than respective restricted groups within breed and age ($P<.05$). In addition, the younger Angus steers were more efficient than the older Angus steers within the control and restricted treatment groups. This can be attributed to the shorter duration of the growing phase. A reverse trend occured in the Charolais steers. This difference is credited to the younger steers having lost weight early in the experiment and not to a true difference between the two breeds. The older control steers of both breeds and the Charolais younger control steers were more efficient than their restricted subgroups in converting metabolizable energy intake (MEI) to carcass energy gained. The Angus younger steers were similar in efficiency (10.7 Mcal MEI/Mcal gain) which is probably associated with their shorter growing phase and was not evident in the Charolais younger steers, again because of the weight loss.

The Angus and Charolais steers differed in the efficiency of utilization of digestible protein intake (DPI). The younger Angus steers were more efficient than the older steers (4.1 vs 11.1 g DPI/g protein gain) but no difference was observed for the Charolais steers (10.3 g DPI/ g protein gain).

Daily protein gain, fat gain and, consequently, energy gain was greater for the control vs restricted steers within age groups of both breeds. Further, the older Charolais steers deposited more protein and less fat than the older Angus steers within treatment level. However, the breeds did not differ in energy content of the gain.

Finishing Phase

Liveweight Parameters

Liveweight performance of all steers during the finishing phase is presented in Table V. At the onset of this phase, the older control steers were heavier ($P<.05$) than the other three sub-groups within both breeds and the older restricted and younger controls were similar in weight. At the end of the finishing phase (12 mm backfat for Angus steers; 8 mm backfat for Charolais steers) the Charolais steers were heavier ($P<.05$) than the Angus steers and the older steers within each breed were heavier ($P<.05$) than the younger steers. In addition, the older control steers required less time to reach the final endpoint ($P<.05$) than did the other sub-groups within a breed, as was expected due to their heavier weight at the beginning of the finishing phase.

Average daily gain (ADG) did not differ due to breed but was greater ($P<.05$) for the older steers than the younger steers (1.25 vs 1.10 kg). These results indicate that ADG during the finishing phase was positively related to animal age rather than previous level of nutrition, or breed (frame size). When comparing ADG among the groups of steers, however, one environmental factor must be considered. Just after the first group of steers reached the final endpoint and was slaughtered, several weeks of very cold and wet weather conditions prevailed, resulting in a marked decrease in ADG of the remaining steers from that time until their respective time of slaughter. Therefore, it is necessary to compare ADG during the finishing phase in two periods: from the onset until the first group was slaughtered, and from that time until the remaining steers were slaughtered (Table VI). During the first period, the Angus and Charolais

TABLE V

EFFECT OF BREED, TREATMENT AND AGE ON WEIGHT GAIN OF STEERS DURING THE FINISHING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial weight, kg	381.1	221.8	223.6	172.8	474.1	300.1	294.9	289.0	....
Final weight, kg	433.7^{d}	421.3^{d}	381.4^{e}	372.2^{e}	667.4^{f}	653.2^{f}	592.4^{g}	619.1^{g}	21.0
Number of days on feed	58^{d}	182^{e}	160^{e}	202^{e}	163^{f}	279^{g}	260^{g}	269^{g}	12
Average daily gain, kg	1.29^{d}	1.13^{d}	1.05^{e}	.99^{e}	1.29^{d}	1.28^{d}	1.14^{e}	1.22^{e}	0.13

[a] Least square means; number of observations/mean = 6.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d,e,f,g] Means in the same row with different superscripts are different (P .05).

TABLE VI

EFFECT OF BREED, TREATMENT AND AGE ON WEIGHT GAIN OF STEERS BEFORE AND AFTER THE FIRST GROUP WAS SLAUGHTERED DURING THE FINISHING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Days to first slaughter	34^{e}	61^{f}	32^{e}	84^{f}	121^{g}	154^{h}	133^{gh}	140^{gh}	13
ADG[d] to first slaughter, kg	1.59^{e}	1.65^{e}	1.68^{e}	1.17^{f}	1.25^{f}	1.54^{e}	1.52^{e}	1.49^{e}	0.08
Days after first slaughter	...	121	128	118	89	124	126	130	13
ADG after first slaughter, kg	...	.87	.83	.84	.82	.88	.71	.88	.19

[a] Least square means; number of observations/mean = 6.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] ADG = average daily gain.

[e,f,g,h] Means in the same row with different superscripts are different (P .05).

older restricted and younger control steers, which entered the finishing phase at similar weights within breed, showed no difference (P>.05) in ADG. These results support those of Coleman et al. (1976) which indicated that feedlot gains were independent of animal age and of previous plane of nutrition and are closely related to animal weights upon entering the finishing phase.

The older restricted Charolais steers exhibited a compensatory growth response when compared with their control counterpart (1.54 vs 1.25 kg/day) but no difference in ADG (P=.57) was observed between these two groups of Angus steers (restricted, 1.65; control, 1.59 kg/day). The compensatory growth seen in the Charolais steers parallels results from other studies with both large frame steers (Drori *et al.*, 1974) and with smaller frame steers (Fox *et al.*, 1972; Perry *et al.*, 1972; Drori *et al.*, 1974) but is in contrast with results of Levy *et al.* (1971) where Israeli-Friesian bull calves (large frame) failed to show compensatory growth following a restricted period. The results of the Angus steers, however, conflict with those previously mentioned for smaller frame steers. A possible explaination is that the older control steers may have also been exhibiting compensatory growth following the growing phase, since they were not growing to their maximum potential on the alfalfa pellet diet.

Reasons for the compensatory growth observed in the Charolais but not the Angus steers are not apparent. Periods of energy restriction in larger frame steers generally do not result in compensatory growth since the composition of the gain is unaltered; but in smaller frame steers, a restriction is associated with increase in protein and water accumulation and a resulting decrease in fat deposition during the subsequent refeeding period and thus an increase in ADG (Beranger, 1978). During the latter part of the finishing phase, no difference was observed in ADG due to breed, treatment or age ($P>.05$).

Skeletal Dimensions

Steers fed the restricted growing ration grew more slowly ($P<.05$) than their respective control groups during the growing phase as measured by daily increase in height at the withers (Table VII). Also, the younger steers grew more rapidly than did the older steers within each breed. Consequently, the previously restricted steers were smaller than their respective control steers at the end of the growing phase. During the finishing phase, height measurements, taken both at the withers and at the hooks, showed no significant difference in rate of skeletal growth due to breed, treatment or age (actual height measurements are presented in Appendix Table XV). These results are in contrast with other research which suggested that restricted steers exhibit a compensatory growth response in skeletal measurements and are the same structural size as unrestricted counterparts by the end of the realimentation period (Lawrence and Pearce, 1964; Stuedemann _et_ _al_., 1968). These results do indicate, however, that although the rate of skeletal growth was retarded due to the energy restriction, the restriction was not severe or long enough to cause a permanent stunting of the steers.

Nutrient Efficiency and Carcass Compositional Changes

The older steers consumed more dry matter per day during the finishing phase ($P<.05$) than the younger steers of either breed (Table VIII). However, most of the increase was the result of size. When intake was

TABLE VII

DAILY INCREASE IN SKELETAL MEASUREMENTS FOR THE GROWING AND FINISHING PHASES[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial[d]									
Height at withers, cm	94.0	89.9	87.7	87.0	102.9	105.2	103.0	106.0	1.59
Backfat, mm	1.3	1.2	0.8	0.8	0.8	1.0	1.0	1.2	0.44
Growing phase[d]									
Increase height, withers, mm x 10^2/day	56.9[f]	31.7[f]	84.8[g]	50.3[g]	74.7[f]	51.2[f]	95.0[g]	75.0[g]	11.30
Finishing phase[e]									
Increase height, withers, mm x 10^2/day	53.6	67.2	86.9	85.7	39.7	47.7	60.9	51.7	8.43
Increase height, hooks, mm x 10^2/day	50.7	49.0	68.6	77.9	35.9	51.0	87.4	62.0	13.72

[a] Least square means.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] Number of observations/mean = 12.

[e] Number of observations/mean = 6.

[f,g] Means in the same row with different superscripts are different (P .05).

TABLE VIII

EFFECT OF AGE ON FEED AND ENERGY EFFICIENCY OF STEERS DURING THE FINISHING PHASE[a]

	Older	Younger	SEM[b]
DMI[c], kg/day	9.02[e]	7.45[f]	.24
DMI, kg/weight$_{\text{kg}}^{.75}$/day	94.54	90.00	2.35
DMI, kg/liveweight gain, kg	7.61[e]	6.86[f]	.16
MEI[d], Mcal/day	26.34[e]	21.83[f]	.70
MEI, Mcal/liveweight gain, kg	22.25[e]	20.11[f]	.47
MEI, Mcal/carcass gain, Mcal	7.10	6.01	.44

[a] Least square means; number of observations/mean = 24.
[b] SEM = standard error of the mean.
[c] DMI = dry matter intake.
[d] MEI = metabolizable energy intake.
[e,f] Means in the same row with different superscripts are different (P .05).

divided by metabolic body size, differences were not significant. The compensatory growth response observed in the older restricted Charolais steers was not, therefore, due to an increase in dry matter intake, but to an increase ($P<.05$) in utilization. This conflicts with results in sheep (Meyer and Clawson, 1964; Graham and Searle, 1975) where intake was increased during realimentation.

Dry matter efficiency for liveweight gain was greater for the younger steers of both breeds ($P<.05$) throughout the realimentation phase. Within the Angus steers, there was no difference in dry matter efficiency (Table IX) for any treatment group. In contrast, the restricted Charolais steers were more efficient than their controls ($P<.01$), suggesting not only compensatory gain for the Charolais steers (during the early part of the finishing phase) but compensatory efficiency as well.

Metabolizable energy (ME) efficiency for liveweight gain followed the same trend as did dry matter efficiency during the finishing phase. The younger steers were more efficient ($P<.05$) than the older steers and the restricted Charolais steers required less ME per unit of liveweight gain than their control steers ($P<.01$). No differences occured due to treatment for the Angus steers ($P>.1$). These results indicate that dry matter and energy utilization, as measured by liveweight gains, are dependent on animal age and that younger steers are more efficient. Two factors need to be considered here: first, the younger steers had a lower average daily weight during the finishing period and therefore, a lower maintenance requirement; second, the gain of the younger steers (especially the Angus) contained less energy. As a result, the difference in efficiency observed on the basis of liveweight gain does not occur when

TABLE IX

EFFECT OF BREED AND TREATMENT ON FEED AND ENERGY EFFICIENCY OF STEERS DURING THE FINISHING PHASE[a]

	Angus		Charolais		
	C[b]	R[b]	C	R	SEM[c]
DMI[d], kg/day	8.24	7.32	9.27	8.11	.70
DMI, kg/weight$_{kg}^{.75}$/day	101.7	102.6	85.8	79.0	6.75
DMI, kg/liveweight gain, kg	7.04^{fg}	7.09^{f}	8.21^{g}	6.61^{f}	.47
MEI[e], Mcal/day	23.88	21.41	27.19	23.86	2.04
MEI, Mcal/liveweight gain, kg	20.45^{fg}	20.76^{f}	24.07^{g}	19.44^{f}	1.36
MEI, Mcal/carcass gain, Mcal	6.17	5.26	8.80	5.99	1.27

[a] Least square means; number of observations/mean = 12.
[b] C = control growing ration; R = restricted growing ration.
[c] SEM = standard error of the mean.
[d] DMI = dry matter intake.
[e] MEI = metabolizable energy intake.
[f,g] Means in the same row with different superscripts are different (P .05).

efficiency is expressed on an energy basis (Mcal intake/Mcal gain).

These results further indicate that efficiency was not affected by previous plane of nutrition in the small frame steers which supports results of Coleman _et al_. (1976) with crossbred steers. Restricting the larger frame steers resulted in greater efficiency during realimentation, similar to work by Levy _et al_. (1971), Fox _et al_. (1972) and Folman _et al_. (1974) even though their cattle were of typical British breeding.

Metabolizable energy required per Mcal carcass gain, however, did not differ for any breed, treatment or age subgroup ($P>.05$). A trend (non-significant) was observed for the restricted Charolais steers to be more efficient. The fact that no significant differences occured when comparing energy efficiency for carcass energy gain suggests differences in the composition of the gain. Therefore, energy utilization may be more accurately compared among groups by considering the composition of the gain and not weight gain alone.

Daily digestible protein intake (DPI) was greater ($P<.05$) for older steers than younger steers (651.6 vs 540.7 g/day). Protein efficiency, as measured by DPI per unit of protein gain and by the conversion of digestible crude protein for protein gain above maintenance (%), indicates no differences ($P>.05$) within the Charolais breed (Table X). However, Angus control steers were more efficient according to both of these efficiency measurements than their restricted counterparts. No difference ($P>.05$) occured in protein efficiency due to age. These results for the Charolais steers agree with results of Fox _et al_. (1972) where no difference in protein efficiency above maintenance (%) was observed between compensatory and control Hereford Steers slaughtered at 454 kg.

TABLE X

EFFECT OF BREED AND TREATMENT ON PROTEIN EFFICIENCY OF STEERS DURING THE FINISHING PHASE[a]

	Angus		Charolais		
	C[b]	R[b]	C	C	SEM[c]
DPI[d], g/day	592.5	531.2	671.9	589.0	50.8
DPI, g/carcass protein gain, kg	5.17[e]	6.45[f]	6.69[ef]	6.50[ef]	0.52
Conversion of DPI for gain[e], %	40.21[e]	30.67[f]	29.47[ef]	34.07[ef]	3.40

[a] Least square means; number of observations/mean = 12.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] DPI = digestible protein intake.

[e,f] Means in the same row with different superscripts are different (P .05).

Rate of energy gain (daily) was greater (P=.07) for the older steers than for the younger steers (Table XI). Since the older steers also had a greater ADG than the younger steers during the finishing phase, this suggests a positive relationship between ADG and rate of energy gain. Rate of protein deposition was greater for older than younger steers (P=.10). While no difference was observed in the Charolais steers (P>.2) due to treatment, the control Angus steers had an increased rate of protein gain (P=.07) when compared to the restricted Angus steers (122.7 vs 86.9 g progein/day, respectively). Fat deposition (g/day) was similar (P>.1) for all steers. There was a trend, however, towards an increased deposition rate for the older steers vs the younger steers and for the older restricted steers vs the older control steers. These results support data of Byers and Rompala (1979) which indicated an increase in protein and fat deposition with increased ADG but contrasts their observation of greater rates of protein gain with larger vs smaller frame steers.

Carcass Parameters

Slaughter data for steers at the end of the finishing phase, adjusted to a constant backfat thickness, is presented in Table XII. Charolais steers were heavier than the Angus steers and the control steers were heavier than the restricted steers. No differences (P> .05) were observed in hot dressing percent or rib eye area although the Charolais steers did tend to have larger rib eyes. In addition, quality grade was higher for older steers than for younger steers. Additional slaughter information is presented in Appendix Table XVIII.

When considering carcass composition at final slaughter (Appendix Table XIX), the older control steers of both breeds contained less fat

TABLE XI

EFFECT OF AGE ON COMPONENTS OF CARCASS GAIN OF STEERS DURING THE FINISHING PHASE[a]

	Older	Younger	SEM[b]
Protein gain[c], g/day	110.5	96.9	4.77
Fat gain[c], g/day	391.6	345.9	18.84
Energy gain[c], Mcal/day	4.287[d]	3.782[e]	0.161

[a] Least square means; number of observations/mean = 24.
[b] SEM = standard error of the mean.
[c] Carcass compositional changes are based on hot carcass weight.
[d,e] Means in the same row with different superscripts are different (P .05).

TABLE XII

EFFECT OF BREED AND AGE ON SLAUGHTER DATA AND CARCASS DATA OF STEERS AT THE END OF THE FINISHING PHASE[a]

	Angus		Charolais		
	Older	Younger	Older	Younger	SEM[c]
Slaughter weight, kg	422.5[d]	372.3[e]	614.9[f]	580.2[g]	21.6
Empty body weight, kg	405.1[d]	359.3[e]	594.4[f]	359.6[g]	21.3
Hot carcass weight, kg	272.5[d]	246.0[e]	400.6[f]	378.8[g]	10.6
Hot dressing percent	64.38	65.78	65.18	65.37	1.14
Backfat thickness, mm	15.4	13.8	7.8	7.1	.75
Rib eye area, cm^2	12.19	11.21	15.43	15.26	1.48
Quality grade[c]	13.5[d]	12.3[e]	12.4[d]	11.2[e]	0.6

[a] Least square means (backfat thickness is the actual measurement); number of observations/mean = 12.
[b] SEM = standard error of the mean.
[c] 10 = average good; 13 = average choice; 16 = average prime.
[d,e,f,g] Means in the same row with different superscripts are different (P .05).

(% of body composition) than the other groups within each breed. The older control steers were heavier than the other groups at the end of the growing phase as a result of the longer duration on the control ration and therefore required less time on the high energy finishing ration to reach the final slaughter point (Angus, 58 vs 181 days; Charolais, 163 vs 269 days, respectively). These results indicate that those steers spending longer on the finishing ration at an increased ADG (vs the growing ration), yielded carcasses with a greater fat content which again suggest a positive relationship between ADG and rate of fat deposition. Additional data for body composition at the onset of the growing phase and at the end of the growing and finishing phases is presented in Appendix Table XIX.

Growing and Finishing Phases Combined

Liveweight Parameters

The older restricted steers of both breeds had the lowest ($P<.05$) ADG of any age and treatment group for the growing and finishing phases combined (Table XIII). As a result, the same steers were on the experiment longer ($P<.05$) than any other group. The time required from the onset of the study to final slaughter was similar for the younger control and restricted steers of both breeds. Within treatment, the older Angus steers, which had equal gains and energetic efficiencies during the finishing phase, had lower ADG and an increased length of time on trial than the younger Angus steers. Similar results have been reported, both in studies where compensatory growth was observed (Fox et al., 1972; Morgan, 1972) and not observed (Steudemann et al., 1963; Levy et al., 1971). No difference was observed in ADG for the Angus and Charolais steers within the control group. This disagrees with Newland et al. (1979) who indicated a greater ADG for larger frame steers than British crossbred steers. The reason for this discrepancy is not apparent, but the lower gain for the Charolais steers was primarily noted during the first 100 days of the finishing phase (Table VI). Within the restricted steers, daily gains of Angus were lower than of Charolais steers. Therefore, while no difference due to breed occured with control steers, small frame steers were more adversly affected by the restriction than were larger frame steers.

These results indicate that nutrient restriction for a short period of time may not affect overall steer performance in the larger frame steers but longer periods of restriction will lead to an increased inventory time which will more than offset any increased efficiency of steers exhibiting compensatory growth during the finishing phase. Thus, even if compensatory gain can be expected, overall profitability of the production scheme would be questionable. Producers may take advantage of the compensatory growth response when attempting to make more efficient utilization of forages or home grown grains where availability is influenced by season, rainfall, temperature, etc. But, more commonly, the compensatory growth phenomenon is used when different owners are involved in the growing and finishing phases, and then by one at the expense of the other.

Nutrient Efficiency and Body Compositional Changes

Dry matter, energy and protein intake and efficiencies are presented in Table XIV. The older control steers of both breeds consumed more ($P<.05$) dry matter per day than any other treatment and age group. Intake was greater for the Charolais than Angus steers. Dry matter intake per kg weight$^{.75}$ (MBS) was greater for the older steers than the younger steers but there was no difference due to breed or treatment. The older restricted steers were the least efficient group for converting dry matter intake to liveweight gain, again due to the longer growing phase at near maintenance. The restricted younger steers were similar in efficiency to the younger control steers. Steers spending less time on the growing phase were more efficient. Nutrient restriction did not alter dry matter efficiency of younger steers since the growing phase was of shorter duration. Metabolizable energy efficiency for liveweight gain and for carcass gain was not different due to breed or treatment but younger steers were more efficient than older steers.

Control steers were less efficient at converting digestible protein intake above maintenance to protein gain than were the restricted steers (21.6 vs 55.1%). The older control steers were less efficient in converting the digestible protein consumed for protein gain than other treatment and age groups (9.26 vs 6.28 g digestible protein/g protein gain). In the latter measurement, maintenance and gain are pooled in the efficiency data.

A breed x treatment x age interaction existed in overall rate of protein deposition (Table XIII). The primary reason for the interaction was a reversal in rate of protein gain for the young steers. With the Angus, the controls gained faster whereas with the Charolais, the restricted steers gained faster. In the older steers, the controls gained faster and trends were similar for both breeds. Daily fat and energy gain followed a similar trend in that the younger steers had an increased rate of deposition when compared with the older steers, which is most likely due to the length of time spent in the growing phase. Breed and treatment had no apparent effect on daily fat and energy gain.

CHAPTER V

SUMMARY

The objective of this experiment was to determine the effect of two levels of nutrition for two durations during the growing phase on subsequent finishing phase performance of steers.

Angus and Charolais weanling steers were fed either a control or restricted growing ration for a 306 (older steers) or 95 (younger steers) day duration. Steers were then switched onto a high energy finishing ration (80% concentrate). Representative steers from each breed, treatment and age subgroup were slaughtered initially, and at the end of the growing and finishing phases to determine body composition and nutrient efficiency data.

Compensatory growth was observed in the older restricted Charolais steers when compared to the older control Charolais steers during the first part of the finishing phase. Average daily gains were, however, similar for the restricted and control Angus steers. Dry matter efficiency followed a similar trend in that the Charolais restricted steers were more efficient than their controls but no differences were observed in the Angus steers.

The older restricted and younger control steers of each breed which entered the finishing phase at equal weights, gained at similar rates. This indicates that weight gain in the finishing phase was closely related to steer weight, and was independent of previous level of nutrition and breed. This further suggests that the compensatory growth observed in the Charolais steers was due to the lighter weight of the restricted steers at the onset of the finishing phase.

For the entire finishing phase, the older steers grew more rapidly than the younger steers, had a greater rate of protein and fat deposition, and yielded carcasses with a higher quality grade. When considering dry matter and metabolizable energy efficiency for live weight gain, the older steers were less efficient than the younger steers. This was, however, due to the difference in the composition of the gain because when comparing energy efficiency for carcass energy gain, no difference occured due to breed, previous level of nutrition or animal age.

The older control steers were much heavier at the onset of the finishing phase than the other treatment and age subgroups within breed. This was due to their longer time on the growing ration. Further, these steers required a relatively shorter time on the high energy finishing ration to reach final slaughter and yielded leaner carcasses. Therefore, final body composition of steers may be related to rate of gain and steers which are primarily grown at a slower rate (control growing ration) will be leaner at slaughter than steers which attain most of their weight gain on a high energy finishing ration. This may be advantageous to the smaller, earlier maturing breeds but would be detrimental to larger, later maturing breeds.

Growth rates for the growing and finishing phases combined were greater for the younger than the older steers. Further, the younger steers were more efficient in conversion of dry matter and metabolizable energy for live weight gain and in conversion of metabolizable energy for carcass energy gain. From a practical view point, holding steers on a growing ration for a long period of time offers no advantage in overall rate of gain or nutrient efficiency. When steers were held on a growing ration for a shorter period of time on either level of nutrition, no difference was seen in nutrient efficiency for live weight or carcass gain. Overall rate of gain was lower for the younger restricted Angus steers than their controls, but no difference was observed for the younger Charolais steers. In addition, previous level of nutrition did not affect the total length of time required to reach the final slaughter endpoint for the younger steers of either breed.

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APPENDIX

TABLE XIII

EFFECT OF BREED, AGE AND TREATMENT ON WEIGHT GAIN AND COMPONENTS OF CARCASS GAIN OF STEERS DURING THE GROWING AND FINISHING PHASES COMBINED[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial weight, kg	170.9^{e}	160.9^{e}	153.0^{e}	141.3^{e}	218.0^{f}	208.0^{f}	245.9^{g}	274.2^{g}	15.7
Final weight, kg	433.7^{e}	421.3^{e}	381.4^{f}	372.2^{f}	667.4^{g}	653.2^{g}	592.4^{h}	619.1^{h}	21.0
Days on feed	425^{e}	521^{f}	312^{g}	305^{g}	450^{e}	527^{f}	327^{g}	316^{g}	6.0
Average daily gain, kg	$.75^{eh}$	$.52^{f}$	$.92^{gi}$	$.75^{h}$	$.97^{eg}$	$.76^{hi}$	$.95^{g}$	1.00^{g}	0.06
Protein gain[d], g/day	67.0^{eh}	44.9^{f}	78.3^{g}	67.0^{h}	106.6^{i}	80.7^{eg}	94.2^{g}	113.9^{i}	+.56
Fat gain[d], g/day	151.4^{e}	164.6^{e}	252.9^{f}	253.0^{f}	181.2^{e}	200.1^{e}	251.7^{f}	239.9^{f}	29.0
Energy gain[d], Mcal/day	1.792^{e}	1.794^{e}	2.808^{f}	2.746^{f}	2.292^{e}	2.325^{e}	2.884^{f}	2.882^{f}	0.264

[a] Least square means; number of observations/mean = 6.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] Carcass compositional changes are based on hot carcass weight.

[e,f,g,h,i] Means in the same row with different superscripts are different (P .05).

TABLE XIV

EFFECT OF BREED, AGE AND TREATMENT ON FEED AND ENERGY EFFICIENCY OF STEERS DURING THE GROWING AND FINISHING PHASES COMBINED[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
DMI[d], kg/day	8.01^{h}	5.98^{i}	5.82^{i}	5.86^{i}	9.93^{j}	8.53^{k}	8.52^{k}	7.91^{k}	0.61
DMI, kg/weight$_{kg}^{.75}$/day	115.6^{h}	99.5^{h}	92.8^{i}	96.5^{i}	110.9^{h}	108.3^{h}	97.4^{i}	88.9^{i}	73.5
DMI, kg/liveweight gain, kg	34.28^{h}	18.35^{i}	8.68^{jl}	6.28^{jl}	14.59^{k}	9.75^{j}	5.8^{l}	2.75^{l}	1.26
MEI[e], Mcal/day	16.53^{h}	12.95^{h}	14.02^{h}	15.45^{h}	24.03^{i}	21.06^{i}	23.55^{i}	22.57^{i}	1.99
MEI, Mcal/liveweight gain, kg	22.56^{h}	25.91^{h}	15.19^{i}	20.66^{i}	25.14^{h}	27.60^{h}	25.00^{i}	22.71^{i}	2.94
MEI, Mcal/carcass gain, Mcal	9.25^{h}	7.49^{h}	5.52^{i}	5.61^{l}	11.14^{h}	9.40^{h}	8.26^{i}	7.80^{i}	1.01
DPI[f], g/day	704.5^{h}	319.6^{i}	456.1^{i}	392.3^{i}	852.2^{j}	504.1^{k}	664.4^{k}	554.9^{k}	46.0
DPI[g], g/carcass protein gain, g	10.42^{h}	7.20^{ij}	5.64^{i}	5.94^{i}	8.11^{hjk}	6.51^{i}	7.17^{ik}	5.23^{i}	0.71
Conversion of DPI for gain[g], %	11.15^{h}	52.13^{i}	24.18^{h}	60.19^{i}	22.75^{h}	56.36^{i}	28.39^{h}	51.68^{i}	9.92

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[a] Least square means; number of observations/means = 6.

[b] C - control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] DMI = dry matter intake.

[e] MEI = metabolizable energy intake.

[f] DPI = digestible protein intake.

[g] Conversion of DPI for gain, %.

[h,i,j,k,l] Means in the same row with different superscripts are different (P .05).

TABLE XV

EFFECT OF BREED, TREATMENT AND AGE ON SKELETAL AND ULTRASONIC BACKFAT THICKNESS MEASUREMENTS OF STEERS DURING THE GROWING AND FINISHING PHASES

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[a]	R[a]	C	R	C	R	C	R	SEM[b]
Initial[c]									
Height at withers,cm	93.3	91.6	87.5	86.4	104.4	105.9	104.3	104.5	1.94
Ultrasonic backfat thickness, mm	1.2	1.2	0.8	0.8	0.8	1.0	1.0	1.2	0.44
End of growing phase[c]									
Height at withers, cm	110.7	102.5	97.0	91.6	125.5	120.2	114.9	112.2	1.92
Height at hooks, cm	117.3	108.8	102.3	98.2	133.8	129.3	121.0	119.3	2.29
Ultrasonic backfat thickness, mm	5.5	1.3	2.0	1.3	2.4	1.1	1.2	1.1	0.29
End of finishing phase[d]									
Height at withers, cm	115.5	113.3	113.4	108.9	131.2	134.2	129.9	124.7	1.35
Height at hooks, cm	122.4	116.8	115.7	112.2	137.0	144.3	140.6	133.6	1.23
Ultrasonic backfat thickness, mm	12.5	12.5	11.0	10.3	7.5	7.8	8.5	6.8	0.41

[a] C = control growing ration, R = restricted growing ration.
[b] SEM = standard error of the mean.
[c] Number of observations/mean = 12.
[d] Number of observations/mean = 6.

TABLE XVI

EFFECT OF BREED, AGE AND TREATMENT ON FEED, ENERGY AND PROTEIN EFFICIENCY OF STEERS DURING THE FINISHING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
DMI[d], kg/day	9.36^{g}	7.85^{g}	7.11^{h}	6.78^{h}	10.30^{g}	8.55^{g}	8.24^{h}	7.67^{h}	0.80
DMI, kg/weight$^{.75}_{kg}$/day	105.3	103.6	98.1	101.6	87.4	81.8	84.1	76.1	77.3
DMI, kg/liveweight gain, kg	7.45^{g}	7.12^{g}	6.64^{i}	7.06^{i}	9.00^{h}	6.87^{g}	7.41^{j}	6.34^{i}	0.54
MEI[e], Mcal/day	27.07^{g}	22.97^{g}	20.69^{h}	19.85^{h}	30.17^{g}	25.17^{g}	24.21^{h}	22.55^{h}	2.32
MEI, Mcal/liveweight gain, kg	21.58^{gh}	20.83^{g}	19.32^{ij}	20.69^{i}	26.37^{h}	20.21^{g}	21.77^{j}	18.66^{i}	1.56
MEI, Mcal/carcass gain, Mcal	6.93	5.26	5.40	5.27	10.18	6.04	7.42	5.94	1.46
DPI[f], g/day	668.8^{g}	570.5^{g}	516.2^{h}	491.8^{h}	745.3^{g}	621.7^{g}	589.6^{h}	556.3^{h}	58.1
DPI, g/carcass protein gain, g	5.55^{g}	6.40^{h}	4.79^{g}	6.51^{h}	6.74^{gh}	7.01^{gh}	6.4^{gh}	6.00^{gh}	0.59
Conversion of DPI for gain^{g}, %	39.28^{g}	31.03^{h}	41.13^{g}	30.31^{h}	28.83^{gh}	30.07^{gh}	30.10^{gh}	38.08^{gh}	3.9

[a] Least square means, number of observations/mean = 6.
[b] C = control growing ration; R = restricted growing ration.
[c] SEM = standard error of the mean.
[d] DMI = dry matter intake.
[e] MEI = metabolizable energy intake.
[f] DPI = digestible protein intake.
[g,h,i,j] Means in the same row with different superscripts are different (P .05).

TABLE XVII

EFFECT OF BREED, AGE AND TREATMENT ON COMPONENTS OF CARCASS GAIN OF STEERS DURING THE FINISHING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C^{b}	R^{b}	C	R	C	R	C	R	SEM^{c}
Average daily gain, kg	1.29^{e}	1.13^{e}	1.05^{f}	$.99^{f}$	1.29^{g}	1.28^{g}	1.14^{h}	1.22^{h}	0.13
Protein gain[d], g/day	133.9	95.5	111.5	78.3	113.8	98.9	92.8	104.8	15.6
Fat gain[d], g/day	385.0	434.3	372.8	358.5	351.1	396.2	305.8	346.5	61.8
Energy gain[d], Mcal/day	4.355^{e}	4.605^{e}	4.116^{f}	3.798^{f}	3.926^{e}	4.266^{e}	3.384^{f}	3.833^{f}	0.529

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[a] Least square means; number of observations/mean = 6.

[b] C = control growing ration; R = restricted growing period.

[c] SEM = standard error of the mean.

[d] Carcass compositional changes are based on hot carcass weight.

[e,f,g,h] Means in the same row with different superscripts are different (P .05).

TABLE XVIII

EFFECT OF BREED, AGE AND TREATMENT ON SLAUGHTER DATA AND CARCASS DATA OF STEERS AT THE END OF THE FINISHING PHASE[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Slaughter weight, kg	432.6[e]	412.3[e]	380.4[f]	364.2[f]	618.4[g]	611.5[g]	565.5[h]	594.9[h]	25.4
Empty body weight, kg	411.7[e]	398.5[e]	366.6[f]	352.0[f]	594.8[g]	594.0[g]	546.4[h]	572.8[h]	25.0
Hot carcass weight, kg	276.8[e]	268.1[e]	253.2[f]	238.7[f]	402.4[g]	398.8[g]	368.8[h]	388.8[h]	12.4
Hot dressing percent	63.75	65.00	66.03	65.53	65.09	65.27	65.27	65.46	1.24
Backfat thickness, mm	17.4	13.5	17.1	10.4	9.5	6.1	7.6	6.6	.75
Rib eye area, cm^2	12.45	11.92	11.52	10.90	14.89	15.97	15.48	15.04	1.74
Quality grade[d]	12.8[e]	14.3[e]	11.5[f]	13.2[f]	11.9[e]	13.0[e]	11.3[f]	11.1[f]	0.69

[a] Least square means (backfat thickness is the actual measurement); number of observations/mean = 6.

[b] C = control growing ration; R = restricted growing ration.

[c] SEM = standard error of the mean.

[d] 10 = average good; 13 = average choice; 15 = average prime.

[e,f,g,h] Means in the same row with different superscripts are different (P .05).

TABLE XIX

BODY COMPOSITION BASED ON HOT CARCASS WEIGHT OF STEERS SLAUGHTERED INITIALLY AND AT THE END OF THE GROWING AND FINISHING PHASES

	Angus				Charolais				SEM[b]
	Older		Younger		Older		Younger		
Initial									
Hot carcass weight, kg	88.9		75.2		122.5		149.7		9.11
% moisture	79.5		70.2		78.7		72.3		3.29
% fat[c]	5.6		8.3		4.8		3.6		1.01
% protein	19.5		19.8		20.0		20.5		0.15
% ash	1.0		1.0		1.0		1.0		0.01
Treatment level	C[d]	R[d]	C	R	C	R	C	R	
End of growing phase									
Hot carcass weight, kg	261.7	109.6	112.7	89.9	280.9	176.6	188.5	151.5	7.28
% moisture	60.9	77.2	73.9	74.1	68.8	78.0	76.4	78.7	1.16
% fat	21.4	7.7	10.0	9.3	13.6	5.1	6.5	4.5	1.13
% protein	16.1	18.7	19.2	18.9	8-7	19.5	20.4	20.2	0.40
% ash	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.01
End of finishing phase									
Hot carcass weight, kg	295.2	274.6	271.8	232.6	402.4	386.7	352.4	372.0	6.11
% moisture	55.4	49.0	50.2	50.3	62.4	59.2	62.2	61.9	1.31
% fat	28.7	35.6	34.9	33.8	20.2	24.3	21.3	21.5	1.45
% protein	15.3	14.5	14.4	15.2	17.7	16.9	17.2	17.5	0.40
% ash	0.8	0.7	0.7	0.8	0.8	0.9	0.9	1.0	0.03

[a] Number of observations/mean = 6.

[b] SEM = standard error of the mean.

[c] Fat content was determined from ether extract procedure (A.O.A.C., 1975).

[d] C = control growing ration; R = restricted growing ration.

VITA

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Master of Science

Thesis: INFLUENCE OF AGE AND BIOLOGICAL TYPE ON GROWTH AND DEVELOPMENT OF STRESS DURING A GROWING PERIOD OF RESTRICTED OR OPTIMUM NUTRITION AND THE SUBSEQUENT FINISHING PERIOD

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