MANAGEMENT OF STEERS WITH VARIOUS FRAME SIZES ON DIFFERENT NUTRITIONAL LEVELS

by

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Review of Literature

Ways to represent growth and development

Growth is a very complex process in many ways, yet there are certain aspects of the process that can be described quantitively (Bertalanffy, 1957). There is often some confusion between "growth" and "development". Brody (1945) defines growth as a process of biological development, whereas development relates to the coordination of the diverse processes that take place as a young animal is transformed into an adult.

Growth occurs as the result of cell multiplication, cell enlargement or the incorporation of materials taken in from the environment (Brody, 1945). The literature either typifies growth as a change in weight (Brody, 1945; Weinbach, 1941; Bertalanffy, 1957) or as a change in size (Bertalanffy, 1957; Fabens, 1965; Richards, 1959) over time. The "time" element of growth has been used to develop an "age curve of growth" (Brody, 1945). This is determined by plotting body weight or size against age resulting in a sigmoid shaped curve with two principal segments. Brody (1945) describes these segments of the curve as a "self accelerating" phase with an increasing growth rate and a "self inhibiting" phase characterized by a decreasing growth rate.

The two phases of the age-growth curve are separated by the "point of inflection", referring to the point on the curve where the numerical value of the acceleration rate of growth is equal to zero. The point of inflection is a reference point marking the end of the phase of maximum velocity of growth and the transition to a decreasing velocity of growth. It maybe the age at puberty and can be a geometric point of reference for determining equivalence of age of different animals (Brody, 1945).

Growth can be represented as absolute weight gain, relative growth, rate or cumulative weight gain (Brody, 1945; Weinbach, 1941; Richards, 1959). The average absolute growth rate can be determined by dividing a gain in weight by the time taken to gain that weight. Brody (1945) contends that as you shorten the time interval you will obtain an absolute growth rate that is closer to the "true growth rate". But if you shorten the time interval up to a point where you have no increase in the velocity of growth rate you can estimate an "instantaneous growth rate" expressed as a ratio of weight change with respect to time.

A growth rate can be expressed as a percent or relative growth rate. This can be derived by dividing the weight change, by the initial weight, and multiplying by 100 to obtain a percent. When weight gain is relatively small in comparison to the weight of the organism this is also closer to the true weight gain of the animal. The resulting instantaneous relative growth rate may be expressed as the ratio of the instantaneous growth rate to weight, at the instant the rate is measured. This is impossible to measure in the lab, but by using abstract mathematics it is possible to derive an instantaneous relative growth rate (Brody, 1945).

Brody (1945) points out that a given percentage rate of growth does not indicate equivalent developmental stages. During the self-accelerating phase of growth the instantaneous growth rate is proportional to the size of the individual, and during the self-inhibiting phase of growth, the instantaneous growth rate is proportional to available space, food, etc.

Thus the integrated form of the growth equation prior to the point of inflection is represented by ($W = Ae^{kt}$) where W is size at time t, A is mature size of the individual and k is growth rate. The integrated form of the growth equation after the point of inflection is represented by ($W = A - Be^{-kt}$) where B is the growth yet to be made.

Weinbach (1941) concentrated on prenatal growth and describes the fundamental process of fetal growth as cell multiplication. It is straight-forward then to state that the total weight of the embryo at any time is proportional to or dependent on the amount, or weight of embryonic tissue already there, as cells arise only from pre-existing cells. This gives rise to a growth equation that describes growth rate as a function of an "effective weight" for growth. At conception the effective weight may be equal to the actual weight of the embryo, but as organs differentiate the effective weight may no longer be equal to actual weight.

The concept of an "impulse to grow" seems inherently related to fetal growth and growth from birth to maturity (Brody, 1945; Weinbach, 1941). Weinbach (1941) points out that it is a given quantity of fetal tissue that has an effect on rate of growth, equivalent to an additional supply of tissue. This resulted in the integrated form of the growth equation ($W = Be^{kt} - A$) or ($W = Ae^{k(t-t')} - A$) where ($B = Ae^{-kt'}$) so that t' is equal to the age parameter where the age curve crosses the age axis when $t = t'$ and $W = 0$. The constants A, k and t' can be evaluated by choosing three points equally spaced on the time axis (Weinbach, 1941).

It has been noted by Brody (1945) that growth is virtually inseparable from metabolism. Bertalanffy (1957) also discussed metabolic rates and their relationship to body size. He classified metabolic rates by their relationship to either surface area of the organism, body weight of the organism, or as metabolism related to both weight and surface area. A metabolism rate related to surface area is characterized by a decrease in oxygen consumption with an increase in size, but oxygen consumption remains constant with surface area. Oxygen consumption is proportional to body weight when metabolism is related strictly to body weight. The last situation where metabolism is related to weight and surface area is characterized by a decrease in oxygen consumption with an increase in weight but an increase in oxygen consumption with an increase in surface area.

As Bertalanffy (1957) noted different "metabolic types", he also noted different "growth types" of organisms. Growth occurs when biological synthesis (anabolism) prevails over biological breakdown (catabolism). When anabolism and catabolism are equal the instantaneous growth rate is equal to zero. This follows the laws of allometry, meaning the rate of anabolism and catabolism can be expressed as a power function of body mass.

Bertalanffy (1957) contends that the rate of catabolism is directly proportional to body weight so the exponent in the power function would be equal to 1 (one). In general, most mammals fit into Bertalanffy's first metabolic type. Here the surface rule would apply and the surface area of the animal is equal to body weight to the 2/3 power. As long as the animal is small, surface-proportional anabolism prevails over weight-proportional catabolism and the animal grows. The larger it grows the less growth there is yet remaining to be made and eventually a steady state will be reached where anabolism and catabolism balance each other and growth comes to an end.

Richards (1959) used Bertalanffy's growth function to illustrate that the numerical value of the body weight exponent for anabolism determines the three basic forms of growth equations.

Basic form of the Bertalanffy growth function:

$$W = A\ (1 - be^{-kt})^m$$

W = size at time t

A = maximum value of W

k = rate constant

b = a scaling parameter

The value of the exponent for anabolism (m) determines the slope of the line and determines the proportion of the final size of the organism at the point of inflection. Through a series of derivations when m = 0 an equation of the monomolecular form is obtained with a rate that is equal to k (A - W).

Monomolecular $W = A\ (1 - be^{-kt})$

When m = 2 an equation of the autocatalytic form is obtained with a rate equal to kW (A - W) / A.

Autocatalytic $W = A\ /\ (1 + be^{-kt})$

When m = 1 the logarithmic form of the equation is of the Gompertz type ($\log_e W = \log_e A - be^{-kt}$) with a rate equal to kW $\log_e(A - W)$.

Gompertz $W = (Ae^{-be})^{-kt}$

Since the function of size is specific for each curve type, depending on the slope, it is difficult to interpret differences in the rates derived from the different curve forms (Richards, 1959). Empirically, differences in the k's from curves having different m's is not needed, but biologically the different rates are important in theories about growth which contribute to the final size of an animal. The relationship between growth rate and time is affected by the k's mathematically (Richards, 1959).

Fabens (1965) points out that in Bertalanffy's growth curve, the function has parameters that do not change in value as an animal grows. The parameters might take on different values for different taxonomy or when different methods of measuring size are used. Getting a set of parameters so that all values of size fit the curve is usually not possible due to errors in measurement and individual errors as well. So parameter values are chosen that make the curve come as near as possible to all the data points so the amount of assumed error is as small as possible. If the observed values group around the fitted curve and do not show any definite tendency away from the curve, the curve is assumed to be correct. Curve fitting is a means of summarizing data (Fabens, 1965).

Fitzhugh (1976) notes that size measured by itself on several animals all at the same age or stage of development provides very little information about growth patterns. Growth curves reflect the lifetime interrelationship between an individuals impulse to grow and mature and the environment the animal is in. Primarily the objectives for fitting growth curves include:

1) Descriptive: information contained in the sequence of size-age points is consolidated into a relatively few parameters.

2) Predictive: the derived parameters are utilized to predict growth, feed consumption and response to selection.

The primary reasons for comparing methods of fitting growth curves include:

1) Biological interpretability of the parameters: this can be helpful to rank individuals according to biologically important characteristics like growth rate or mature size.

2) Goodness of fit: refers to minimizing deviations of actual data points from the corresponding points on the fitted curve.

3) Computational difficulty: this varies with the choice of the function and in the characteristics of the data set.

Fitzhugh (1976) further points out the best fit of n size-age points is an (n-1) polynomial, but the parameters derived are not likely to be biologically interpretable. When using logarithmic functions, again, mathematically correct, but biologically infeasible estimates of the parameters may be computed. At any given time the growth curve for a trait will represent the composite of all growth curves for all components contributing to the trait. Fitzhugh (1976) also suggests that if important events like puberty and lactation do not effect all components of a size trait similarly, then observing the composite curve and not the curves of the components may obscure the event.

Some of the biological interpretations of the parameters of growth curve functions are given by Brown et al. (1976c) and Fitzhugh (1976). These include:

A = asymptotic value for size as time (t) approaches infinity. This can be interpreted as average size at maturity independent of fluctuations in size due to the environment.

u_t = proportion of mature size attained at age (t). Degree of maturity for (y) is presumed to be correlated to other measures of maturity.

b = a scaling parameter of constant integration. This is established by the initial value of Y_0 and t_0, and this variable adjusts for situations when for example, only postnatal observations are available.

y_I = size at (t_I), age at which growth rate is a maximum. y_I, t_I are coordinates of the point of inflection and for the monomolecular curve which has no point of inflection, growth rate is a maximum at y_0, t_0.

k = a maturing index and is a function of the ratio of maximum growth rate to mature size. The specific function varies with the value of m. Since k depends on (dy/dt), A and (y_I, t_I), it serves as a measure of rate of change in growth rate.

m = the inflection parameter. This establishes degree of maturity at the point of inflection.

These biological interpretations have been used to derive some equations for traits of interest including some weighted average lifetime growth rates and some instantaneous growth rates at the point of inflection (Fitzhugh, 1976).

It has been pointed out that when making comparisons of smaller animals to larger animals, larger animals consume more and produce more in proportion to their body weight, but take longer to do so in proportion to the 0.27^{th} power of their mature body weight (Taylor, 1980a). Thus Taylor (1980a) developed two rules for introducing information on different genotypes into the growth equations. Rule number one states that you need to treat all "age" and "time" variables for the i^{th} genotype as directly proportional to $A_i^{0.27}$ where A_i is equal to mature body weight of the i^{th} genotype. This rule scales time (t_i) to a "standardized" or "metabolic" time. This results in an equation where metabolic age is equal to a ratio of time to the 0.27^{th} power of mature body weight (Taylor, 1980a; Taylor, 1980b). If it takes about 3.5 days for the fertilized egg to travel to the uterus, then metabolic age would start at (t-3.5) since growth starts then (Taylor, 1980b).

When time is age in days from an origin 3.5 days after conception, metabolic days is equal to (Taylor, 1980b):

$$O_i = \frac{@ \, (t_i - 3.5)}{A^{0.27}}$$

$@$ = weight in $Kg^{0.27}$

t_i = age in days

A = mature weight in Kg

O_i = metabolic days

The other rule that Taylor (1980a) states is that at every age that has been standardized as in rule number one you should treat all cumulated inputs and outputs for the i^{th} genotype as directly proportional to (A_i) mature body weight. This will scale variables like food consumed and live weight to standardized variables. Standardized food consumption would be a ratio of food consumed to mature body weight and standardized degree of maturity would be a ratio of current weight to mature body weight.

Another method of describing growth was introduced by Warren et al. (1980) which uses three linear regression lines fitted simultaneously. Weights of each animal were regressed on age. This procedure is useful when there are large fluctuations in the weights caused by environmental effects. The biological importance of the y-intersect of the first line is that it is representative of birth weight. The first regression coefficient represents the initial growth rate, the second represents the decreasing rate of growth after maximum growth rate is reached and the third represents the increase in weight after maturity. The intercept of the first and second regression line marks age where growth rate decreases and the intercept of the second and third regression line is the age where lean mature weight or structural size of an animal is reached. This is not necessarily the maximum weight an animal may attain.

Oltjen and Owens (1986) have noted that linear regression is a very good way to get estimates of the growth parameters for a set of data, but warn that extrapolating beyond the data set is risky. On the other hand mechanistic models can be extrapolated with some confidence depending on the accuracy of the model's simulation of fundamental biological growth.

The computer has been used by Oltjen et al. (1986b) to develop a model to predict growth. Rather than the typical sigmoid growth curve that results when growth is plotted against time, they take current body composition and combine a level of nutrition to adjust growth and the resulting components of growth, to determine a pattern of growth.

Trenkle and Marple (1983) pointed out that growth can be observed by measuring the change in body weight per unit of time or by plotting body weight against age. The change in weight per unit of time plot can be used to compare effects of different treatments or can be used to describe growth rates. The plot of weight against age can be used to construct curves that can be used to describe patterns of growth of animals or specific tissues.

Maturity and its relation to growth

Brody (1937) recognized the fact that there was a difference in "chronological" time and "physiological" time as well as a difference in "gravitational" weight and "physiological" weight. He noted that chronological time has a different physiological time significance in the life of different organisms as well as having a different physiological time significance at different ages in different organisms. A chronological time unit has different physiological time significance in organisms at different ages. It was also noted by Brody (1937) that physiological time may be accelerated or retarded in an organism by available food supply, environmental temperature, hormonal action, etc..

In growth equations the "k" term refers to the relative or fractional decline in the velocity of growth in relation to increasing age. Brody (1937) notes k for a cow is equal to 0.054 and k for a rat is equal to 0.664. This means that a rat matures (0.644/0.054=11.9) 11.9 times faster than a cow. Another way to look at this is that one month in the life of a rat is equivalent to 11.9 months in the life of a cow and by comparison 1 month in the life of a cow is equivalent to (0.054/0.644=0.08) 0.08 months in the life of a rat.

In relation to weight, gravitational live weight has but relative significance (Brody, 1937). It has been pointed out that large animals are less active per unit of live weight than small animals. Metabolism of materials per unit live weight decreases with increasing live weight, and productivity of milk, meat, etc. per unit live weight decreases with increasing live weight. The physiological significance per unit live weight, may often be increased or decreased by regulating food supply, activity or hormonal action. In general the activity and the "active mass" is greater per unit of live weight in thin animals compared to fat animals (Brody, 1937).

Brody (1937) recognized that metabolism, excretion and production does not increase linearly with body weight but rather with the 0.73^{rd} power of body weight. Thus the physiologic unit of mass should not be simple gravitational weight of an animal but rather a fractional power of gravitational weight. Physiological mass is then equal to some parameter multiplied by live weight in kg to the 0.73^{rd} power. Brody (1937) also noted that the metabolic and productive processes of an animal varies with the 0.73^{rd} power of live weight as the weight of the "active" visceral organs contrasted to the connective and supportive tissues of an animal vary with the 0.73rd power of body weight.

The relationship between mature live weight and the time it takes to reach mature live weight has been discussed by Taylor (1965). He points out that in many situations mature live weight of an animal can give a reasonable measure of mature size of that animal but suggests that the effects of the environment can be so great that any unqualified use of mature live weight is almost worthless. This compounds the problem, as if mature size is not clearly defined then it is impossible to say how long it takes an animal to reach its mature size. Taylor (1965) points out that since growth is dependent on the plane of nutrition of the animal, the error in estimating time taken to mature will always be greater than estimating mature size. In naturally occurring situations the time taken to mature has less variation than mature weight. In general the larger the mature size, the longer tends to be the time an animal takes to mature. Taylor (1965) has calculated that the time a species takes to reach any particular degree of maturity tends to be directly proportional to its mature weight raised to the 0.27th power.

Fitzhugh and Taylor (1971) have determined that the "degree of maturity" that an animal has reached is a ratio of the trait in question to mature size. Since growth rate is a change in weight over time, and maturation rate is a change in maturity over time, then a maturation rate is actually a growth rate relative to mature size. They have noted that in order to make any analysis involving degree of maturity the minimum information required would include a measure of the mature size of the animal and at least one of the following:

1) age at some fixed size.

2) size at some fixed age.

3) size and age at a constant degree of maturity or some definable stage like puberty.

The research by Fitzhugh and Taylor (1971) points out that animals more mature at a given age were more mature at a later age. In relation to live weight, animals more mature at any age tend to be lighter at maturity or animals heavier at maturity tend to be less mature at earlier ages. They also note that animals that mature faster and at earlier ages tend to mature more slowly at later ages and animals with a higher than average relative growth rate early in the growing period tend to have a lower than average relative growth rate towards the end of the growing period. Size at any immature age, then is the extent, or what proportion of its mature size it has reached. Any deviation from this proportionality will result from differing maturing rates.

Brown et al. (1972a) note that variation in patterns of growth is to be expected as a consequence of past selection procedures that have included:

1) visual appraisal.
2) pedigree selection.
3) emphasis on single measures of weight.
4) a multitude of breeding objectives.

They note that the weight of an animal cannot be properly evaluated as to its meaning in terms of a projected mature weight or to a rate of maturing unless the approximate stage of maturity is known. Selection for weight and selection for gain do not involve identical sets of genes (Brown et al., 1972b). Thus selection for large early gains would not necessarily increase body weight at all ages nor would selection for heavy body weight at fixed ages necessarily mean an increase in gain over all periods.

In trying to relate gain to rate of maturity it has been pointed out that gains at young ages are negatively correlated to gains at older ages, as large early gains indicate early maturing individuals which have a rapid decline in growth after a relatively short period of rapid linear growth (Brown et al., 1972b). Brown et al. (1972b) also note that the large gains of the early maturing individuals gave them a weight advantage until a high degree of maturity had been reached. At this time the later maturing individuals with smaller gains but a longer growing period became heavier than the earlier maturing individuals. They note that it seems that genotype for gain, and genetic limits on mature weight combine to establish the general rate of maturing and development pattern of the animal.

Degree of maturity cannot be as accurately measured on an immature animal as you can measure a weight or a height on an animal. By using known gains and body weights of immature cattle along with some measure of body composition, and knowing the growth curve of the sire and dam you can get an approximation of degree of maturity (Brown et al., 1972b). They also point out the key to evaluating maturity and interpreting weight changes, is to have an accurate estimate of the eventual mature weight. This gives an idea of the relative amount of development that has taken place.

Nutrition and management

An animal's growth response in relation to the level of nutrition presented to the animal has interested researchers a great deal, as evidenced by the amount of literature on the topic. Heinemann and Van Keuren (1956) investigated weaned calves wintered on three levels of nutrition producing three different average daily gains. The cattle were then grazed to determine the effect of different winter gains on subsequent growth. At the end of the grazing period there was a negative correlation between the winter gain and the pasture gain, those cattle that had a lower average daily gain during the winter had a higher average daily gain during the grazing period. These cattle were then placed on full feed, but they recognized no significant differences in this period of growth.

Bohman (1955) reported that cattle fed earlier maturity hay during the wintering period expressed greater weight gains when compared to cattle fed later maturity hay during the same period. The following summer these cattle were grazed on pasture, and the cattle fed the lesser quality hay gained more during the grazing season than the cattle fed the better quality hay during the winter. By the end of the first year the difference in the weight of the two groups of cattle were small with the cattle having received the better hay weighing slightly more than the other group. By the end of two years the two groups of cattle were equal in weight.

Bohman and Torrell (1956) further investigated the concept of compensatory growth by considering the effects of a protein supplement fed in conjunction with different quality hay. Cattle that had their growth retarded by poor quality hay expressed accelerated growth rates during the summer pasture season, and were as heavy as those that had received better quality hay during the winter. All cattle that received a protein supplement during the winter were heavier than the nonsupplemented cattle by the end of the first year.

Guenther et al. (1965) evaluated the differences in the deposition of bone, lean and fat in relation to nutritional level. Steers were fed two levels of nutrition, a high level and a moderate level, and slaughtered at an age-constant and at a weight-constant basis. They noted that rate of deposition of lean tissue reach a maximum early in the test and diminished as the steers reached maturity. The rate of lean deposition favored the steers on a higher level of nutrition. At an age-constant basis the steers on a high level of nutrition produced more lean, but as the steers were allowed to reach a weight-constant basis before slaughter there was not a significant difference in the two levels of nutrition. Fat deposits were most rapid in the later stages of the feeding period. They also noted a sharp increase in the deposition of fat after lean tissue production had subsided. Steers on a high level of nutrition deposited more fat than the moderate level steers, but the differences were not significant at all slaughter points. Skeletal development was not affected by the level of nutrition and seemed to be more related to the age of the animal or the time on feed.

Berg and Butterfield (1968) were unable to determine the relation of muscle and bone tissue, or how plane of nutrition affects the growth of these tissues. It may be no more than a slowing down or speeding up of the whole growth process. They point out that the fattening process can be enhanced or retarded, relative to muscle and bone, by altering the nutrition of the animal. A low plane of nutrition retards fat deposition, and an animal in a semi-starvation state will deplete fat deposits. When an animal is allowed normal nutritional levels this will lead to a normal relationship of bone, fat and muscle, if allowed enough time. They do point out that the immediately postnatal period might be the most critical for normal muscle-weight distribution.

Meyer et al. (1965) compared the response of cattle fed different levels of nutrition during different periods of time. During the first period cattle were fed a low, medium or high level of nutrition. The high level cattle were slaughtered and the low and medium cattle were placed on feed in period two on a low, medium, liberal, and high level of nutrition. The high level cattle were slaughtered and the other cattle were continued on a high level of nutrition. In each period a compensatory gain response was demonstrated in the cattle, even though the realimentation occurred at different levels of nutrition. The major difference they noted was that the cattle receiving the high energy ration throughout had a lower net energy requirement. The cattle realimented on the high energy compared to realimentation on low to medium levels of nutrition also had lower net energy requirements. Those fattened in period three of the test did not have a higher total net energy requirement, but it did require more days to get the cattle to an equal empty body weight. This agrees with Henrickson et al. (1965) who reported that cattle need to be fed to gain rapidly to reach slaughter weight earlier and more efficiently.

Stuedemann et al. (1968) compared calves on mothers that were producing different levels of milk. At the end of eight months some of the calves in each respective group were slaughtered for comparison. As the level of nutrition increased live weight gain increased and in the slaughtered calves the higher nutritional levels produced favorable dressing percents, carcass grade and skeletal scale. As the level of nutrition was decreased the amount of fat, lean and bone decreased. In the feedlot phase of the experiment they did not detect any significant differences due to preweaning milk level. They did note that it required more days to reach a desired constant weight for the calves receiving the lower nutrition levels prior to eight months of age. They pointed out that at constant slaughter weights, carcasses tended to contain a higher percent of lean and bone with a lower percent of fat as the level of nutrition increased during early life.

The efficiency of production, another important consideration, was investigated by Joandet and Cartwright

(1969). They note that the efficiency of individual slaughter cattle measured as an output/input function of the individual, may rank quite differently when compared to the output/input function of the herd. As a result, within a herd, heifers should be bred according to weight rather than age. Weight at which heifers should be bred was different for different breed groups. They also point out that weight of the female can fluctuate considerably due to reproduction and lactation status. Thus comparison of weights of cows taken at constant ages does not appear logical without considering the environmental conditions.

Levy et al. (1971) point out the factors that influence the growth response following a period of restricted gain include:

1) age at which restricted feeding is started
2) duration of restricted feeding period
3) slaughter weight desired
4) level of nutrition

They fed bull calves to determine if they could detect a compensatory gain response based on the above factors. In their research they did not find any compensatory gain. They did note that the underfed animals typically exhibited less kidney, pelvic and cod fat and required less fat trimming, resulting in a higher proportion of saleable meat. The carcasses of the underfed cattle contained a higher percent of bone. The underfed cattle also exhibited a lower feed conversion.

In another attempt to look at growth responses in terms of level of nutrition Perry et al. (1971) wintered some calves, under similar conditions, and then supplemented the calves on grass to receive different levels of nutrition. They found supplementation produced an increased average daily gain during the pasturing phase, but the calves that were supplemented and gained higher on pasture had reduced average daily gains in the subsequent feedlot phase. They did not find significant differences in the feedlot phase of the project but did note that the unsupplemented cattle on grass did require less concentrates for the total period of the test, but required more days to reach a Choice quality grade.

Fox et al. (1972) reported that steers with compensatory gain deposit more protein during the first period of realimentation and deposit more fat during the last period of realimentation in comparison to steers fed continuously. This was the result of feeding steers on a maintenance ration for five to six months before putting them on full feed and comparing them to steers placed on full feed immediately and then slaughtering representative steers from each group at slaughter weights of 364 kg and 454 kg. The carcasses of steers with compensatory gains were higher in protein and lower in fat at 364 kg but were similar in composition at 454 kg. The compensatory steers required more time to reach the respective slaughter weights, and the total energy required was slightly more than the continuously fed steers.

In a similar study Lancaster et al. (1973) placed one group of steers on a growing ration for 76 days before placing them on full feed and placed another group on full feed immediately. At the end of the growing period the steers that had been on full feed were heavier, gained faster, utilized less feed per pound of gain, had more wither height growth and were consuming more feed per day. During the second period when all cattle were on full feed the grower steers exhibited a higher average daily gain and consumed more feed per day. The continuously fed steers had a more efficient feed to gain ratio. Overall, the average daily gain was not different for the two groups of steers. The continuously fed steers had higher hot carcass weights and more carcass fat which resulted in higher marbling scores and higher carcass grades. The grower steers exhibited higher cutability carcasses.

Lake et al. (1974) investigated the management of yearling steers on grass and how supplementation of grain affected gains. Energy supplementation increased gains in all cases when compared to nonsupplemented cattle, but the maximum response to supplementation was at the 4.0 lb. level. Gains were higher during the first 63 days than the remainder of the grazing period. The best response to the 4.0 lb. level as compared to higher levels of supplementation was explained by the fact that the higher levels of supplementation reduced the intake of the high protein forage, thus reducing performance. Another consideration for supplementation during grazing is the fact that the protein to energy ratio may be wider resulting in more efficient nitrogen utilization. When cattle were placed in the feedlot, daily gains, dry matter consumption and feed conversion were not affected by the previous treatment of the cattle. None of the carcass characteristics were affected by level of energy fed on pasture. Supplementation on pasture reduced the number of days required in the feedlot.

A comparison of production resulting from different management systems has also been investigated by Bowling et al. (1978). They note that in general, any management system which provided a higher level of energy intake caused a noticeable increase in weight. In all cases grain feeding resulted in heavier steers with higher dressing percents and higher USDA Quality Grades. Yearlings raised and slaughtered from grass feeding only or from grass-grain combination feeding, yielded a higher percent of primal cuts when compared to grain fed cattle. By two years of age there was no advantage in the grain-fed versus the forage fed cattle. The steers fed grain had higher dressing percents but had more trimmable fat which lowered the yield of primal cuts while the grass-fed steers with lower dressing percents had a higher yield of primal cuts. Grass-fed steers graded lower and in order for a carcass to reach the choice quality grade cattle had to gain 225 kg or more on a grain diet.

Slaughter calves produced almost twice as much protein per day, but less than half as much total protein as cattle slaughtered at two years of age (Bowling et al., 1978). As age increased the rate of protein production decreased, however the decrease was less in management systems that utilized feedstuffs with a higher energy concentration. Grass-fed steers had a higher percent bone and lean and a lower percent fat, this resulted from a deficiency of fat and not an increase of bone or lean. Subcutaneous fat paralleled the energy concentration of the diet. Rib eye area varied with energy intake but was largely the result of the size of the carcass produced.

An attempt to determine the most profitable system of backgrounding or grazing beef cattle has resulted in a linear program model derived by Jessee and Buccola (1979). This model can be used to develop guidelines for the efficient use of farm resources, labor and capital. More specifically the model allows:

1) Livestock purchase, sale, and production activities with variable rates of gain and variable purchase and sale weights.

2) Feed purchase, sale, and production activities at variable levels of fertilization and on alternative soil classes.

3) Capital borrowing activities.

4) The option of hiring additional labor.

The linear program model then generates by period, the profit maximizing crop mix and rates of fertilization, optimal buying and selling weights of cattle, the optimal ration, and the optimal average daily gains for cattle, given a set of crop and livestock prices and costs.

Danner et al. (1980) investigated the effect of feeding system by comparing performance of yearling steers and steer calves fed different levels of concentrates and corn silage. Heifer calves were fed at different protein levels as well. Yearling steers fed a 40% concentrate ration compared to those fed an 85% concentrate ration had similar average daily gains early in the feeding period, but later in the feeding period the steers receiving the higher level gained faster and more efficiently. Steer calves fed an 85% concentrate ration had higher gains than calves fed only silage but the difference was not as great as noted in yearling steers. Steers fed high silage rations had lower dressing percents than those fed high grain rations. Heifers showed the same trend but there was less difference. As a result the final live weights were adjusted to the mean dressing percent for all treatments within each trial to remove this bias. Steer calves were the most efficient followed by the heifer calves and then the yearlings when feed efficiency was based on metabolizable energy consumed per kilogram of retail product gain.

Another way to look at different growth responses is to start with cattle of different frame sizes and subject them to similar nutritional levels as Maino et al. (1981) have done. They selected cattle representative of frame size 3, 4 and 5, and placed them in a postweaning grazing test. They noted the frame size 5 cattle at the end of the test had the heaviest carcass weights, the largest rib eyes, less backfat, the least kidney, heart and pelvic fat, the most percent lean, the lowest yield grade and the lowest quality grade. They detected no differences in the frame size 3 and 4 cattle. They found no average daily gain advantage in the larger framed cattle. There were no actual feed efficiency data available, but with no gain advantage plus higher initial weights the larger framed cattle would indicate a lower feed efficiency.

As Thonney et al. (1981), investigating feed efficiency of cattle of different mature sizes, pointed out that dietary energy density does effect growth rate and feed efficiency when diet dry matter intake is constant. They note that energetic efficiency may be an impractical measure of production efficiency, as production of lean is more desirable than production of fat. Making accurate comparisons of the efficiencies of different cattle types depends on the expression used to evaluate efficiency as well as the endpoint at which the comparison is made. They further point out that the economics of feeding cattle depends partially on the added net return expected from additional weight gain. Thus you must know the number of days required for a specific weight gain, the price of cattle at different weights and the cost of feed required for cattle to gain additional weight.

The effect of pasture growth rate and the effect of live weight gain in cattle has been researched by Ebersohm and Moir (1984). Managing pastures so that growth rate of the pasture increases, resulted in more dry matter available to livestock. They felt that this may be counter productive as there was a negative correlation between pasture dry matter and dietary energy concentration.

Dikeman et al. (1985) have considered accelerated beef production versus conventional beef production using larger and smaller framed cattle. Higher average daily gains were achieved when cattle were produced in an accelerated management system when compared to cattle produced in a conventional management system. Metabolizable energy required per kilogram of gain was lower for cattle on the accelerated system. Larger framed cattle gained faster and consumed more metabolizable energy per day than the smaller framed cattle in the accelerated management, but the larger framed cattle were still more efficient than the smaller framed cattle. There was no efficiency difference in the larger and smaller framed cattle in the conventional system of production. They note a considerable advantage in breakeven price when large framed cattle are produced in the accelerated system as compared to a conventional system. The smaller framed cattle had equal breakeven prices in both systems. They also note that the cost per kilogram of retail product favored cattle produced in the accelerated system. The larger frame type of cattle with genetic potential for rapid growth were most economical when fed for maximum growth after weaning. The smaller frame type cattle did not have the genetic potential for rapid growth needed to go directly to the full feeding phase. The smaller frame cattle raised in the conventional production system, can be economical when the cattle are slaughtered at lighter weights.

Schalles et al. (1983) point out that there is no difference in the total feed energy required to produce a pound of retail cut when you compare breeds or management system. But when the additional costs of yardage, facilities, labor and interest are considered, then the accelerated management system is more economical than the conventional production scheme.

Most of the literature mentioned so far has referred to experiments where earlier maturing cattle were used. Steen (1986) investigated the growth response of the Fresian cattle, as they are a later maturing breed. He noted that when growth was restricted below 0.73 kg per day during the growing period in the winter, there was a reduction in compensatory response during a later growing and feeding period. The major reason for this was that the later maturing breeds during a period of restricted growth may lose more muscle as they are not carrying much fat. When the cattle are allowed to compensate for the restricted growth they were unable to regain to a level comparable to steers that were less severely restricted.

Oltjen et al. (1986b), in their development of a computer model to describe growth, have noted some differences in fat and thin animals. Fatter animals fed a high energy diet ad lib remain fatter through subsequent periods of growth. Larger framed steers fed lower energy diets were leaner than those fed high energy diets. As body weights increase the composition of thinner animals approaches that of fatter animals and at usual slaughter weights, small, medium and large framed steers have similar compositions.

In a recent article White et al. (1987) wintered cattle on four levels of nutrition. Some of the cattle were restricted to lose weight. Half of the cattle were grazed and then placed on full feed while the other half were placed directly on feed. The cattle were slaughtered at about 420 kg live weight. Even though some of the cattle lost weight during the wintering phase it had little influence by the time the cattle had completed the finishing phase.

In relation to feed intake levels for feedlot cattle, Hyer et al. (1986) have suggested that intake levels decline as the percent of empty body fat reaches 32% plus or minus 1%. This corresponds to a point where steers typically reach the Choice Quality Grade. As intake levels are reduced this would also be a point where a cattle feeder would expect to see decreased performance.

I. MANAGEMENT OF STEERS WITH VARIOUS FRAME SIZES ON DIFFERENT NUTRITIONAL LEVELS

SUMMARY

Hip height was used to calculate frame scores for 221 Simmental, White Park, Limousin and Hereford sired crossbred steers weaned in the fall. Scores of 1.59 to 3.79, 3.80 to 4.61 and 4.62 to 7.02 respectively were designated small (S), medium (M) and large (L). Three gain levels of: 0.50, 0.73, 0.95; 0.55, 0.77, 1.00; and 0.60, 0.82, 1.05 kg/d were targeted for steers in (S), (M) and (L) groups, respectively.

Following a wintering phase of 105 d individuals from each winter treatment and frame group were randomly assigned to native range pasture at stocking rates of 1X, 2X, 2.5X and 3X of normal stocking, and six monoculture Switchgrass pastures stocked at a normal rate. Half of the cattle were provided 1.8 kg of sorghum grain (IFN 4-20-893) per head/d with 200 mg of Rumensin. After 75 d on pasture 201 steers were finished for 93 d in a commercial feedlot and slaughtered.

Final weight means of 635, 575 and 555 kg for L, M and S steers were different ($P<.05$). Small steers produced carcasses with mean backfat of 10.51 mm which was greater ($P<.05$) than the 9.19 mm of M and 8.14 mm of L. Carcass yield grades of 2.13, 1.98 and 1.67 were recorded for S, M and L respectively ($P<.05$). Although steers wintered at lower levels of ADG expressed compensatory gains in later

feeding regimes, they failed to achieve final weights equal to those wintered at higher ADG levels. Larger framed steers wintered at low ADG levels and grazing pastures which provided low levels of nutrition produced carcasses that were too heavy with insufficient fat to meet packer acceptability.

Introduction

For years cattleman have tried to capitalize on the compensatory gain response that is expressed by cattle following a period of restricted growth. Conventional management of fall weaned calves has included a wintering period in which the cattle were fed to gain only minimal amounts of fat and yet continue to grow in frame and muscle. These yearlings were then summered on grass and eventually placed in the feedlot to be fattened.

With the importation of the European cattle breeds into the United States, it seems that frame size has tended to increase in many cattle and yet many cattle remain relatively small. Even though we have been able to detect these changes in the cattle, many cattleman continue to manage their stock as they have in the past.

This experiment was initiated to determine if managing the nutritional level cattle receive during the various phases of a conventional wintering-summering-feedlot management program would have any effect on the compensatory gain response and ultimately the carcass produced by cattle of diverse frame sizes.

With the continual change in the growth pattern exhibited by cattle, it is necessary to evaluate current husbandry techniques practiced by cattlemen in order to continue to produce a product that is in demand by the packer and consumers from the range of frame size that begin the chain of events that ultimately produce the beef we consume.

Experimental Procedure

Two hundred twenty-one Hereford X Simmental, White Park X Hereford, Angus X Limousin and seventy-five percent Simmental cross steer calves with recorded birth dates were acquired from four ranches near Hays, Kansas. On January 14, 1986 hip heights were measured and frame scores calculated from the following equation (Beef Improvement Federation, 1986):

$$FS = -11.548 + 0.4878(Ht) - 0.0289(DA) + 0.00001947(DA)^2 - 0.0000334(Ht)(DA)$$

FS = Frame Score

Ht = Hip Height

DA = Days of Age

Calves with frame scores ranging from 1.50 to 3.79 were designated the small-frame group, 3.80 to 4.61 the medium-frame group and 4.62 to 7.02 the large-frame group. The cattle were weighed on January 17, 1986 and the frame groups were further divided into high, medium and low nutrition groups with target daily gains presented in Table 1. The rations fed and actual daily gains are also presented in Table 1.

Following a 105 day wintering period, the cattle were weighed and ultrasonic backfat measurements were recorded. This completed the wintering phase and the steers were used to stock 14 pastures with different supplementation treatments and intensities of grazing.

Pastures consisting of native range at the Fort Hays Branch Experiment Station (Olson 1987) were stocked at 1X (a normal stocking rate), 2X (twice normal stocking rate), 2.5X (two and one half times normal stocking rate) and 3X (three times normal stocking rate) levels and six monoculture Switchgrass (Panicum Virgatum L.) pastures were also stocked (table 2). At each level of stocking, and the switchgrass pastures, a supplement was provided to one half of the cattle. Supplementation consisted of 1.8 kg of sorghum grain (IFN 4-20-893) with 200 mg of Rumensin per head/day. The steers received a Synovex implant before they were placed in their respective pasture.

The steers were weighed and ultrasonic backfat measurements were recorded at the end of a 75 day grazing period. The steers on the 1X stocked pastures were returned to complete their full grazing season and dropped from this study. The other 201 steers were placed in a commercial feedlot north of Hays, Kansas. The cattle were placed in pens according to their respective wintering groups. A typical feedlot ration was provided to all cattle (table 3).

At the end of a 93 day feedlot feeding phase the cattle were slaughtered. Carcass weights were used to calculate individual final weights using a dressing percent of 63%. Carcass backfat was measured at the 12th rib and a marbling score was recorded.

All data where analyzed by least-squares analysis of variance utilizing the General Linear Models procedures of the Statistical Analysis System (SAS, 1985). F-tests were conducted to determine significant effects and t-tests were utilized to determine significant differences among main effect and interaction means of the significant effects. Animal age was used as a covariate in all analysis.

Weight data collected at the end of the wintering phase were analyzed using the following model:

Dependent variable = winter nutrition group, frame group, animal age.

Ultrasound backfat measurements recorded at the end of the wintering phase were analyzed using the following model:

Dependent variable = winter nutrition group, frame group, animal age, winter nutrition group * frame group.

Weight data and backfat data collected at the end of the pasturing phase were analyzed in a split plot design. The following model was used:

Dependent variable = frame group, winter nutrition group, frame group * winter nutrition group, pasture treatment, supplementation, winter group * supplementation, frame group * supplementation, animal age.

The frame group * winter nutrition group interaction becomes the error term for the whole plot.

Weight and carcass data recorded at the end of the finishing phase were analyzed using a split-split plot design. The following model was used:

Dependent variable = frame group, winter nutrition group, frame group * winter nutrition group, pasture treatment, supplementation, pasture * supplementation, frame * pasture * supplementation, animal age.

The frame group * winter nutrition group interaction becomes the error term for the whole plot while the pasture treatment * supplementation becomes the error term for the split plot.

TABLE 1. WINTER RATIONS AND DAILY GAINS (kg/day)

	Nutrition Group		
	Low	Medium	High
Small-frame			
Sorghum Silage (3-04-468)	14.5	15.9	15.9
Prairie Hay (1-03-191)	2.5	1.27	0.0
Sorghum grain (4-20-893)	0.0	1.36	3.09
Soybean Meal (5-04-600)	.45	.36	.25
Urea (5-05-070)	.027	.027	.027
Projected Daily Gain	0.50	0.73	0.95
Actual Daily Gain	0.53	0.78	1.02
Medium-frame			
Sorghum Silage (3-04-468)	16.8	18.18	17.73
Prairie Hay (1-03-191)	2.5	1.27	0.0
Sorghum grain (4-20-893)	0.0	1.36	3.41
Soybean Meal (5-04-600)	.52	.41	.27
Urea (5-05-070)	.027	.027	.027
Projected Daily Gain	0.55	0.77	1.00
Actual Daily Gain	0.55	0.82	.98
Large-frame			
Sorghum Silage (3-04-468)	19.55	20.91	19.55
Prairie Hay (1-03-191)	2.5	1.27	0.0
Sorghum grain (4-20-893)	0.0	1.36	3.86
Soybean Meal (5-04-600)	.59	.45	.29
Urea (5-05-070)	.027	.027	.027
Projected Daily Gain	0.60	0.82	1.05
Actual Daily Gain	0.60	0.85	1.08

TABLE 2. PASTURE STOCKING RATES

Pasture	Treatment	Acres/steer
1A	Season-long	3.6
1B	3X (IES)[1]	1.2
2A	2.5X (IES)	1.4
2B	2X (IES)	1.8
3A	3X (IES)	1.2
3B	Season-long	3.6
4A	2X (IES)	1.8
4B	2.5X (IES)	1.4
SWITCHGRASS:		
SW1-6		3.0

[1] Intensive Early Stocking

TABLE 3. FEEDLOT RATION (dry matter basis)

	%
Alfalfa Hay (1-00-063)	9.0
Fat (4-00-367)	2.0
Molasses (4-04-696)	3.0
Protein Supplement (45% CP)	4.5
Sorghum grain (4-16-295)	40.75
Corn (4-28-244)	40.75
	100.0

Results and Discussion

Of the 221 head of steers that started the experiment only 201 head have final weight and carcass information, as the others were used in the full season grazing comparison of the Switchgrass, 2X, 2.5X and 3X stocking rates.

Mean weights for the large framed cattle at the end of the wintering phase were significantly heavier than either small or medium framed steers ($P \leq .0001$). This trend continued through the end of the pasture ($P \leq .0001$) and feedlot phase ($P \leq .0001$). Similar results were obtained by Maino et al. (1981). The large framed steers produced carcasses with less backfat than small framed steers ($P \leq .0006$), although there was little difference in the large and medium framed steers. USDA Cutability Grades for carcasses from large framed steers were numerically lower when compared to the carcasses from the medium or small framed steers ($P \leq .0003$). Marbling scores from carcasses produced by the large framed steers were significantly lower than the medium or small framed steers ($P \leq .01$), and USDA Quality Grades tended to follow the same trend (table 4). Maino et al. (1981) reported carcass data very much in agreement with the data reported here.

The medium framed steers were intermediate in their mean weights at the completion of the wintering phase, grazing season and at the end of the feedlot phase ($P \leq .0001$). The carcass backfat mean for the medium framed steers was slightly more than the large framed steers which resulted in USDA Cutability scores different from the large framed steers ($P \leq .0003$), although far from undesirable. The Marbling score means for the medium framed group was higher than those in the large framed group ($P \leq .01$) (table 4).

The small framed type of steers had the lightest mean weights at the completion of all phases of the experiment ($P \leq .0001$). There was significantly more carcass backfat on the small framed steers when compared to the medium or large steers. USDA Cutability scores for the small framed cattle were higher numerically when compared to the large framed steers ($P \leq .0003$) as well as marbling scores ($P \leq .01$). USDA Quality Grade scores tended to be higher for the small framed steers when compared to the large framed steers (table 4).

Cattle on the high energy winter ration were heavier than the medium or low level of nutrition at the completion of the wintering period and grazing season ($P \leq .0001$), and when fed out were heavier ($P \leq .0006$) (table 5). These findings are in contrast to those reported by Heinemann and Van Keuren (1956) and similar to the results reported by Bohman (1955) and Bohman and Torrell (1956). Backfat measurement means at the end of the wintering phase were 4.67mm, 3.27mm and 2.65 mm for the high, medium and low level winter nutrition, respectively. These differences ($P \leq .0001$) continued through the end of the grazing season with backfat measurements of 3.78 mm, 3.21 mm and 2.84 mm for the high, medium and low nutrition groups, respectively ($P \leq .0001$) (table 5). At the completion of the feedlot phase the low nutrition level of wintering resulted in carcasses with less carcass backfat than the medium or high level of nutrition ($P \leq .0019$). Carcass backfats were 10.30 mm, 9.41 mm and 8.18 mm for the high, medium and low nutrition groups respectively, with no difference between the high and medium level of nutrition (table 5). Marbling scores from carcasses of steers wintered on a high level of nutrition were higher than medium or low levels of nutrition during the winter period ($P \leq .0015$). This tends to agree with Guenther et al. (1965) as well as Oltjen et al. (1986a) and Oltjen et al (1986b).

Cattle grazed on 2X and 2.5X grazing management programs had the highest mean weights at the end of the grazing season ($P \leq .0004$) (table 6). Cattle in the 3X system tend to have less backfat at the end of the grazing season. Ending weights were heaviest for cattle grazed on the 2X and lowest for cattle grazed at the 3X stocking rate ($P \leq .0004$) (table 6). The indications are that the 3X stocking rate is too high to maintain sufficient gains, while the 2X and 2.5X rates may be more suitable (Ebersohm and Moir, 1984).

Supplementation on pasture resulted in heavier weights at the end of the grazing season ($P \leq .0001$) (Lake et al., 1974). This was also the case at the end of the feedlot feeding phase as well ($P \leq .0228$) (table 7). Similar results were reported by Bohman and Torrell (1956).

Levy et al. (1971) point out that the growth response potential following restricted nutrition feeding is effect by, among other factors, the slaughter weight desired. If we would have slaughtered these steers at a weight constant basis in each frame group, the low level wintered steers would have probably exhibited final weights and carcasses very similar in composition to the high level wintered steers if allowed sufficient time. This tends to bring home the point made by Henrickson et al. (1965), that cattle need to be fed to gain rapidly to reach slaughter weights earlier.

Although not significant at a $P < .05$ level, the WINTER*FRAME interaction revealed that backfat at the end of the wintering phase was highest in the small framed cattle fed high levels of nutrition during the winter period and lowest for the large framed cattle fed low levels of nutrition during the wintering phase. This indicates the differences in nutritional requirements to produce fattening in the different frame groups.

There was a general tendency for large frame cattle to be heavier on all stocking rates. Small framed cattle placed in the Switchgrass and 3X grazing programs had the lightest ending weight means. The large framed cattle in the 2X and 2.5X pasture management systems produced carcasses with lower Marbling scores, lower USDA Quality Grades and numerically lower USDA Cutability Grades. The medium and small framed cattle managed in a 2.5X and 3X grazing system had numerically lower USDA Cutability Grade scores. This points out that nutritional levels that cattle have received prior to the finishing phase do have an effect on the carcass produced by steers when slaughtered after a 93 d period.

Steers wintered on high levels of nutrition and grazed in a 2.5X pasture management regime were heaviest at the end of the grazing season. The 2X cattle were very similar in their mean weight. The cattle wintered on a low level of nutrition and placed on the Switchgrass pastures performed the poorest. Steers provided a low level of nutrition during the winter followed by a 3X system were not much heavier at the end of the grazing season. Steers from the 2X and 2.5X grazing systems produce carcasses that have lower USDA Quality Grade scores. Steers wintered on a higher energy ration and placed in a Switchgrass and 3X grazing system produced carcasses with higher marbling scores. The difference in the carcasses was because cattle receiving higher levels of nutrition prior to the finishing phase gained at a lower daily rate in the feedlot which resulted in lower USDA Quality grades after a 93 d feeding period.

Large framed cattle not receiving supplement had the least backfat at the end of the grazing season, while large framed cattle receiving a supplement on grass had the most backfat. Small framed cattle receiving a supplement on grass results in carcasses with higher amounts of carcass backfat and a numerically higher USDA Cutability scores. This points out that maintaining a higher level of nutrition on pasture will produce carcasses with more backfat.

Cattle on high levels of nutrition during the winter and supplemented during the summer grazing season, had more backfat than the cattle wintered on low levels of nutrition in the winter and no supplement during the grazing period. This points out that low levels of nutrition provided during the winter and a continuation of that management during the summer grazing period, did not provide adequate nutrition to cause an increase in backfat, and may not be providing for maximum growth. Cattle wintered on a higher level of nutrition and supplemented on pasture produced numerically higher carcass USDA Cutability scores.

Small framed cattle in a 2X grazing system receiving a supplement produce carcasses with the most carcass backfat and the numerically highest USDA Cutability scores. In comparison, large framed cattle pastured in a 3X grazing system without pasture supplementation produced carcasses with the least amount of carcass backfat. This indicates that cattle of different frame groups need to be provided with adequate nutrition during the summer grazing period if you expect these cattle to produce a desirable carcass by the end of a typical finishing period.

Cattle wintered on a high nutrition level in all frame groups, and pastured on Switchgrass and 3X grazing management systems had higher USDA Quality Grade scores. This is in contrast with the fact that cattle wintered on medium and low levels of nutrition in all frame groups pastured on the Switchgrass and 3X grazing systems produce carcasses with lower Marbling scores. This reiterates the point that the level of nutrition during the winter and pasturing season do have an effect on the carcass produced at slaughter.

Each frame group, whether it be large, medium or small, had individuals that produced carcasses that were acceptable to the packer in the time periods described by this experiment. There were individuals that produced carcasses that were too light and individuals that produced carcasses that were too heavy for current packer preferences. This research points out the need for producers, feeders and packers to evaluate cattle types and make decisions concerning the nutritional management that would enhance the possibility of producing an acceptable product for all.

TABLE 4. FRAME GROUP MEAN WEIGHTS AND CARCASS TRAITS

	Frame size		
Measured trait	Large	Medium	Small
End of winter weight kg	414.32[a]	377.07[b]	345.61[c]
End of grazing weight kg	449.81[a]	406.42[b]	382.06[c]
Final liveweight kg	605.41[a]	585.91[b]	573.88[c]
Carcass backfat mm	8.14[a]	9.19[a]	10.51[b]
Carcass marbling[d]	4.31[a]	4.59[b]	4.63[b]
Carcass USDA yield grade	1.67[a]	1.98[b]	2.13[b]

[a,b,c] Means in the same row with the same superscript are not different ($P<.05$)

[d] 4=slight and 5=small

TABLE 5. WINTER NUTRITION GROUP MEAN WEIGHTS AND CARCASS TRAITS

	Wintering Level of Nutrition		
Trait measured	High	Med	Low
End of winter weight kg	402.80[a]	379.25[b]	354.96[c]
End of grazing weight kg	430.43[a]	411.25[b]	396.61[c]
Final liveweight kg	605.41[a]	585.91[b]	573.88[c]
End of winter backfat mm	4.67[a]	3.27[b]	2.65[c]
End of grazing backfat mm	3.78[a]	3.21[b]	2.84[c]
Carcass backfat mm	10.30[a]	9.41[a]	8.18[b]
Carcass marbling[d]	4.74[a]	4.44[b]	4.35[b]
Carcass USDA yield grade	2.07[a]	1.96[a]	1.76[b]
USDA quality grade[e]	2.65[a]	2.49[b]	2.44[b]

a,b,c Means in the same row with the same superscript are not different ($P<.05$)

d 4=slight and 5=small

e 2=select and 3=choice

TABLE 6. STOCKING RATE MEAN WEIGHTS

Stocking rate[a]	End of grazing weight kg	Final Liveweight kg
S	406.67[b]	580.46[b]
2X (IES)	422.08[c]	601.39[b]
2.5X (IES)	420.96[c]	595.52[b]
3X (IES)	401.35[b]	576.22[b]

[a] S=Switchgrass, 2X=2X Intensive Early Stocking (IES), 2.5X=2.5X IES and 3X=3X IES

[b,c] Means in the same column with the same superscript are not different (P<.05)

TABLE 7. PASTURE SUPPLEMENTATION MEAN WEIGHTS

Supplementation	End of grazing weight kg	Final Liveweight kg
1.8 kg Sorghum grain	421.03[a]	596.20[a]
None	404.50[b]	580.60[a]

[a,b] Means in the same column with the same superscript are not different (P<.05)

II. GROWTH CURVE ANALYSIS TO DETERMINE APPROPRIATE NUTRITIONAL MANAGEMENT FOR STEERS

Summary

Weight-age data from 201 steer calves were used to construct individual growth curves. Steers with frame score (FS) 1.50 to 3.79, 3.80 to 4.61 and 4.62 to 7.02 were designated small, medium and large frame groups respectively. The low winter nutrition for small, medium and large frame were targeted at 0.50, 0.55 and 0.60 kg/d, 0.70, 0.77 and 0.82 kg/d were targeted for the medium nutrition group and 0.95, 1.00 and 1.05 kg/d were targeted for high winter nutrition.

Summer gains were classified low (0.24-0.31 kg/d), medium (0.40-0.54 kg/d) and high (0.65-0.68 kg/d). Liveweights were recorded initially, at the end of wintering, at the end of the grazing period and at the completion of the study. Ultrasonic backfat measurements were recorded at the end of winter and end of the summer period, while carcass backfat was recorded after slaughter.

Liveweights were adjusted to a backfat thickness of 0.2794 cm by one of three methods. Method I (KS), was a regression of backfat on weight; Method II (FR), was a regression of backfat and backfat*frame score interaction on weight and Method III (TX), was a regression of backfat on percent weight change.

Using the adjusted weights for each of the above methods, individual growth curves were constructed using Brody's growth function. The assumption was made that

asymptotic weight is highly related to FS and "A" in Brody's equation is replaced by B(FS). "B" is a regression coefficient that when multiplied by FS will give an estimate of asymptotic weight.

Residuals obtained by contrasting actual weights and predicted weights from each method were compared. Analysis of the growth curve components indicated differences between the frame groups ($P \leq .10$). The KS method resulted in residuals considerably less than when unadjusted liveweights were used. The FR method resulted in a reduction in residuals as compared to the KS method and the TX method resulted in the smallest residuals of the three methods.

The greatest difference between actual and predicted weight occurred at slaughter weight. This indicates that use of backfat alone was not sufficient to adjust weight for differences in fat.

By assuming the TX method with the lowest residuals, was the best prediction equation, then nutritional management comparisons were made. Based on this study the medium level of wintering was most appropriate for small framed cattle. Medium or high level of wintering was appropriate for medium framed and high level of wintering was most appropriate for large framed steers, followed by a high or medium level of nutrition during the grazing season.

Introduction

The cattle feeder of today can not afford to deprive their livestock of the chance to express their genetic potential for growth. With the diverse genotypes represented in our beef cattle, avoiding nutritional mismanagement can be difficult.

Many of the husbandry techniques of decades past are still practiced by those who background and finish steers for slaughter beef. In some cases these practices are very appropriate for the type of cattle involved, but there are many steers in our cattle population today that are entirely different in their genetic ability for growth and ultimately fattening.

Some biological types of steers have been condemned by feedlot operators and packers when these cattle would not conform to the expectations of the feedlot or the packer. It also appears that "performance" of cattle has been deemed "better" by only making comparisons to other cattle handled similarly during similar phases of the beef production system. Although there is currently a trend for the cow-calf producer to try to take advantage of the genetic potential of his calves and get them to slaughter as soon as possible, there are still many calves sold daily to feeders with no knowledge of the growth potential of those cattle.

There is a wealth of information indicating that cattle will grow and develop at different rates according to the nutrition provided. There is limited information making comparisons of different biological types of steers handled in similar feeding regimes and even less information making comparisons of different types of steers fed to gain at different rates during the critical periods prior to reaching slaughter weights.

This study was initiated to determine specific nutritional management programs that are better suited for cattle of a certain frame score. This should aid the cattleman in making decisions to improve his current husbandry practices.

Experimental Procedure

Data from 201 steer calves with complete carcass information were used to construct individual growth curves. Steers with frame scores (FS) (BIF, 1986) of 1.50 to 3.79, 3.80 to 4.61 and 4.62 to 7.02 were designated small, medium and large frame groups, respectively. The low winter nutrition group gained 0.53, 0.55 and 0.60 kg/d for small, medium and large frame groups respectively, gains of 0.78, 0.82 and 0.85 kg/day were obtained on the medium winter nutrition and 1.02, 0.98 and 1.08 kg/d on the high winter nutrition.

Gains produced from various stocking rates and pasture supplementation during the summer were classified as low (0.24-0.31 kg/d), medium (0.40-0.54 kg/d) and high (0.65-0.68 kg/d) summer gain (table 8). Liveweights were recorded at the start of the study and at the end of the wintering phase (W1), pasturing phase (W2) and at the end of the feeding phase (W3). Ultrasonic backfat measurements were recorded at the end of winter and end of summer period, while carcass backfat was recorded after slaughter.

To make an accurate comparison of different individual's growth curves, differences in condition or body fat must be accounted for (Fitzhugh, 1976; Goonewardene et al., 1981). Backfat (BFAT) measurements at each time the steers were weighed provided a basis for making weight adjustments to provide a fat constant weight. Backfat thickness was adjusted to 0.2794 cm which is approximately the backfat thickness at growth curve weight of cattle of this age and maturity as estimated by Sanders (1977). Liveweights were adjusted by three different methods.

Method I (KS). Regression of fat on weight was used to determine weights adjusted for fat differences.

Adjusted W1 (AW1)=W1-(BFAT-.2794)80.53

Adjusted W2 (AW2)=W2-(BFAT-.2794)80.73

Adjusted W3 (AW3)=W3-(BFAT-.2794)41.56

Method II (FR). Regression of fat and fat*frame score interaction were used to determine weights adjusted for fat differences.

AW1=W1+199.1(BFAT-.2794)+89.0(BFAT(FS)-.2794(FS))

AW2=W2+212.0(BFAT-.2794)+93.8(BFAT(FS)-.2794(FS))

AW3=W3+127.2(BFAT-.2794)+48.4(BFAT(FS)-.2794(FS))

Method III (TX). Regression of fat on percent weight change, from work by Herd (1986), was used to develop weights adjusted for fat differences.

AW1=W1/((BFAT - .2794)(.274)+1)

AW2=W2/((BFAT - .2794)(.274)+1)

AW3=W3/((BFAT - .2794)(.274)+1)

Making the assumption asymptotic weight (A) is highly dependent on frame score (FS) (BIF, 1986), the nonlinear model procedure (SAS, 1985) was used to determine a regression coefficient (B), that when multiplied by FS, would give an estimate of asymptotic weight:

$$A = B(FS)$$

Substituting B(FS) into Brody's growth function (Brody, 1945):

$$Y_t = A\ (1 - be^{-kt}) \qquad \text{(Equation 1)}$$

Yields:

$$Y_t = B(FS)\ (1 - be^{-kt})$$

or:

$$Y_t\ /\ (FS) = B\ (1 - be^{-kt})$$

The growth function now becomes:

$$Y_t = B(FS)\ (1 - e^{-k(AGE)}) \qquad \text{(Equation 2)}$$

Liveweights at the beginning and end of the winter phase, liveweights at the end of the grazing phase and final liveweights were used to construct individual growth curves using a nonlinear model procedure (SAS, 1985). The primary growth curve component of interest was the residual between the actual weights and the weights predicted by Brody's function.

The General Linear Model (GLM) procedure (SAS, 1985) was used to analyze the residual component of the growth curve for significance among frame group, winter nutrition groups and summer gain groups. The FRAME*WINTER*SUMMER interaction was also considered.

Using Equation 2 individual growth curves were constructed using the adjusted weights from each of the methods previously described. The residuals obtained by each method were compared. The method with the lowest residuals was assumed to provide the best predicted weight at times weight was measured.

TABLE 8. PASTURE STOCKING RATES AND SUPPLEMENTATION PROVIDED FOR CLASSIFYING SUMMER NUTRITION.

STOCKING RATE	SUPPLEMENT PROVIDED[a]	GAIN kg/d	SUMMER NUTRITION
3X[b]	NONE	0.24	LOW
SWITCHGRASS[c]	NONE	0.31	LOW
3X	YES	0.42	MEDIUM
SWITCHGRASS	YES	0.54	MEDIUM
2.5X	NONE	0.40	MEDIUM
2X	NONE	0.41	MEDIUM
2.5X	YES	0.68	HIGH
2X	YES	0.65	HIGH

[a] 1.8 kg Sorghum grain (IFN 4-20-893) with 200 mg of Rumensin per head/day.

[b] Intensive Early Stocking (Olson, 1987)

[c] Monoculture of Panicum Virgatum L.

Results and Discussion

With steers of varying frame size on varying levels of nutrition during the winter and summer grazing period, it was determined that meaningful comparisons of cattle type and nutritional management could be made by using growth curve comparisons. Goonewardene et al. (1981) pointed out that Brody's growth equation was one of the simplest growth functions that tended to fit age-weight data points collected from two lines of cows. At ages similar to the ages of these steers, Brody's equation had the best fit of the functions he compared.

Fitzhugh (1976) has also recommended that when choosing a growth function to describe growth patterns in a data set, "goodness of fit" is important as well as mathematical simplicity. Brown et al. (1976) also pointed out Brody's function fit data points as well as the more complex Richards model for ages beyond six months.

Analysis of the growth curve components resulting from fitting Brody's equation using unadjusted liveweights indicated differences in residuals ($P \leq .10$) between frame groups, with small framed steers having a residual of 11,519 compared to 9,121 and 10,537 for medium and large framed steers, respectively (table 9).

The predicted W1 and W2 were somewhat higher than actual W1 and W2, while actual W3 was considerably higher than predicted W3 for all frame groups. This demonstrates the reason weights must be adjusted for fat. W3 is the weight that contains the most fat (table 10), and by using an unadjusted W3, it forced the predicted weight to be considerably higher at W1 and W2. The predicted and actual weight curves were relatively parallel during the winter period for all frame groups. During the summer period the small framed cattle tend to maintain that pattern, while the differences in predicted weight and actual weight for medium and large framed cattle tends to be greater at W2 than at W1. Possibly the nutrition provided during this time was insufficient to maintain the growth pattern exhibited during the winter period. The frame group mean backfats indicated that on the average there is a slight decrease in BFAT from the W1 measurement to the W2 measurement (table 10). Also one reason small framed cattle have a higher residual, was more of their weight gain was fat, as the mean backfat measurements indicate at W3.

The KS method of adjusting weights resulted in residuals considerably less than when unadjusted liveweights were used (table 9). The overall growth patterns were similar, but the residuals tend to be considerably larger for the small framed cattle than either the medium or large framed cattle. This suggested that the adjustments for fat improved the fit of the curve more for large and medium framed cattle, and that measurable backfat did not affect weight equally for cattle of different frame score groups.

The FR method of adjusting weights resulted in a reduction in the residuals as compared to the KS method of adjusting weights for the large and medium framed cattle, but larger residuals were still obtained for the small framed cattle. Higher residuals with the FR method could be caused by the range of frame scores in the small framed group being greater than in the other frame groups. More reduction in residuals, was made in the large framed cattle than in the medium framed cattle, but this could be due to the large framed cattle having less fat to adjust for, especially when W3 backfat was measured.

Method III (TX) resulted in the smallest residuals of any method of adjusting for fat (table 9). This method predicted weights very comparable to actual weights at W1 and W2. At the W3 measurement, there was considerable difference in the actual and predicted weights. This method was based on a change in backfat being equivalent to a change in empty body weight fat percent, which would cause a change in weight.

With all of the methods the greatest difference between predicted weight and actual weight was the W3 weight. Adjusted weight in all cases was considerably higher than predicted weight, indicating that backfat was not the only factor that should be considered when adjusting liveweight to a fat constant weight, comparable to the weight predicted by Brody's growth function. Yet by assuming the TX method does a good job of adjusting for fat differences at W1 and W2, this allows the use of the predicted weights from the TX method to evaluate the nutritional management prior to the feeding phase in the experiment.

By using the predicted weights from the TX method as the basis for comparison, the different winter and summer nutritional regimes can be compared in their ability to produce weight gain responses that were sufficient to result in weights that were approximately equal to the predicted weights. The only nutritional management scheme that produced weight gains continuously above the predicted weights at all phases of the experiment in the large framed cattle was the high winter, high summer (H+H) combination. The low winter, medium summer (L+M) combination produced the poorest gains up until the feeding phase. The residuals for this treatment combination also were the highest. The treatment of the large framed group with the lowest residual was the (M+H), because the medium wintering nutrition resulted in a W1 almost equivalent to the predicted W1. The high summer treatment also maintained a gain response relatively close to the predicted weight. Predicted weights at W1 and W2 of large framed cattle may not be high enough, as these cattle may be capable of gaining faster and reaching heavier weights at earlier ages if given adequate nutrition. The (M+H) nutritional combination also resulted in a carcass BFAT mean of 0.66 cm, the lowest carcass BFAT mean for large framed cattle.

The medium framed steers wintered on a high level of nutrition weighed more than or very close to predicted weights up through the end of the grazing period. Steers wintered on low levels of nutrition weighed less than predicted at W1 and W2. The lowest residual was recorded for the (L+H) nutritional combination, while the (L+M) combination resulted in the least amount of carcass BFAT.

Cattle wintered on low and medium levels of nutrition exhibit gain responses that are below predicted. The (H+L) combination resulted in the lowest residuals, while the (M+L) resulted in the highest residuals. The (L+L) nutritional combination resulted in the least amount of carcass BFAT and the (L+H) resulted in the most carcass BFAT.

Current packer criterion for desirable carcasses (Dikeman 1987) are:

Carcass Weight Range	272-386 kg
Carcass Backfat Range	.63-1.27 cm
Minimum Quality Grade	High Select
Yield Grade Range	1.5-2.9
Dressing Percent (average)	63%

Small frame steers on the high or medium winter nutrition and medium or low summer gains (figure 1) were within these carcass criterion. Small frame cattle with high summer gains had excess carcass backfat. Those on the low winter nutrition had inferior quality grades.

Medium frame steers on the high or medium winter nutrition and any of the summer gain groups met these carcass criteria. The most appropriate combinations were medium or high winter and summer levels (figure 1). Medium frame steers on low winter nutrition tended to produce carcasses with inferior quality grade.

Large frame steers produced carcasses that were heavier than desired. Of the combinations used in this study, high winter and summer were the most appropriate (figure 1). These large frame steers probably should have gone directly to the feedlot following the high winter nutrition to produce desirable carcasses.

Originally the calculated residuals were to be used to determine appropriate nutritional management for different types of cattle based on their frame score. We had difficulties in determining an appropriate asymptotic weight to give the curve some point to focus on. Using only backfat to determine the amount of fat in a feedlot animal was not sufficient to adjust actual liveweights to a fat constant basis. This was complicated by the fact that fat changes in different frame size steers did not produce an equivalent amount of change in weight.

For practical production it appears that steers should be fed to allow them to exhibit their growth potential without any delay. The concept of compensatory gain is a natural response to a period of nutritional mismanagement.

The steers in this study were managed similarly to the way many cattle are handled in the midwest and it is obvious that many cattle should be handled differently. Otherwise they will not attain their growth potential nor their profit potential.

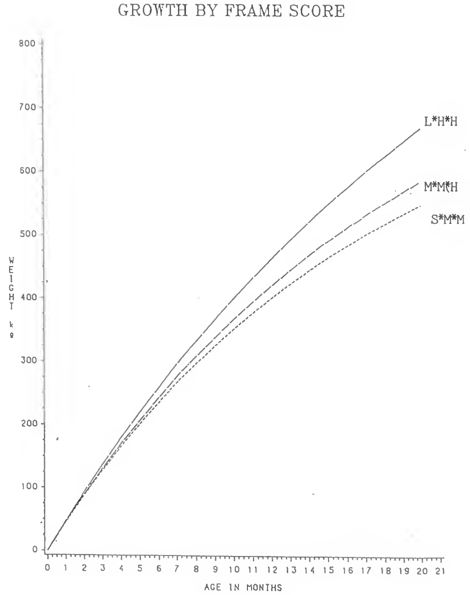
TABLE 9. MEAN RESIDUALS BY FRAME GROUP AND METHOD OF ADJUSTING FOR A CONSTANT FAT.

FRAME	METHOD			
GROUP	NONE	KS	FR	TX
L	10537	349	210	139
M	9121	561	495	245
S	11519	1077	1642	550

TABLE 10. MEAN BACKFAT MEASUREMENTS BY FRAME GROUP AT TIMES W1, W2 AND W3 WERE MEASURED.

	BACKFAT cm		
FRAME GROUP	W1	W2	W3
Large	.33	.32	.81
Medium	.37	.33	.92
Small	.34	.33	1.04

FIGURE 1. GROWTH CURVES OF LARGE, MEDIUM AND SMALL FRAMED STEERS WINTERED AND GRAZED MOST APPROPRIATELY.



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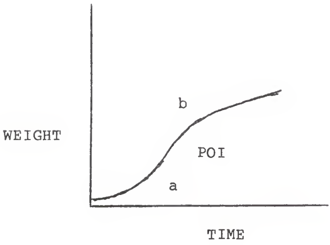
APPENDIX

BRODY'S GROWTH CURVE



a = self accelerating phase

b = self inhibiting phase

POI = point of inflection

BRODY'S EQUATIONS

Average Absolute Growth Rate

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

W_1 = initial weight

W_2 = ending weight

t_1 = initial time

t_2 = ending time

Instantaneous Growth Rate

$$\frac{dW}{dt}$$

Relative Growth Rate

$$RGR = \frac{W_2 - W_1}{W_1} \times 100$$

Instantaneous Relative Growth Rate

$$\frac{(dW / dt)}{W}$$

W = weight at the instant the rate (dW/dt) is measured

BRODY'S EQUATIONS CONTINUED

Instantaneous Relative Growth Rate

$$k = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

k = instantaneous relative growth rate

$\ln W_2 - \ln W_1$ = difference in natural logarithms of W_2 and W_1

$t_2 - t_1$ = time interval

Physiologic Mass

Physiologic mass = Aw^n

w = live weight (gravitational weight)

n = a fractional power (approximately = 0.73)

A = a parameter dependent on units employed

wt. in kgs, energy in kcal-- 70.5

wt. in lbs., energy in BTU-- 156.8

wt. in lbs., energy in kcal-- 39.5

Physiological Time and Weight

Unit of physiologic time = $k\ (t - t^*)$

Physiological weight = 0.73^{rd} power of live weight

WEINBACH'S EQUATIONS

$$\frac{dW}{dt} = kW'$$

dW/dt = instantaneous rate of growth

W' = "effective" weight for growth

k = proportionality constant

$$dW/dt = k\,(A + W)$$

dW/dt = instantaneous growth per unit of time

k = constant of proportionality

A = weight of equivalence of "impulse to grow"

W = weight at time t

$A + W = W'$ (effective weight for growth)

Solutions for Parameters

$$A = \frac{W_2 - W_1 W_3}{W_1 + W_3 - 2W_2}$$

$$k = \frac{2 \ln[(W_2 - W_1) / (W_3 - W_2)]}{t_1 - t_2}$$

$$t' = t_1 - (1/k) \ln [(A + W) / A]$$

BERTALANNFY'S EQUATIONS

$$dW/dt = vW^m - kW^n$$

v = constant of anabolism

k = constant of catabolism

m and n = exponents relating v and k to some power of body weight (W)

Surface Rule

$$S = bw^{2/3}$$

s = surface area

bw = body weight

Results in:

$$dW/dt = vW^{2/3} - kW$$

Bertalanffy's Growth Function

$$x = a\ (1 - be^{-kt})$$

x = some measure of :

- linear size
- length
- girth
- cube root of weight
- etc.

t = age in convenient units of time

FITZHUGH'S EQUATIONS

Weighted Average Lifetime Rates

Absolute Growth Rate = .5Amk / 2m - 1

Absolute Maturing Rate = .5mk / 2m - 1

Relative Growth Rate = mk / m-1

Instantaneous Growth Rates at the POI

POI = (y_I, t_I)

Absolute Growth Rate = $(mk/m-1)(y_I)$

Absolute Maturing Rate = $k[(m-1)/m]^{m-1}$

Absolute Growth Rate = mk/m-1

FITZHUGH AND TAYLOR'S EQUATIONS

Degree of maturity = u = y/A

y = trait in question

A = mature size

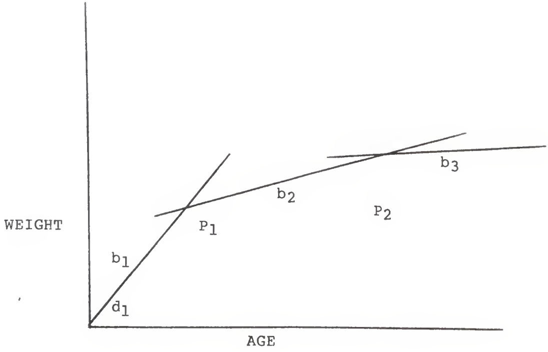
Size = y = Au or: ln y = ln A + ln u

Change in u = du/dt

Average Absolute Maturing Rate = $(u_{t2} - u_{t1})/(t_2 - t_1)$

Average Relative Maturing Rate = $(\ln u_{t2} - \ln u_{t1})/(t_2 - t_1)$

THREE REGRESSION LINES
FITTED SIMULTANEOUSLY



ANALYSIS OF VARIANCE TABLES

WINTERING PHASE

DEPENDENT VARIABLE: End of winter weight.

SOURCE	DF	SUM OF SQUARES
Winter nutrition group	2	84684.07
Frame group	2	171440.78
Age	1	56532.71
Error	215	188919.85

DEPENDENT VARIABLE: Backfat at end of winter.

SOURCE	DF	SUM OF SQUARES
Winter nutrition group	2	156.45
Frame group	2	4.35
Age	1	5.05
Winter*Frame interaction	4	8.96
Error	211	282.69

GRAZING PHASE

DEPENDENT VARIABLE: Weight at the end of grazing.

SOURCE	DF	SUM OF SQUARES
Frame group	2	151813.60
Winter nutrition group	2	38703.14
Frame*winter interaction	4	1678.74
Pasture treatment	3	15663.12
Supplementation	1	13348.66
Winter*supplementation	2	618.89
Frame*supplementation	2	1267.15
Age	1	38890.51
Error	184	153001.76

GRAZING PHASE CONTINUED:

DEPENDENT VARIABLE: Backfat at end of grazing.

SOURCE	DF	SUM OF SQUARES
Frame group	2	0.00426
Winter nutrition group	2	0.29883
Frame*winter interaction	4	0.01255
Pasture treatment	3	0.04765
Supplementation	1	0.00444
Winter*supplementation	2	0.03268
Frame*supplementation	2	0.03452
Age	1	0.02682
Error	183	1.36494

FINISHING PHASE

DEPENDENT VARIABLE: Final liveweight.

SOURCE	DF	SUM OF SQUARES
Frame group	2	224049.0
Winter nutrition group	2	32976.0
Frame*winter interaction	4	1228.0
Pasture treatment	3	19851.0
Supplementation	1	11283.0
Pasture*supplementation	3	7783.0
Frame*pasture*supplement.	14	20418.0
Age	1	66928.0
Error	170	363388.0

DEPENDENT VARIABLE: USDA quality grade.

SOURCE	DF	SUM OF SQUARES
Frame group	2	1.134
Winter nutrition group	2	1.616
Frame*winter interaction	4	0.357
Pasture treatment	3	0.045
Supplementation	1	0.282
Pasture*supplementation	3	0.078
Frame*pasture*supplement.	14	3.955
Age	1	3.030
Error	170	39.250

DEPENDENT VARIABLE: USDA cutability grade.

SOURCE	DF	SUM OF SQUARES
Frame group	2	7.001
Winter nutrition group	2	3.211
Frame*winter interaction	4	1.229
Pasture treatment	3	0.608
Supplementation	1	0.151
Pasture*supplementation	3	3.202
Frame*pasture*supplement.	14	7.314
Age	1	0.578
Error	170	70.412

DEPENDENT VARIABLE: Carcass backfat.

SOURCE	DF	SUM OF SQUARES
Frame group	2	1.775
Winter nutrition group	2	1.481
Frame*winter interaction	4	0.580
Pasture treatment	3	0.163
Supplementation	1	0.181
Pasture*supplementation	3	0.719
Frame*pasture*supplement.	14	1.991
Age	1	0.070
Error	170	19.437

DEPENDENT VARIABLE: Marbling.

SOURCE	DF	SUM OF SQUARES
Frame group	2	3.882
Winter nutrition group	2	5.635
Frame*winter interaction	4	0.699
Pasture treatment	3	0.270
Supplementation	1	1.532
Pasture*supplementation	3	0.156
Frame*pasture*supplement.	14	4.808
Age	1	5.903
Error	170	71.080

TX B'S, K'S AND RESIDUALS BY FRAME AND NUTRITION GROUP

FS*	W *	S	B		K		RESID	
L	HI	HI	215.07+/-	31	.0013+/-	.00032	197+/-	197
L	HI	LOW	215.49	28	.0013	.00029	113	180
L	HI	MED	223.08	20	.0013	.00021	129	127
L	LOW	HI	215.72	28	.0012	.00029	90	180
L	LOW	LOW	175.94	34	.0016	.00036	133	221
L	LOW	MED	199.78	20	.0014	.00021	207	127
L	MED	HI	198.32	34	.0013	.00036	82	220
L	MED	LOW	175.73	24	.0016	.00025	154	156
L	MED	MED	203.49	21	.0015	.00022	146	133
M	HI	HI	252.06	34	.0014	.00036	222	220
M	HI	LOW	200.19	28	.0018	.00029	239	180
M	HI	MED	217.41	19	.0017	.00020	177	122
M	LOW	HI	171.45	31	.0021	.00032	175	197
M	LOW	LOW	214.26	28	.0016	.00029	323	180
M	LOW	MED	216.96	19	.0015	.00020	365	122
M	MED	HI	216.67	40	.0017	.00041	325	255
M	MED	LOW	163.75	28	.0025	.00029	193	180
M	MED	MED	187.68	19	.0020	.00020	186	122
S	HI	HI	229.10	34	.0024	.00036	759	221
S	HI	LOW	236.81	26	.0021	.00027	247	167
S	HI	MED	287.62	21	.0016	.00022	479	133
S	LOW	HI	200.27	28	.0023	.00029	264	180
S	LOW	LOW	266.29	28	.0020	.00029	717	180
S	LOW	MED	245.08	22	.0018	.00023	381	140
S	MED	HI	248.42	28	.0019	.00029	290	180
S	MED	LOW	274.51	31	.0020	.00032	1203	197
S	MED	MED	250.55	22	.0019	.00023	617	140

MANAGEMENT OF STEERS WITH VARIOUS FRAME SIZES ON DIFFERENT NUTRITIONAL LEVELS

by

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Hip height was used to calculate frame scores for 221 Simmental, White Park, Limousin and Hereford sired crossbred steers weaned in the fall. Scores of 1.50 to 3.79, 3.80 to 4.61 and 4.62 to 7.02 respectively were designated small (S), medium (M) and large (L). Gain levels of: 0.50, 0.73, 0.95; 0.55, 0.77, 1.00; and 0.60, 0.82, 1.05 kg/d were targeted for steers in (S), (M) and (L) groups respectively.

Following a wintering phase of 105 d, individuals from each winter treatment group were placed on native range pasture at stocking rates of 1X, 2X, 2.5X and 3X, and six monoculture Switchgrass pastures. Half of the cattle were provided 1.8 kg of sorghum grain (IFN 4-20-893) per head/d with 200 mg of Rumensin. After 75 d on pasture 201 steers were finished for 93 d in a commercial feedlot and slaughtered.

Final weight means of 635, 575 and 555 kg for L, M and S steers were different ($P \leq .05$). Small steers produced carcasses with mean backfat of 10.51 mm which was larger ($P \leq .05$) than M and L with 9.19 and 8.14 mm respectively. Carcass yield grades of 1.67, 1.98 and 2.13 were recorded for S, M and L respectively which were different ($P \leq .05$). Although steers wintered at lower levels of nutrition expressed compensatory gains in later feeding regimes, they failed to achieve final weights equal to those wintered at higher levels. Larger framed steers wintered at low ADG levels and grazing pastures which provided low levels of nutrition produced carcasses that were too heavy with insufficient fat to meet packer acceptability.

Using the weight-age data from the 201 steers that completed the study, individual growth curves were constructed. Liveweights were adjusted to a backfat thickness of 0.2794 cm by one of three methods. Method I (KS), was a regression of backfat on weight; Method II (FR), was a regression of backfat and backfat*frame score interaction on weight and Method III (TX), was a regression of backfat on percent weight change.

Using the adjusted weights for each of the above methods, individual growth curves were constructed using Brody's growth function. Residuals obtained by contrasting actual weights and predicted weights from each method were compared. Analysis of the growth curve components indicated differences between the frame groups ($P \leq .10$). The KS method resulted in residuals considerably less than the unadjusted weights. The FR method resulted in a reduction in residuals as compared to the KS method and the TX method resulted in the smallest residuals of the three methods.

Based on this study the nutritional management most appropriate for small framed cattle was a medium level of wintering. Medium or high level of wintering was best suited for medium framed cattle and a high level of wintering was most appropriate for large framed steers, followed by a high or medium level of nutrition during the grazing season.