Effect of feed intake level and feeding regime on feedlot performance and carcass characteristics of yearling steers

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CHAPTER 1. GENERAL INTRODUCTION

Introduction

For decades, researchers have been studying the growth and development of beef cattle. Recently, emphasis has been on methods of influencing cattle growth and body composition using genetic evaluation, exogenous hormones, and nutrition manipulation. Producers have made progress towards the goal of more consistent beef animals within individual breeds, however, the variation between breeds of beef cattle presents a hindrance when the goal is a consistent, economical beef product. Implanting strategies and feeding regimes have been explored that may provide a means of superseding the genetic predestined composition of cattle, particularly smaller framed animals, and meshing them with the current industry production goals. In this dissertation the implications and applications of limiting the dry matter intake of beef cattle will be discussed.

The experiment used a series of feedlot studies begun November 8, 1979 and concluded March 18, 1996. Data were collected at the Allee Research Center in Newell, Iowa during 1979 through 1989 on 5711 steers. Data were obtained at the Western Iowa Research and Demonstration Farm at Castana, Iowa (1092 steers) from November 1990 through March 1997. Data were also available on 96 Holstein steers fed during 1994 at the Allee Research Center and 2105 yearling steers fed in commercial feedlots and these were used in feed intake comparisons. Cattle raised at Castana were used in two separate experiments. In the first experiment (Chapter 2) there were two feeding frequencies: 1) feeding once per day at 0800, 2) feeding twice per day at 0800 and 1600. The cattle were also assigned to a feed intake level: ad libitum, 95% of ad libitum, or 90% of ad libitum. In the second experiment (Chapter 3) there were three feeding frequencies: 1) feeding once per day at 0800, 2) feeding once per day at 1600 or 3) feeding twice per day at 0800 and 1600. The feed intake levels were ad libitum, 95% of ad libitum and 90% of ad libitum. An economic analysis was performed using the data obtained at Castana and was summarized in Chapter 4. Using the feedlot performance data obtained from 884 steers, two equations were developed (Chapter 5) for predicting the dry matter intake of yearling steers based on body weight, days on feed, and diet composition. Data collected on the 2105 steers fed in commercial feedlots and 112 steers fed at the Western Iowa Research and Demonstration Farm were used to validate the equations and adjustment factors.

Dissertation Organization

This dissertation is arranged as a series of papers and includes a literature review before the papers and a general conclusion and suggestions for future research after the papers.

Literature Review

Impact of carcass fat on the beef cattle industry

A major concern of fat in meat animals is the amount of fat deposited subcutaneously during the finishing period (Vernon, 1986). Over $1x10^9$ kg of excess fat were trimmed from beef carcasses in the United States in 1973, which at the time represented a cost of $1.15 billion to be absorbed by producers, processors and consumers (Hendricks, 1974).

Savell (1992) and Griffin (1992a) estimated in the National Beef Quality Audit Strategy Workshop that the United States lost $219.25 for every steer and heifer slaughtered in 1991 as a direct result of excessive fat production. Of that loss $111.99 was due to excess subcutaneous fat and $62.94 was due to excess intermuscular fat. Of the approximately 7375 carcasses sampled by the 1991 National Beef Quality Audit, 10% were YG 1, 34% were YG 2, 40% were YG 3, 14% were YG 4, and 3% were YG 5. This indicates that 17% or about 1,254 carcasses were too fat and thus were penalized.

According to Abraham et al. (1980), adjusted fat thickness accounted for 67% of the variation in the yield of boneless, closely trimmed retail beef cuts. May et al. (1992) found that 12th rib fat thickness was one of two traits having the greatest effect on boneless sub-primal yield and the production of trimmable fat. Savell et al. (1989) concluded that consumers in the United States find external fat to be undesirable and prefer closely trimmed beef cuts at the retail level. The National Beef Market Basket Survey (Savell et al., 1991) documented the mean external fat cover on retail cuts to be 0.3 cm; according to the National Beef Quality Audit, only 11.0% of the carcasses had less than 0.8 cm 12th rib fat thickness.

Lorenzen et al. (1993) compared the 1991 National Beef Quality Audit with the USDA Market Consist Report conducted in 1973-1974 and found a reduction ($P < .05$) in marbling score from Small-plus to Small-minus. Lorenzen et al. (1993) suggested that the statistical significance of the .08 cm decrease in adjusted fat thickness during the 17 years from the 1974 to 1991 was more a reflection of the large sample size in both surveys rather than a marked reduction in fatness. Thus, they concluded, the United States cattle population is still too fat.

Characteristics of adipose tissue

Compared to muscular tissue, adipose tissue has a very simple structure. Adipose cells contain, essentially, lipids with only a small part of their total composition being composed of structural components (Vermorel, 1976). Adipose tissue has a lobular structure in which fat cells develop in clusters around a capillary bed and are supported in a matrix of connective tissue. The fat, which is largely triglycerides, first appears in the cell as a series of droplets which coalesce to form a single large globule in the center of the cell, with the nucleus and cytoplasm pushed to the periphery (Ganong, 1991; Smith and Smith, 1995). There is likely a limiting size for the growth of fat cells, but the oxygen-requiring and metabolically-active components are forced to the periphery of the cell, making the distance from the blood supply to the cell the limiting factor, rather than a diffusion problem within the cell (DeBoer and Martin, 1978).

Ingle et al. (1972a) compared the lipogenic activity of adipose tissue of several fat depots. They sampled adipose tissue of the perirenal, omental, rump, shoulder and abdominal regions of calves, market steers and lactating cows. Market steers had substantial subcutaneous fat depots with shoulder and abdominal adipose tissue being several times higher in lipogenic capacity than the internal depots sampled. The higher rate of FA synthesis by subcutaneous adipose tissue of mature sheep and market steers is consistent with the development of these depots after mature growth has been attained. Adipose tissue cannot be considered as a homogenous tissue for ruminant animals as shown by the differing rates of lipogenesis from sampled depot sites. The internal fat depots incorporate greater amounts of acetate into FA as compared to subcutaneous sites (Ingle et al., 1972b).

The composition of ruminant adipose tissue is independent of the dietary triglyceride composition. There is, however, a relationship with the amount of grain fed and FA biosynthesis. Biohydrogenation of dietary FA in the rumen, involving NADPH and NADH, occurs due to the action of rumen microbes. Plant triglycerides are rapidly and completely digested in the rumen. Thus, long chain fatty acids which are absorbed in the small intestine have no relation to dietary fat (Byers and Schelling, 1988).

Another important aspect concerning the characteristics of developing adipose tissue is the histological development. The development of adipose depots, like the development of muscle tissue, exhibits both hyperplasia and hypertrophy. In bovines the number of adipocytes is fixed by 8 months in the perirenal and subcutaneous depots, whereas hyperplasia continues until 14 months of age in the intramuscular depot (Hood and Allen, 1973). Different regulatory processes control de-novo fatty acid synthesis in intramuscular and subcutaneous adipose tissue (Smith and Crouse, 1984). The two fundamental metabolic processes which contribute to the development of adipose tissue are lipogenesis and lipolysis. These processes occur primarily in the adipose tissue itself in ruminants and pigs, while the liver plays the larger role in chickens and rabbits (Vermorel, 1976).

Fat distribution in the carcass

Butterfield (1966) defined maturity type in cattle as the ability of different breeds or strains to lay down fat . He further argued that maturity type was a product of genetic and nutritional factors. Suess et al. (1969) suggested that the rate of intramuscular fat deposition could be regulated, without altering muscle growth rate, by changing the nutritional planes in definite ways. Johnson et al. (1972) explored further whether fat patterns were capable of being modified by nutrition. It is apparent from several studies that carcass fat deposition can be increased, relative to muscle deposition, by increasing nutrient intake, specifically increasing energy intake (McMeekan 1940a, 1940b; Pomeroy 1941).

Johnson et al. (1972) slaughtered and dissected 23 cattle. They separated the right side of each carcass into its individual muscles, bones, four major fat depots (intermuscular, subcutaneous, kidney, and channel), and connective tissue. Channel fat was defined as the fat within the pelvic cavity caudal to the external iliac vein. There were four side weight ranges: 3.15 to 3.35 kg (fetuses), 8.62 to 22.34 kg, 43.66 to 80.20 kg, and 119.01 to 179.23 kg. Partitioning of fatty tissues between the four major fat depots and intramuscular fat was examined in each range. All animals were fed on a high plane of nutrition, the oldest group was fed a high grain diet. The animals were of similar genetic background, fed the same, and processed the same, thus the results can be viewed as normal fat accretion at various tissue sites. Total side fat as a percent of side weight was 1.6, 3.2, 20.9, and 31.3%, respectively. For carcass sides in the 119.01 to 179.23 kg weight range the depot fat as a percent of total side fat was 50.4% intermuscular, 28.4% subcutaneous, 11.3% intramuscular, 8.3% kidney, and 1.6% channel fat.

Kempster et al. (1976) found that at constant total fat weight, carcasses from Ayrshire and Ayrshire crosses tended to contain less subcutaneous fat and more intermuscular, kidney knob, and channel fat than those from Friesian and crosses of beef breeds with Friesian cattle. The proportion of subcutaneous fat was lower for cattle fed on grass/cereal diets than for cattle of the same breed type fed on cereal diets. The left side of each carcass was dissected for 643 steers of 15 breed type x feeding system groups. The various fat component sites were defined as: 1) Subcutaneous fat: the peripheral layer of fat down to the level of the connective tissue sheaths covering the most peripheral muscle layer, but excluding *M. cutaneous trunci* which lies in the subcutaneous fat. 2) Intermuscular fat: the fat lying between the muscles, together with thin connective tissue, small blood vessels, and small quantities of muscle that are physically difficult to separate. 3) Kidney, kidney knob, and channel fat (KKCF): the perinephric and retro-peritoneal fat. 4) Cod fat: the scrotal fat separated from the subcutaneous fat in a standard manner using skeletal reference points. Angus cattle fed a high grain diet, had mean total fat per side of 44.3 kg of which 46.6% was intermuscular, 36% was subcutaneous, 12.9% was KKCF, and 4.5% was cod fat. Friesian (n = 106) cattle fed a high grain diet had mean total fat per side of 26.5 kg of which 50.9% was intermuscular, 28.6% was subcutaneous, 16.2% was KKCF, and 4.3% was cod fat. The authors concluded that dairy breeds deposit a higher proportion of their total fat internally and a lower proportion subcutaneously than traditional British beef breeds.

In a study by Koch et al. (1976) purebred Ayrshire and Jersey crossbred cattle had the highest relative KKCF weight and Hereford and Angus crosses the lowest. Results for intermuscular fat were less clear, although the Hereford crossbred cattle were consistent in having a very low intermuscular fat weight. Breed differences in fat partitioning occur in sheep as well. Wood et al. (1980) compared several breeds and found that meat sire breeds, such as Suffolk and Hampshire, had less internal body fat than the ewe-type breeds.

In 1979 Kempster reviewed studies of the British Meat and Livestock Commission on fat partitioning and distribution. He highlighted the commercial importance of these characteristics as well as the fact that little was known about the extent to which fat partitioning is influenced by environmental factors. Kempster said that information available from breed trials indicated there was substantial genetic variation for all three species (cattle, sheep, and swine) in the partitioning of fat between depots.

Kempster (1979) emphasizes that there are few well defined anatomical boundaries within adipose tissue, thus making it difficult to study as a unit. There has been a tendency for research workers to regard fat as a nuisance in growth studies because it is unstable and interferes with the ratio of muscle to bone. The result has been an emphasis on muscle and bone growth on a fat-free basis. Kempster discusses several reasons which make study of the growth and development of adipose tissue important for the world livestock industries. Subcutaneous fat can be trimmed easily in comparison to intermuscular fat and is removed in carcasses containing fat in excess of consumer demands. It is impossible to trim excess intermuscular fat from some areas without causing damage to retail product. Also many of the simple predictors of overall carcass composition used in seedstock selection involve the measurement of subcutaneous fat thicknesses. The precision achieved with such measurements depends on consistent fat partitioning and distribution between animals. If, for example, animals from different feeding regimens differ significantly in the characteristics, biases will exist in predicted composition unless separate prediction equations are used (Kempster et al., 1976). Also, if there is a poor genetic relationship between the growth of different depots, selection against overall fatness based on one depot, such as backfat, may not provide an effective reduction in other fat depots.

Fat partitioning is also involved with consumer perceptions about eating quality. Intramuscular fat (marbling) has traditionally been an indicator of beef quality and, because it is a later developing depot, high levels of fatness have been thought necessary to ensure high eating quality. With the increased consumer demand for lean meat, the relationship between fat and eating quality has become an important consideration. Fat partition differences are an expression of different physiological types of cattle, which have characteristic differences in metabolic efficiency and meat quality (Lister, 1976).

Intermediary metabolism of adipose tissue in ruminants

Fatty acids stored as triglycerides in adipose tissue, arise from two sources, the uptake of preformed fatty acids from gut absorption and de-novo synthesis of fatty acids from other metabolites (Bauman, 1976). In the ruminant animal, adipose tissue is the site of de-novo fatty acid synthesis and the liver is primarily responsible for gluconeogenesis (Bauman and Davis, 1975). Pothoven et al. (1975) observed decreases in rates of fatty acid synthesis in bovine adipose tissue with increasing steer weight when rates were expressed on a tissue weight basis. However, when expressed on a cellular basis, fatty acid synthetic rates in bovine adipose tissue remain the same or increase with age in the major adipose tissue depots of growing and finishing cattle.

Ruminant adipose tissue cannot utilize glucose as a substrate for fatty acid synthesis. This inability relates to the extremely low activities of two key enzymes, ATP citrate-lyase and NADP-malate dehydrogenase. The source of reducing equivalents to support fatty acid synthesis in ruminant adipose tissue also differs from nonruminants. The activity of cytosolic NADP-isocitrate dehydrogenase is extremely high in ruminant adipose relative to its activity in nonruminants (Ingle et al., 1972b). The advantage of the isocitrate cycle to ruminants is that acetate can be utilized to generate NADPH (Bauman et al., 1970), this is the glucose sparing effect found in ruminant lipogenesis.

The large food reservoir in the rumen results in ruminants absorbing a rather constant and continuous supply of nutrients relative to nonruminant species. As a consequence, ruminant animals generally have a much longer period to adapt at the tissue level to many physiological situations. With this in mind it is not surprising that lipid metabolism in ruminant adipocytes does not show the dramatic in vivo and in vitro responses to endocrine signals (Bauman, 1976).

Enzymatic and hormonal control of adipose tissue metabolism

In adipose tissue triglycerides are synthesized largely via the α-glycerol phosphate pathway. Primary regulation of rate of fatty acid synthesis occurs at the reaction catalyzed by acetyl-CoA carboxylase. Short-term regulation of acetyl-CoA carboxylase activity involves changes in intracellular concentrations of citrate and palmitoyl-CoA and changes in the phosphorylation state of the enzyme. Long-term regulation of lipogenesis is accomplished via changes in intracellular content of acetyl-CoA carboxylase and fatty acid synthetase. Of these, fatty acid synthetase probably plays a lesser role in regulation of lipogenesis, however, the quantity of synthetase within adipose cells is regulated by diet and fasting (Burton et al., 1969).

Lipoprotein lipase is the enzyme responsible for regulating hydrolysis of plasma triglycerides. The activity of lipoprotein lipase varies with changes in nutritional and physiological conditions (Garfinkel and Schotz, 1973). During times of dietary energy excess, the enzyme activity is high in adipose tissue but low in muscle; during deficit conditions, the opposite relationships exist (Robinson et al., 1975). The major site of regulation of lipoprotein lipase activity seems to be the secretion of the enzyme by the adipocyte, because the early effect of insulin on adipose tissue is to increase the extracellular lipoprotein lipase activity.

Catecholamines act by binding a β-receptor on the surface of the adipocyte. This binding leads to increased adenylate cyclase activity, which in turn increases intracellular cAMP concentration, which activates hormone-sensitive lipase (Masoro, 1977). In addition epinephrine infusion has been found to cause vasodilation in subcutaneous adipose tissue; a result of direct stimulation of the vascular β-receptors in the adipose tissue (Simonsen et al., 1992).

Chronic responses of adipose tissue to cold or heat usually become evident over a period of days and are reflected by changes in tissue metabolic capacities and(or) by changes in responses to acute hormonal stimuli. Thyroid hormone and growth hormone appear to act, in part, on adipose tissue by increasing amounts of adenylate cyclase in the tissue. Increased adenylate cyclase levels presumably lead to increases in adipose sensitivity and responses to acute hormonal stimuli (Baldwin et al., 1976).

Thyroid interaction with adipose tissue

Increases in thyroid activity during exposure to cold depend upon the severity and duration of cold stress. The response of the thyroid to cold stress appears to develop slowly and therefore its role is probably more aligned with the slower acclimative changes than with rapid responses to acute cold. Changes in thyroid activity in both cold- and warm-exposed animals appear also to be interrelated with appetite, food intake and digestive functions (Young, 1981).

Thyroid hormones have effects in almost all tissues of the body. In many respects thyroid hormones may be viewed as tissue growth factors because normal overall body growth does not occur in the absence of thyroid hormones despite adequate levels of growth hormone (Griffin, 1992b). Thyroid hormones have multiple effects on lipid metabolism. Cholesterol synthesis and its metabolic conversions are depressed in thyroid hormone deficiency. One mechanism that may account for enhanced cholesterol metabolism in response to thyroid hormones is the ability of thyroid hormones to increase the number of low-density lipoprotein receptors on the cell surface. Fatty acid metabolism is affected by thyroid hormones which enhance lipolysis in adipose tissue (Griffin, 1992b).

Protein synthesis and degradation are stimulated by thyroid hormones in ruminant animals. Stimulation of protein synthesis may be responsible for a portion of the calorigenic effect of thyroid hormones seen as a response to chronic cold exposure. The positive influence of thyroid hormones on normal body growth is derived largely from stimulation of protein synthesis (Griffin, 1992b).

Insulin effects on adipose tissue

Insulin seems to be both an acute and a chronic effector of adipose function. Insulin, acting directly or indirectly over a longer term, depresses adipose lipolytic capacity and increases lipogenic capacity. Insulin is the principal hormone inhibiting lipolysis. Inhibition of lipolysis in-vivo is due, in part, to stimulation of glucose uptake and free fatty acid reesterification by insulin. In addition, insulin prevents activation of hormone-sensitive lipase via the cAMP mechanism (Steinberg and Khoo, 1977). It also has been proposed that insulin decreases cAMP levels by increasing the activity of phosphodiesterase, but this doesn't seem to be the principal mode of action of insulin inhibition (Masoro, 1977).

Environmental effects on performance and metabolism

When discussing the thermodynamics of cattle environments certain terms are often used to describe metabolic functions. Heat production refers to the generation of thermal energy by metabolic processes inside an animal. Dissipation or loss of heat refers to the transfer of thermal energy from the surface of an animal to the ambient air. The thermoneutral zone is the range of environmental temperature within which metabolic rate is minimum, constant and independent of temperature. Lower critical temperature is the lower limit to the thermoneutral zone (Ehrlemark, 1991).

Cold thermogenesis in adult sheep and cattle has been shown not to involve an increase in protein catabolism, but was met by an increased oxidation of fat. The body composition of a growing animal, in terms of its fat and protein contents, is determined by the relative rates of fat and protein accretion, virtually all the energy retained being in these forms. If cold affects fat deposition proportionately more than protein, animals raised in the cold would have less fat than those in warm environments. If feed is available ad libitum, a reduced rate of fat deposition at high temperatures is primarily a consequence of a reduced feed intake; reduced fat deposition in the cold is due to the failure of voluntary feed intake to increase sufficiently to match the increased energy expenditure (Fuller, 1976).

Mader (1989) found that cattle with feedlot starting dates of December 1, March 1, mid-June and mid-August had average backfat depths at slaughter of 1.40, 1.40, 1.09 and 1.30 cm respectively. These cattle had access to an overhead shelter. It was not mentioned whether month started on feed had a significant effect upon backfat thickness.

Berkelo and Sorensen (1990) conducted a summer and a winter feeding trial during 1989 and 1990 with steers fed both at an ad libitum and a 93% of ad libitum level. The ad libitum cattle had an average backfat thickness of 1.19 cm for the summer trial and 1.17 cm for the winter trial, which were not different statistically. The cattle limited to 93% of ad libitum had the same fat thickness in summer and winter trials (1.17 cm).

In a progress report of research (Rabearimisa et al., 1993) cattle were placed on feed in March, June, September and December. The cattle started in March had an average backfat of 1.09 cm (averaged across 3 restricted feeding levels), June cattle had the highest backfat with 1.27 cm on average, September was nearly the same (1.24 cm) and December had the least amount of backfat with .97 cm across feeding levels.

Environmental effects on feed intake

Environmental temperature affects the nutritive value of a given feed and also an animal's need for a feed (Curtis, 1983). In response to a change in the climatic environment, animals can adjust their voluntary feed intake. When lactating dairy cows are fed free choice a diet consisting of 60 to 65% high-quality roughage and 35 to 40% concentrates and exposed to constant temperature conditions, feed intake will increase approximately 35% at -20^{o}C over the level at 10 to 20^{o}C. Also, lactating cows under continuous heat stress begin to show a decline in intake at 25 to 27^{o}C with a marked decline occurring above 30^{o}C. At 40^{o}C intake is usually no more than 60% of the 18 to 20^{o}C level. Rate of feed intake increases during cold exposure because it minimizes discomfort from cold (Church et al., 1974).

Voluntary feed intake of beef cattle has been shown to vary with differing thermal environments. Temperatures above 35^{o}C cause a marked depression in intake, especially with high humidity and(or) solar radiation and where there is little night cooling. Cattle on full feed experience a 10 to 35% depression. Intakes are depressed less when shade or cooling is available and with low fiber diets. At temperatures from 25 to 35°C feed intake is depressed 3 to 10%. Temperatures in the range of 15 to 25°C are preferred values for beef cattle. Ambient temperatures of 8°C down to -15°C tend to stimulate voluntary feed intake from 2 to 25% respectively. Voluntary feed intake may also be affected by nonthermal stressors. Rain may result in a temporary depression of feed intake of 10 to 30%. Mud depths of 10 to 20 cm depress intakes 5 to 15%. Deep mud (30 to 60 cm) tends to depress intakes 15 to 30%. Mud effects are greatest when access to feed is limited and when there is lack of a suitable bedded area (NRC, 1976).

Modeling beef cattle dry matter intake

Hicks et al. (1990b) analyzed feed intake records from a large commercial feedlot to determine the feed intake differences due to gender and breed type. Compared with DMI of beef steers of similar initial weight, DMI for heifers averaged 2% lower, whereas for Holstein steers DMI averaged 12% greater. The equation which best described DMI included initial shrunk weight, days on feed, and mean DMI from day 8 to day 28 on feed as independent variables. By including mean daily DMI from day 8 to 28 as an independent variable, R^2 was increased by .14 to .20 units for heifers and by .10 to .28 units in Holstein steers.

Fox and Black (1984) presented a model for prediction of dry matter intake of beef cattle. They also discussed several factors effecting the efficiency with which dietary energy is used for body maintenance or tissue growth in beef cattle, especially feedlot steers housed outside. According to the authors, adjustments should be made to animal nutrient requirements to account for animal frame size, body weight, sex, breed, rate of gain, growth stimulants, environment, digestive stimulants, previous nutrition, and daily dry matter intake. Frame size is important because the relationship of fat to lean body components at a given weight varies with frame size. Larger frame cattle have heavier weights at the same composition.

Body weight itself is an important consideration because the animal's maintenance energy requirement is a function of shrunk body weight. The energy requirement for gain, however, is a function of the amount of fat and protein in the tissue gain (Garrett, 1959). Whether the animal is a bull, steer, or heifer influences weight at a given composition. Klosterman and Parker (1976) determined that heifers were about 15% lighter than steer contemporaries at the same body composition and feed requirements for gain. When heifers and steers of four breed types were compared at 29.2% carcass fat, Harpster et al. (1978), found that heifers averaged about 80% of steer weight, regardless of frame size or breed. This indicates that the major difference in body composition between the sexes is related to the weight at which they have the same percentage of body fat.

Fox and Black (1984) did not make adjustments to their intake prediction model for energetic efficiency of beef breeds or beef crosses because research had shown (Harpster et al., 1978; Smith et al., 1976; Crickenberger et al., 1978; Klosterman, 1974) differences between breeds in postweaning feed efficiencies were small when compared at the same stage of growth. Fox and Black (1984) did, however, make an adjustment for Holsteins based on studies of Holsteins versus British breed cattle (Garrett, 1971; Ayala, 1974; Anrique, 1976; Crickenberger et al., 1978). The authors stated that the Holsteins used in their studies were energetically less efficient, had a larger NEm requirement and required more NE/kg gain when compared to British breeds at equivalent body composition. Based on these results, they increased NEm and NEg requirements 12% for Holsteins after adjusting for frame size.

The NRC (1976) adaptation of The California Net Energy System (CNES), requires no adjustment for rate of gain. It instead increases NEg requirements per unit gain with increased rate of gain, which Fox and Black (1984) argue may underpredict the NEg requirements of rapidly growing calves fed high energy diets.

Animals given a growth stimulant will have an increased weight compared to nontreated animals at the same body composition. Because CNES (NRC, 1976) nutrient requirements for gain were based on cattle given diethylstilbestrol, adjustments were made by researchers for cattle not given a growth stimulant.

Cold stress is not a problem under most conditions for growing and finishing cattle because of their body size, effective thermal insulation, and heat of fermentation. Stress from chilling is a problem when the effective insulation is removed due to wet and (or) muddy conditions, and prolonged wind exposure (NRC, 1981). Conditions which result in heat stress also increase the maintenance requirement. The NRC (1981) data indicate that during extreme heat stress NEm should be increased by about 8% for rapid shallow breathing and about 15% for deep, open mouth panting in cattle.

Adjustments for the change in feed net energy (NE) value that occurs when feed additives are used were developed by Fox and Black (1984). They did so by finding the NEm and NEg values that would have had to exist to support the daily gains reported in feeding trials by other researchers, after adjustment for the effect on intake. Based on the data from

Bertrand (1968) a factor of 1.04 was developed by Fox and Black (1984) to adjust for the influence of antibiotics on feed NE values. They also arrived at a multiplier of 1.11 for feed NE values for monensin fed at the rate of 33 ppm from the experiments summarized by Elanco Products Company (1976). Data summarized by Givens et al. (1982) was used to determine a factor of 1.06 for feed NE values for lasalocid fed at 33 ppm. Fox and Black (1984) examined data from Wittler et al. (1982) and found the effects of antibiotics and ionophores are additive. The nutritional history of an animal prior to being placed in the feedlot has an impact on the efficiency of energy utilization. Feed NE values were adjusted by the authors based on previous rate of gain and body condition at the time the animal was placed on feed. Daily dry matter intake was assumed by Fox and Black (1984) to be limited by high fiber content in diets. As the energy density increases further, a point is reached (between 60 and 70% corn grain equivalent, DM basis) at which chemostatic and thermostatic controls take over. Beyond about 90% concentrate, daily gain is depressed and daily dry matter intake falls off rapidly (Fox and Black, 1984). Daily DMI was not adjusted upward for cattle started on feed in 'thin' condition; they consume more dry matter initially versus cattle in average condition, but intake over the entire feeding period does not appear to differ from that of cattle whose growth was not restricted (Fox, 1970).

Oltjen and Garrett (1988) compared the various predictions of energy concentration of gain (EG) of empty body weight gain of beef steers available from the NRC (1976, 1984) and discussed how these predictors could be used in predicting performance of beef steers. They determined that the accuracy of prediction of energy concentrations of empty body weight gain by models available was limited. The mean values for EG in 46 pens of steers were used to evaluate EG predicted by the two systems. The NRC (1976) overpredicted mean EG of implanted steers (P<.05) by 0.26 Mcal/kg, while NRC (1984) underpredicted mean EG of nonimplanted steers (P<.05) by 0.38 Mcal/kg. The longer cattle were on feed the more EG became overpredicted. Both NRC systems tended to overpredict EG (P<.01) for steers with more body fat when placed on feed. The NRC systems also underpredict the EG of thin animals due to compensatory gain. At higher levels of dietary energy EG was also underpredicted (P<.01).

Dietary energy effects on growth and carcass

Fox (1978) reported that over nine trials including 448 cattle fed at a variety of dietary energy levels, those fed high-grain diets were 15.7% fatter at slaughter. All the animals were calves started on trial 30 to 60 days postweaning and implanted with a growth stimulant. Within each trial, the data were all adjusted to the same final empty body or carcass weight within a cattle type.

Tatum et al. (1988) found that by limiting energy concentration in the diet of small, medium or large frame crossbred calves (Angus, Brown Swiss, Charolais, Hereford, Holstein, Jersey, Limousin, Longhorn, Red Angus, Shorthorn, and Simmental) from Colorado producers by feeding corn grain (flaked, 3.03 Mcal ME/kg DM), corn silage (2.46 Mcal ME/kg DM), or an alfalfa hay/forage diet (2.06 Mcal ME/kg DM), fat percentage in the carcass was reduced. The cattle were slaughtered at constant weights by frame size (small = 408 kg, medium = 499 kg, large = 590 kg). The fat percentages in the carcass for the small frame steers were 25.1, 24.3, 16.8 (P < .05), for medium frame steers were 25.6, 21.6, 17.6

(P<.05) and for the large frame steers were 23.0, 19.8, 17.4 (P<.05), for steers fed the corn grain, corn silage, and alfalfa diets, respectively.

Harrison and Randel (1986) concluded that energy restriction (75% of NRC dietary energy for maintenance) reduced corpora lutea (CL) weight and decreased insulin secretion, but not luteinizing hormone (LH) or progesterone in intact heifers. Exogenous insulin increased ovulation rate in energy deprived beef heifers.

Grimaud and Doreau (1995) fed four dry cows (747 kg) a forage-based diet at a level above maintenance requirement for seven weeks (9.4 kg DM per day). They then fed the cows, at a low level of intake, the same diet for five months (5.2 kg DM per day), after which the cows were again fed at 9.4 kg DM per day. Estimates of digestion were made before cows were restricted in intake and at 1, 5, 9 and 19 weeks of underfeeding. Organic matter (OM) digestibility initially declined due to underfeeding (62.7 and 56.2, before and 1 week after underfeeding). However by 19 weeks of underfeeding OM digestibility had increased again (61.5%). Differences in ruminal apparent OM digestion were nonsignificant (P > .05). Similar to OM digestion, N retention decreased (P < .01) with underfeeding initially and increased (P < .05) during the underfeeding period, due to a decrease in fecal and urine losses. This experiment showed a temporary response of digestion to underfeeding, which is unusual. The authors suggest that knowledge of adaptation of digestion to low intakes needs to be improved. A similar increase in OM digestion was observed in limit fed cows by Leaver et al. (1969) as well.

Murphy et al. (1994c) found that lambs fed a 92% concentrate diet and restricted to 90% of ad libitum intake had higher apparent nitrogen digestion (P < .001) as well as digestibilities of dry matter, organic matter, ADF, starch, and crude protein ($P < .001$). In addition, it was determined (Murphy, 1994b) that restricted feeding increased rumen pH and ammonia ($P < .06$), while ruminal liquid dilution rate decreased ($P < .05$).

Coleman et al. (1993) assigned 96 Angus and Charolais weanling steers to one of two growing diets: 1) control diet of pelleted alfalfa or, 2) a restricted diet of cubes containing 19% grass hay, 13% alfalfa hay, 10% SBM, 13% wheat straw, and 45% cottonseed hulls. The control diet furnished 2.1 Mcal/kg of ME, while the restricted growing diet furnished 1.4 Mcal/kg ME. Diet type had an effect on final BF in mm ($P < .01$). Angus steers fed the control diet had more backfat than those fed the restricted diet (17.4 versus 11.8 mm). Similarly, Little and Sandland (1975) found that restricted fed lambs had, at comparable levels of body fat, a significantly lower percentage of total body fat in the subcutaneous fat depot.

Loerch (1990) reported that steers restricted to 70% of ad libitum intake of a high-concentrate diet had higher feed efficiencies and diet digestibilities ($P < .01$) compared with cattle fed corn silage ad libitum.

Differences between sexes in carcass composition

Among Holsteins fed at either ad libitum or 70% of ad libitum, Fortin et al. (1980) found that those limited in intake were affected differently depending on the sex of the animal. Bulls fed the low energy diet had a higher rate of water accretion in the empty body ($P < .05$), while the rate of fat accretion was reduced ($P < .05$). In Holstein heifers the rates of protein, water, and fat accretion in limit fed cattle were not different from control heifers. Holstein steers limited to 70% of ad libitum showed an increased rate of protein deposition in the empty body ($P < .05$).

Effect of limiting feed or water intake on performance and carcass composition

Turgeon et. al. (1986) looked at what effects growth rate and compensatory growth had upon body composition in lambs. They separated the feeding trial into a growing and a finishing phase. Lambs were fed three concentrate levels in the growing phase (30, 50, or 70%) to create three different growth rates: slow, medium, and rapid. The finishing phase was separated into early, 30 to 38 kg, and late, 38 to 45 kg. All lambs were fed a 70% concentrate diet during the finishing phase. As growth rate increased, during the growing phase, percent fat increased in a curvilinear fashion ($P < .05$). Empty body protein decreased linearly ($P<.05$) as growth rate increased, for animals slaughtered after the growing phase at 30 kg body wt. During the finishing phase, rate of protein deposition (g/d) increased linearly ($P<.01$) as growth rate increased for weights 30 to 38 kg, however in the late finishing phase (38 to 45 kg) rate of protein deposition did not differ with increasing rates of gain. The researchers found fat deposition decreased curvilinearly ($P<.01$) as growth rate during the growing phase increased.

Notter et al. (1983) fed Rambouillet, Dorset, and Finnish Landrace ram lambs a pelleted diet containing 2.96 kcal ME and 0.169 g digestible protein/gram of DM at 100, 85 or 70% of ad libitum from ages 48d to 258d of age. Rams restricted to 85 and 70% of ad libitum had less backfat when slaughtered than rams fed ad libitum, although the differences were not significant. Restricted rams had similar longissimus muscle areas compared to ad libitum fed rams. Restricted rams had more KPH fat and a higher percent body fat versus the ad libitum fed rams.

Hart and Glimp (1991) fed lambs (29 kg) a 90% concentrate diet composed of either complete pellets or whole shelled corn with a protein supplement. They fed the diets at three levels of feed intake: ad libitum, 92.5% of ad libitum, and 85% of ad libitum. They found that limiting the intake of lambs did not reduce DM digestibility or the digestibilities of starch and crude protein. Likewise, ruminal fluid pH, ammonia concentration, and VFA concentrations were not affected by feed intake restriction. Digestibility of ADF was increased by restricting intake ($P < .10$).

Toelle et al. (1986) fed various breeds of beef bulls to three slaughter weights (320, 440, 560 kg) at three concentrate feeding levels (100, 85, and 70% of ad libitum). Upon plotting the data the researchers found no curvilinearity for lean or fat gain with respect to body weight gain or energy intake. This is in contrast to trends in swine in which lean gain may plateau as feed intake increases to high levels (Whittemore, 1986). Steers and heifers have been shown to deposit more fat per unit of gain when fed high energy diets than bulls (Fortin et al., 1980). The researchers estimate that it may be possible that lean growth would show a curvilinear relationship to body weight gain in steers and heifers. Linear regressions to describe growth have been used in other studies (Luitingh, 1962; Robinson, 1976). These studies suggest that linear regressions explain growth well from postweaning to slaughter with no significant contribution from curvilinear forms.

Prior (1983) fed 40 Angus X Hereford crossbred steers (250 kg initial wt) in a Calan™ gate system. Steers were initially fed pelleted sun cured alfalfa hay for a period of 91 days. After this 30 steers were switched to a pelleted high concentrate diet. The remaining 10 steers served as a controls. Carcass data obtained at slaughter (460 kg) showed that the concentrate fed steers tended to have higher quality grades, greater fat thickness (1.12 vs. 0.88 cm), and a greater KPH fat percent (2.73 vs. 2.25), although these differences were not significant. Hay fed cattle consumed about 25% more DM and had a higher intake of ME.

Firkins et al. (1986) used four Angus-Hereford crossbred steers (550 kg) and four Hereford steers (350 kg) to determine ruminal and total tract digestion of diets including prairie hay (chopped or ground), supplemented with protein from either dry corn gluten feed (DCGF) or dry distillers grains (DDG), and fed at two intake levels (90 and 60 % of ad libitum). They found that steers fed ground hay diets digested higher ($P < .05$) percentages of total digestible organic matter (OM) and neutral detergent fiber (NDF) in the rumen. The surface area of ground hay is larger and thus allowed more extensive ruminal fermentation. When steers were fed at high-intake levels (1.6% of body weight), ruminal dilution rates were not increased ($P < .05$) due to forage particle size or level of intake treatments. Acetate production in the rumen was increased by limit feeding cattle, at the expense of butyrate production ($P < .05$). The intake of NDF was reduced ($P < .05$) in limit fed cattle, but apparent ruminal NDF digestion, as a percent of intake and as a percent of total NDF digestion, was increased ($P <.05$).

Murphy and Loerch (1994) found that cattle fed a 100% concentrate whole-corn diet and limited to 90% of ad libitum had less backfat and lower quality grades ($P < .04$) compared to ad libitum fed cattle, while liver weights were not affected.

Hicks et al. (1990a) fed 72 yearling steers (374 kg) a wheat-based high concentrate diet. The cattle were fed at two feed intake levels: ad libitum or limit fed at 85% of ad libitum. Efficiency of feed conversion was improved ($P = .03$) by limit feeding (8.78 versus

8.06 kg feed/kg gain). Cattle were slaughtered after 149 days on feed. Ad libitum fed cattle had heavier live weights at slaughter (584 versus 573 kg; $P < .05$). Carcass weights were not different between the two treatments. Ad libitum fed cattle tended to have a little more fat thickness over the 12th rib, but not significantly so (.87 versus .80 cm). Ad libitum cattle had a higher marbling score (12.5 versus 12.1; $P < .10$) and a larger percentage of cattle grading Choice, adjusted for hot carcass weight (60.8 versus 42.0; $P < .02$).

Hicks et al. (1990a) fed 80 yearling beef heifers (293 kg), in a similar experiment, a high-corn diet. In this second experiment one feed intake level was designed to give cattle ad libitum access to feed while the second intake level was 89% of the ad libitum feed intake amount. Limit feeding tended to improve the efficiency with which feed was used for live weight gain (6.82 versus 6.16 kg feed/kg gain; $P = .11$). Cattle were slaughtered after 140 days on feed. Ad libitum fed cattle had heavier live weights at slaughter (526 versus 519 kg; $P < .05$). Carcass weights were not different between the two treatments. Ad libitum fed cattle tended to have a little more fat thickness over the 12th rib, but not significantly so (1.12 versus 1.02 cm). Ad libitum cattle tended to have both a lower marbling score, adjusted for hot carcass weight (11.5 versus 11.9; $P = .11$) and a larger percentage of cattle grading Choice, adjusted for hot carcass weight (47.1 versus 37.9; $P = .11$).

Adams and Kartchner (1984) fed five ruminal-cannulated steers alfalfa hay once daily at 1.40, 1.65, 1.90, 2.15, and 2.40% of body weight. As forage consumption increased from 1.40 to 2.40%, rumen liquid volume declined from 149.3L to 99.5L. At the same time liquid dilution rate increased from 4.3% per hour to 7.2% per hour. The authors concluded that level of dry matter intake is an important determinant of liquid dilution rate and that higher levels of intake are associated with a reduced rumen liquid volume.

Gingins et al. (1980) fed a diet of 78% wheat, 10% straw, 5% soybean meal, 5.7% molasses, and 1.6% vitamin and mineral premix to seven mature wethers with a 45 kg initial weight. As intake increased from 150 to 1200 g/day, percent digestibility of energy and protein also increased. The authors attribute this unusual trend to the low crude fiber content of the ration (5.7% organic matter). Blaxter (1974) reported similar findings; an increase in the metabolizability of energy was seen with increasing intake of metabolizable energy, if the crude fiber content of the diet remained less than 16% of the organic matter. Gingins et al. (1980) found that the high partial efficiency of metabolizable energy (k_f) during refeeding after feed restriction was due to a protein sparing mechanism which is brought into action in undernourished animals (lower heat production and lower N losses) and carried over during the 37 days of realimentation.

Glimp et al. (1989) controlled the energy intake of 292 Rambouillet ewe and wether lambs (nine months old) by restricting intake of a 90% concentrate pelleted diet. There were ad libitum, 92.5%, and 85% of ad libitum intake levels. For sheep fed the 85% level, daily gains were reduced by 8% compared with wethers allowed ad libitum access to feed. Feed efficiencies were improved 20% ($P < .01$) by limiting intake to 92.5% of ad libitum. Quality grades were reduced on the 85% of ad libitum diet ($P < .05$), but those on the ad libitum and 92.5% of ad libitum diets were the same (average Choice).

Contrary to the above findings, Rust et al. (1989) reported that Holstein steers fed a diet of 50% high moisture corn and 50% high moisture ear corn showed no change in feed efficiency when fed ad libitum, 85%, or 70% of ad libitum.

Asplund and Pfander (1972) studied water to feed ratios in rumen-fistulated yearling wethers. Sheep fed a high feed-low water diet quickly developed rumen impaction problems, reduced defecation, and the animals were able to stay with a seven-day feeding trial in only one of four replications. The apparent digestibility of feed consumed by the high feed-low water group was high because of low fecal output. Rumen pH was lower and VFA levels were higher, likely due to the lower amount of H_2O consumed which would have diluted out the acid present in the rumen. The authors suggested that higher digestibilities seen in other experiments (Balch et al., 1953) where water intake of ruminants was restricted was likely due to feed accumulation in the rumen, rather than a true increase in digestion.

Thornton and Yates (1968) found that restriction of water intake in cattle increases the apparent digestibility of dry matter, nitrogen, and other nutrients. They restricted feed for cattle receiving water ad libitum to that consumed by animals that had their water restricted and concluded that the reduced feed intake observed when animals are restricted in water intake accounts for some but not all, of the increased digestibility observed.

Andersen (1975) used Red Danish bull calves sired by four bulls. Calves were randomly assigned to a slaughter weight (180, 240, 300, 360, 420, 480, and 540 kg) and a feed intake level (100, 85, 70, and 55% of ad libitum). As feed intake level was decreased there was a decrease in daily gain of fat greater than that of lean or bone. The differences became larger with increasing slaughter weight.

Few experiments indicate how the gain of lean, fat and bone is impacted by decreasing feeding level. However, the influence of feeding level on the lean/bone ratio has been reported by several authors. The findings are contradictory; some researchers report that the lean to bone ratio is lower with restricted feeding compared with cattle given ad libitum access to feed (Guenther et al., 1965), while others (Callow, 1961; Henrickson et al., 1965) indicate that the ratio is not affected by feeding level.

Henrickson et al. (1965) found that beef cattle fed at a level slightly less than ad libitum required less energy than those on ad libitum feeding treatments. Researchers have proposed several explanations for this occurrence. The deposition of energy per kg gain on moderate feeding is lower than on ad libitum because of a lower fat content in the gain. Also, the efficiency of energy utilization is higher for maintenance than for growth. Therefore, the net energy of a feed is high at a low level of feeding and decreases with increasing feed intake (Lofgreen and Garrett, 1968). Digestibility of the feed is higher, when fed restrictively. Leaver et al. (1969), Almquist et al. (1971), and Graham and Searle (1972) reported increased digestibilities of feed when animals were fed on a restricted basis versus those given ad libitum access to feed.

Bartle and Preston (1992) fed 371 kg Hereford steers steam flaked sorghum grain ad libitum or restricted to a multiple of maintenance (2.7 and 2.9 times maintenance). Steers restricted to 2.7 times maintenance had a higher rate of gain (1.44 kg/day versus 1.35 kg/day; P=.08) and had better feed efficiencies. The ADG/DMI (g/kg) was 170 versus 163 g/kg for restricted and ad libitum cattle, respectively (P=.15). As far as carcass characteristics, the cattle restricted to 2.7 times maintenance were not different in backfat thickness, KPH, longissimus muscle area, yield, and quality grades from the cattle fed ad libitum.

Pothoven et al. (1975) examined the lipogenic and lipolytic capacities in subcutaneous fat tissue (backfat) of Angus X Hereford beef steers weighing 113, 231, 363, and 505 kg at slaughter. Cattle were fed a finishing diet composed of 80% ground corn grain (air-dry basis), 5% ground corn cobs, 8.9% solvent extracted soybean meal, 4.85% molasses, 1.25% vitamin and mineral premix, ad libitum or on a restricted basis such that restricted fed steers gained 67% that of steers given ad libitum access to feed. Both lipogenic and lipolytic activity were measured on adipose tissue samples taken post-slaughter. The highest lipogenic activity was found in samples obtained from 363 kg steers and the lowest level of activity was found in steers slaughtered at 505 kg live weight. Fat accumulation in restricted-fed steers was equal to that of ad libitum-fed steers, even though the fatty acid synthesis capacity measured in adipose tissue samples from restricted-fed steers was lower versus ad libitum-fed steers. At the 363 kg slaughter weight, carcasses of ad libitum-fed and restricted-fed steers had 19% and 20% fat, respectively. Cattle slaughtered at heavier weights (505 kg) and fed the ad libitum or restricted levels had 32% and 31% carcass fat, respectively.

Baker et al. (1985) fed 36 Friesian steer calves, born in late summer, on either a high or low plane of nutrition through the winter. Six animals from each group were slaughtered after the winter feeding period. The calves on the high plane of nutrition weighed 196 kg on average, while the low-plane calves weighed 127 kg. The empty body composition of the calves fed the high plane of nutrition included 11% fat, 19.9% protein, 4.7% ash, and 64.5% water. The composition of those fed the low plane of nutrition differed somewhat: 11.9%

fat, 19.2% protein, 5.2% ash, and 63.6% water; they had more fat than calves fed on the high plane ($P < .01$).

The effect of feeding two levels of energy intake on body composition was examined by Burton and Reid (1968) in wethers. The sheep were fed to maintain intake of energy at either 278 or 421 kcal gross energy per kg empty-body weight$^{0.73}$ per day. The result was that energy intakes within this range were found to not have an impact on body composition of wethers, outside of the affect on body size.

Chen et al. (1992) took sheep weighing 45 kg on average and provided them with 328, 656, 984, and 1313 g DM day^{-1} of a 49% concentrate diet (barley, molasses, fishmeal, and hay). The researchers found that the DMI to BW ratio determines the rumen passage rate and also outflow of bacteria. Fractional outflow rate per hour, for the liquid portion, increased from .062 to .123 ($P < .05$) and for the solid portion, increased from .019 to .050 ($P < .05$), as DM intake increased from 328 to 1313 g DM day^{-1}. As DMI increased DM digestibility decreased from 71.8 to 67.4%, OM digestibility also decreased, from 73.5 to 68.4% ($P > .05$).

Cherney et al. (1991) fed 12 to 18 month old wethers various types of hay, all similar in NDF (61.3 ±1.9% DM), but different in morphology to determine passage rates as affected by plant structure. The sheep were fed at two levels: forage offered at 100% of ad libitum or forage offered at 1.8% of body weight. The sheep fed at 1.8% of body weight had greater rumen mean retention times for both liquid and solid fractions, as well as for plant stem, leaf blade, and leaf sheath fractions of the digesta ($P < .05$).

Level of roughage in the diet has been shown to influence utilization and digestion of corn fed to feedlot cattle in the whole-grain form (Cole et al., 1976a). Small changes in roughage level change the site and extent of digestion of whole shelled corn rations. The researchers fitted four Hereford steers averaging 390 kg with permanent cannulas in the rumen and abomasum. They were fed diets containing 0, 7, 14, and 21% roughage, in the form of cottonseed hulls, with the remainder of the ration composed of whole shelled corn and pelleted supplement. Dry matter, starch, and cellulose digestion coefficients were lowest for the 14% cottonseed hull diet ($P < .05$). The authors attribute this to decreased digestion of the concentrate portion of the diet due to an increased rate of passage for that particular mixture.

Cole et al. (1976b) used four Hereford steers fitted with ruminal and abomasal cannulae for determination of digestibility. The steers were fed either steam flaked (SFC) or dry rolled corn (DRC) with roughage levels of 0 and 21%, provided by cottonseed hulls. Digestion of DM in the rumen was increased by about 13% ($P < .01$) for rations containing SFC versus DRC and by about 10% ($P < .05$) for rations containing 0 versus 21% cottonseed hulls. Total tract DM digestion was increased 7% ($P < .01$) for SFC versus DRC and 9% ($P < .01$) for rations containing 0 versus 21% cottonseed hulls.

Carstens et al. (1991) fed steers a 70% concentrate diet ad libitum or at a restricted level. The restricted cattle were limited in intake such that they gained an average of .45 kg per day for the first 189 days of the experiment, after which they were fed ad lib to 500 kg. Restriction and realimentation had no effect on subsequent growth of the carcass chemical components protein, fat, water, or ash.

Coleman and Evans (1986) fed cattle a high roughage diet during a 60 day growing phase trial. The cattle were fed to gain either .72 or .25 kg daily. Structural height growth was greater in the control cattle versus the restricted cattle (7.82 and 5.16 cm/day; $P < .05$, respectively). Backfat growth rate was greater for control cattle as well ($P < .10$). After the restriction period the cattle were fed a 70% cracked shell corn finishing diet. The restricted fed steers compensated for their previous lack of energy and finished at a weight similar to the control steers, but with less carcass backfat (.88 versus .62 cm; $P < .05$).

Coleman et al. (1995a) assigned 120 medium-frame Angus steers, with a 260 kg initial weight, to one of two dietary treatments. One group was fed a diet composed of sorghum silage, ground shelled corn, soybean meal, and alfalfa hay ad libitum. The intake of silage was determined weekly as a proportion of metabolic body weight. The NEg intake from the silage diet was then calculated based on OM digestibility and rate of gain was projected using NRC (1984) equations. The other group was fed a ground shelled corn, soybean meal, and cottonseed hull diet. The amount of the grain diet required to produce gains similar to the silage diet was calculated. After being fed the two growing diets for 145 days, all steers were fed a ground shell corn, soybean meal, and alfalfa finishing diet for 105 days to examine how the type of diet fed during the growing phase impacts growth and carcass characteristics. Diet did not effect marbling score, however, cattle fed the corn diet had better quality grades ($P < .05$). In cattle fed either diet, 75% graded Choice or better after only 45 days on the finishing diet. Cattle fed the silage diet through the growing period had less carcass fat at the end of the period (Coleman et al., 1995b) than cattle fed the corn grain diet (21 versus 26%). However, at the end of the 105 day finishing period the silage fed cattle had more carcass fat (28 versus 27%). Steers fed silage during the growing phase and slaughtered early in the finishing phase had tougher ($P < .05$) steaks which tasters perceived as less flavorful ($P < .05$); these differences were no longer detectable after cattle were fed the finishing diet for 75 days.

Dockerty et al. (1973) used 46 Hereford steers in a 2 x 2 x 3 factorial experiment. The cattle were fed at two planes of nutrition (6.5 months at maintenance followed by full feeding versus continuous full feeding), two dietary energy levels (high, corn-based diet vs. low, soybran flake-based diet), and to three slaughter weights (227, 341, and 454 kg). For cattle fed to 454 kg on the high energy diet there was no difference between maintenance and control groups in ribeye area, carcass maturity, marbling, and quality grade. Cattle fed at maintenance had less backfat (.89 vs. 1.32 cm; $P < .01$), better yield grades (2.82 vs. 3.45; $P < .01$), and less trimmable fat (4.18 vs. 5.23%; $P < .01$). When a proximate analysis was performed, cattle restricted to maintenance initially and fed the high energy diet to 454 kg had somewhat less ether extract (34.7 vs. 36.9%) and also had more carcass protein (15.1 vs. 14.4%; $P < .05$).

Jesse et al. (1976) fed Hereford steers a corn grain and corn silage diet from 227 to 545 kg body weight. They were fed four rations with different ratios of corn and corn silage on a dry matter basis. The rations and the corn to corn silage ratios were: A (30:70), B (50:50), C (70:30), D (80:20). The type of ration fed had no effect on the amount of protein, fat, and ash deposited in either empty body or carcass gain. Overall cattle fed diet A gained less ($P < .05$) in terms of empty body weight gain per day.

Effect of previous diet type on body composition

Hancock et al. (1987) grazed yearling Hereford steers on tall fescue (TF), smooth bromegrass-red clover (BG-RC) , or orchardgrass-red clover (OG-RC) pastures prior to placement in the feedlot for finishing. Steers grazing TF entered the feedlot at lighter weights and remained lighter throughout finishing ($P < .05$) even though dry matter intakes and feed conversions were similar ($P > .05$) among grazing treatments. Steers that previously grazed TF had less ($P < .05$) body fat, body protein, fat thickness (.53 versus .74 and .71 cm, respectively; $P < .05$), smaller ($P < .05$) ribeye areas and lower ($P < .05$) yield and quality grades than those grazed BG-RC and OG-RC.

Hancock et al. (1988) in a similar experiment grazed fifty-four Hereford yearling steers on tall fescue (TF), smooth bromegrass - red clover (BG-RC) , or orchardgrass - red clover (OG-RC) pastures before being finished on a high-grain diet. During the first 56 days in the feedlot, live weight and body fat was lower ($P < .05$) for steers that grazed TF compared with steers that grazed OG-RC and BG-RC treatments.

Interaction of ration processing and feed intake

Galyean et al. (1976) processed corn in different ways, fed it to steers with permanent ruminal and abomasal cannulae, and whole tract starch digestion was determined. Cattle fed high moisture corn grain had total tract starch digestibilities of 99.1%, those fed steam flaked corn had digestibilities of 99.1% as well. Cattle fed dry rolled corn had lower starch digestion ($P < .05$; 96.3%). Orskov et al. (1969) reported approximately 21 to 22% of unprocessed corn starch escaped ruminal fermentation. Beever et al. (1970) found ruminal digestion of steam flaked corn to be 95.7% and that of ground corn to be 78.1%. McKnight et al. (1973) found when ensiled high moisture corn was fed to feedlot heifers there was considerably more ruminal fermentation of starch than when dry corn was fed.

Galyean et al. (1979) used crossbred beef steers weighing 285 kg initially, to examine the effect feeding an 84% corn diet, at multiples of maintenance (M) intake, had upon extent of feed digestion in the rumen and total tract. Total tract starch and dry matter digestion was higher for cattle fed at maintenance than for cattle fed 1.67 or 2 times maintenance levels. Average daily dry matter intakes during the 10 day feeding period were 2.6 kg for cattle fed at maintenance, 3.4 kg for 1.33 times M, 4.3 kg for 1.67 times M, and 5.3 kg for 2 times M. Also total organic matter digestion for these levels was 86.4, 84.7, 79.5, and 78.2%, respectively. Intestinal starch digestion coefficients obtained were quite low, suggesting either an overestimation of ruminal starch digestion or low intestinal starch digestion. When expressed as a percentage of presented starch digested, intestinal starch digestion decreased from 93% in M fed cattle to under 10% in cattle fed at 2 times M.

Anderson et al. (1959) feeding a 80:20 concentrate to roughage ration to steers, found that total tract dry matter digestion decreased from 87.5% at one-half maintenance intake to 74.3% at 2.7 times maintenance needs. In studies with dairy cattle Wheeler et al. (1975) observed a decrease in total starch digestion of approximately 12% as intake increased from maintenance to 3.2 times maintenance on 73:30 concentrate/forage diets. Kratchner et al. (1973) observed no difference in ruminal or total tract starch digestion with steers fed ad libitum vs 80% ad libitum using diets of either steam flaked or dry rolled sorghum. Similar results have been reported with rolled barley diets fed to sheep (Macrae and Armstrong, 1969).

Murphy et al. (1994a) looked at the effects of intake level (ad libitum and 70% of ad libitum) and method of corn grain processing (whole or rolled) on dry matter and organic matter digestion. There was an intake x processing interaction ($P < .03$) effect on dry matter and organic matter digestion. The major cause of the interaction was thought to be the decrease in starch digestion seen in limit fed cattle on the whole-corn diet. Nitrogen digestion was increased ($P < .03$) by limiting intake. There was no effect of grain processing on nitrogen digestion. The cattle fed at 70% of ad libitum had lower ruminal turnover rates (percent/hour) as well.

Energy intake and digestion and absorption

Heifers of Hereford and Angus origin were fed three energy levels: 84, 157, or 225 kcal ME/kg body weight$^{0.75}$ (Huntington and Prior, 1983). Apparent digestibility (AD) of dry matter increased linearly ($P < .05$) with increasing energy intake from 76.7 to 84.9%. As energy intake increased AD of digestible energy increased ($P < .05$) in a linear manner as well from 74.3 to 83.4%. Net absorption of volatile fatty acids increased linearly with increased energy intake (311 to 795 mmol/hour). Net absorption of glucose was negative at low intake, but tended to increase to positive values as intake increased.

Effect of implants on carcass composition and metabolism

Bartle et al. (1992) found cattle implanted with an estradiol implant will have higher rates of gain and greater feed efficiencies ($P < .001$), when fed high concentrate finishing rations, than cattle not given an implant. Implanted cattle, at the same backfat thickness, will tend to have heavier carcasses (8 to 22 kg). At the same time the cattle given estradiol will have lower marbling scores ($P < .05$) and a lower percentage of the carcasses grading Choice or better ($P < .01$).

Cecava and Hancock (1994) determined that estradiol 17-B (E2) increased ($P < .05$) N retention and decreased ($P < .05$) plasma urea N concentrations. Implantation (E2 or trenbolone acetate), improved ($P < .05$) growth rate and feed efficiency. No interactions ($P > .45$) between implant type and protein source were observed. Feeding higher ruminal escape protein may enhance the growth of implanted cattle but this relationship is likely impacted by animal growth potential, basal diet fed, and choice of supplemental protein.

Hays et al. (1995) limit fed a group of medium-framed crossbred steers a 35% concentrate diet such that they gained about 0.10 kg d^{-1} during a 66 day restricted feeding period. After this period of limit feeding the cattle were fed one of three diets during a realimentation period. The diets were 80% concentrate and contained 9, 12, or 15% crude protein (CP). The cattle also were either implanted with 24 mg of estradiol 17-β or not implanted. All animals were given ad libitum access to their diet and daily feed intake was monitored using a Calan gate system. Real-time ultrasound was used to measure ribeye area and 12th rib fat (backfat). Steers fed 9% CP weighed less (quadratic, $P < .05$) after 14 days of realimentation than steers fed 12 or 15% CP due to slower (quadratic, $P < .05$) gains during this initial period. Implantation increased ($P < .05$) gains from day 15 to 56 of realimentation. Increasing concentrations of dietary CP resulted in increased ($P < .05$) ribeye area on days 28 and 56, and backfat on day 98. Implantation increased ($P < .01$) IGF-I throughout the realimentation period, whereas IGF-I concentrations were increased (quadratic, $P < .05$) in steers fed 12 and 15% CP on day 28 only. The cattle on the 12% CP diet during the realimentation period had better gains than those on the 9 and 15% CP diets as well as the best feed efficiency values. There was a linear effect of CP concentration on fat thickness after 98 days of refeeding ($P < .05$). Fat thicknesses for 9, 12, and 15% CP diets were .52, .73, and .77 cm, respectively.

Effect of feed restriction on organ size and O^2 consumption

Freetly et al. (1995) fed six wethers ad libitum two hours per day. At 49 kg body weight two were left on the ad libitum diet and the rest were fed 80 days at 70% of their previous average feed consumption. The O_2 consumption of hepatic and portal drained viscera was measured after 80 days of restriction and were decreased by 40% in portal drained viscera and 35% in hepatic tissue. After realimentation (switch to two hours per day ad libitum), portal drained viscera required 47 days to return to an oxygen consumption of within 1% of the new post restriction steady state. Hepatic tissue required 36 days to reach the same level.

Researchers have measured O_2 consumption in vitro and organ weight data which indicate that visceral tissue are primary components of whole-animal energy expenditures (Ferrell and Koong, 1985; Burrin et al., 1989b). In vivo measurements in growing animals have confirmed that visceral tissues use a large proportion of the O_2 consumed by the whole animal (Burrin et al., 1989a; Eisemann and Nienaber, 1990).

Huntington et al. (1988) compared net nutrient absorption and oxygen consumption by portal-drained viscera (PDV) of catheterized Holstein steers (333 kg). The animals were fed alfalfa or orchardgrass silage at two equalized intakes. Type of silage fed had no influence ($P > .10$) on blood flow to or O_2 consumption by PDV or net absorption of glucose, L-lactate, acetate, propionate, or urea-N. Oxygen consumption by PDV as a percentage of whole-animal O_2 consumption was not different ($P > .10$) for steers when fed either silage type. The authors concluded that the PDV accounted for a substantial portion of whole-animal O_2 consumption.

Changes in endogenous hormones during feed restriction

The ruminant digestive system is unique, variations in diet composition and intake produce dramatic changes in ruminal fermentation. Optimizing nutritional management requires an understanding of how these variations and changes influence digestion and metabolism. The pancreas plays a central role in digestion and nutrient metabolism, however little is known about pancreatic adaptation to nutritional changes in the ruminant. Increasing starch intake has been suggested to increase pancreatic α-amylase. Some research suggests that dietary energy may drive these changes and that interactions with other nutrients may exist. Studies describing the influence of altered protein and lipid intakes on pancreatic adaptation in ruminants are lacking. Pancreatic secretion of both insulin and glucagon respond to the intravenous infusion of volatile fatty acids (VFA) in a dramatic fashion; the influence of VFA on insulin and glucagon in feeding studies suggests the in vivo response is more subtle. Assessment of pancreatic endocrine secretion is also complicated by a variable removal of insulin and glucagon by hepatic tissues. Studies of these controlling mechanisms should consider the entire array to more fully understand hormone secretion.

Blum et al. (1985) fed growing steers restricted levels of energy and protein, just above calculated maintenance levels, for a period of five months. During this time concentrations of thyroxine (T^4), 3,5,3'-triiodothyronine (T^3), insulin, glucose, and α-amino-acid nitrogen were reduced. Concentrations of growth hormone and nonesterified fatty acids were elevated. Concentrations of 3,3',5 triiodothyronine (rT^3) and albumin were not different from unrestricted cattle.

Ellenberger et al. (1989) fed beef steers ad libitum a 70% cracked corn, 30% pelleted alfalfa plus supplement diet and they gained on average 1.4 kg d^{-1} from 240 to 510 kg live weight. Six steers were restricted in their feed intake such that they gained .37 kg/day from 240 to 307 kg. Once the restricted cattle reached 307 kg they were switched to the ad libitum diet and fed to 510 kg. Serum concentrations of growth hormone (GH) were elevated during restricted growth (45.6 vs 23.4 ng/ml; $P < .05$) and serum concentrations of insulin-like growth factor-I (IGF-I) decreased (108 vs 167 ng/ml; $P < .05$) compared with control steers given ad libitum access to feed. Levels of T4 and glucose (GLU) also were lower ($P < .05$) during restricted growth. During early realimentation, levels of GLU ($P < .05$), IGF-I ($P < .01$), T4 and blood urea nitrogen ($P < .01$) increased. Levels of IGF-I seemed to follow growth rate and may explain why GH levels can be elevated during periods of reduced growth rate in beef cattle.

Hayden et al. (1993) restricted one group of cattle to a forage based diet containing 2.13 Mcal ME/kg, while a nonrestricted group received a diet with 2.76 Mcal ME/kg. The restricted diet was fed at 2.0% of body weight and the nonrestricted diet was fed at 2.4% of body weight, adjusted weekly for changes in body weight. Deposition of empty body protein was decreased ($P < .001$) in restricted animals compared with nonrestricted controls. Deposition of empty body fat was also decreased ($P < .001$) in restricted animals (187.7 g/d) compared with nonrestricted controls (396.8 g/d). Cattle fed the restricted diet had decreased levels of blood glucose, IGF-I, insulin, T_4, and T_3 ($P < .05$). However, plasma urea nitrogen, nonesterified fatty acids, and growth hormone levels were increased ($P <.05$), and IGF-II concentrations were similar between restricted and nonrestricted steers. These results suggest that compensating steers are more metabolically efficient; rapid body tissue gain occurs during a period of reduced nutrient digestibility. Empty body weight gains were reduced in restricted cattle (.53 and 1.17 kg/d; $P < .001$). Daily DMI and feed efficiencies were reduced as well ($P < .001$).

Chan et al. (1993) examined how the expression of liver IGF-I was affected by the degree and duration of reduced feed intake. Twelve adult male rats were fed 60% the feed intake of 12 control rats and four of each group were sacrificed on days 10, 15, and 20. Compared to controls, body weight gain of the animals on reduced feed intake was significantly lower and was correlated with the reduction of liver IGF-I mRNA.

Elsasser et al. (1989) fed several diets to British crossbred steers weighing 280 kg initially. Diets were formulated such that CP was 8, 11, and 14% and ME was either 1.96 or 2.67 Mcal/kg, allowing cattle to gain at varying rates. The primary feed ingredients were cracked corn, 44% soybean meal, cottonseed hulls, and wheat straw. The high protein diet increased the frequency of growth hormone secretion ($P < .05$). Cattle fed the 8% protein diet, however, had a higher 6 hour sampling interval mean GH concentration than cattle fed either the 11 or 14% CP diet (5.07, 4.25, and 4.97 ng/ml, respectively; $P < .05$). Cattle fed the 8% CP diet had lower mean thyroxine levels compared to cattle fed either the 11% or 14% CP diet (97.5, 125.3, and 119.0 ng/ml, respectively; $P < .05$). Cattle restricted in energy intake had lower mean thyroxine levels as well (98.3 vs 129.6; $P < .05$). Restricted intake cattle had lower basal levels of IGF-I when compared to cattle on full feed (82 vs 121 ng/ml).

Diet composition and intake affect plasma concentrations of IGF-I in steers. In cattle, CP may be the nutritional determinant of basal IGF-I production, but the IGF-I response to CP may be affected by the energy available in the diet.

Fox et al. (1974) fed steers on two planes of nutrition: five or six months on a maintenance diet and full fed following the limit period or continuously full fed. Steers limited in intake had lower growth hormone concentrations than full fed steers when sampled at 320 to 360 kg live weight ($P < .05$). Limit-fed steers had lower thyroid secretion rates during the period of intake restriction and the first part of the realimentation period of full feeding, which agrees with earlier work by Post and Mixner (1961). Thyroid secretion rates even exceeded that of control cattle as the full feeding phase continued. The authors noted that the changes in thyroid secretion rates suggest there was a lower energy requirement for maintenance during the period of energy restriction and the first part of the full feeding period, and as a result the restricted cattle were able to better utilize energy and protein more efficiently when placed on full feed.

Effect of frame size and muscling on carcass characteristics

According to Dolezal et al. (1993), whether cattle are placed in the feedlot as calves, yearlings, or long yearlings impacts the percentages of carcass components when cattle are fed to a constant subcutaneous fat depth ($P < .05$). Cattle fed as long yearlings versus those fed as calves, have been found to have a greater percentage of carcass fat (33.2 vs. 31.9%; $P < .05$). Also, less of the carcasses of long yearlings is composed of bone, compared with cattle fed as yearlings or calves (15.0, 15.6 and 15.6%, respectively; $P < .05$).

Effect of breed component on carcass characteristics

DeRouen et al. (1992) postulated that when considering breeds for use in production of feeder type cattle, maternal additive and heterotic effects appear to be of lesser importance than the direct additive and heterotic effects for carcass traits such as hot carcass weight, retail yield, longissimus muscle area, fat thickness, marbling score, and Warner-Bratzler shear force.

Fortin et al. (1980) looked at the empty body chemical composition in 159 cattle. There were steers, bulls, and heifers representing both Angus and Holstein breeds, processed into beef at weights ranging from 121 to 706 kg. The cattle were fed at two intake levels: ad libitum and 65 to 70% of ad libitum. The accretion rates of protein and ash were higher ($P < .05$) in Holsteins than in Angus, regardless of sex. A breed influence on the accretion rate of chemical fat was detected only for bulls, where Angus had a higher accretion rate. In Angus cattle, across all sexes, the accretion rate of protein was more rapid ($P < .05$) in the low intake group; however, the accretion rate of chemical fat was slower ($P < .05$).

Gregory et al. (1994a) used steers from three composite populations of beef cattle at the Meat Animal Research Center, Clay Center, NE, to examine retained heterosis for meat traits. The cattle were finished on two levels of energy (2.82 Mcal of ME and 3.07 Mcal of ME), with each diet containing 11.5% crude protein. They found that marbling score was a poor predictor of meat palatability parameters, based on phenotypic correlations. The researchers determined estimates of heritability which were intermediate to high for measures of fatness and low for palatability characteristics. They found a high negative genetic correlation (-.56) between percentage of retail product and marbling score. Combined with the relatively low genetic correlations between percentage of retail product and palatability characteristics led the authors to suggest the need for simultaneous attention to percentage of retail product and palatability attributes rather than to only marbling score. Because there is limited opportunity for selecting among breeds to achieve high levels of marbling and high retail product yield, simultaneously, the most logical approach is to form composite breeds with breed contributions organized to achieve an optimum balance between favorable carcass composition and desirable palatability attributes at optimum slaughter weights. The authors conclude that this is a possible resolution to the genetic antagonism between desirable carcass composition and less favorable palatability.

Gregory et al. (1994b) determined MARC II cattle (generation three; ¼G ¼S ¼H ¼A) had a lower percentage retail product and carcass lean than the mean of contributing purebreds ($P < .01$). They also had a higher percentage of fat trim, carcass fat, and chemical fat in the 9-10-11th rib cut ($P < .01$).

Season effects on performance and carcass composition

Huffman et al. (1990) fed yearling steers during the summer (warm season) in Florida and found they had higher ($P < .05$) unshrunk ADG than calves fed in the cool season, but ADG calculated on an empty-rumen basis did not differ between the two age-seasons of feeding. Calves fed in the cool season were more efficient ($P < .05$) than yearling steers fed in the warm season when compared on a shrunk basis. Ribeye area per 100 kg of hot carcass decreased with increasing hot carcass weight. Marbling also increased as fat thickness increased up to 1.5 cm.

Kappel et al. (1972) found steers had, on average, 1/3 higher quality grades when fed during the summer versus the winter in Louisiana; this was not statistically significant. Cesar

(1985) in Florida, observed that steers fed during the cool period of the year had a significantly better yield grade (2.7) than those fed during the warm period (3.0; $P < .05$) and a significantly larger loin-eye area per 100 kg warm carcass ($P < .05$). Seasonal changes in plasma FFA levels have been observed in sheep, with lowest levels in winter and spring and highest levels in summer and autumn, suggesting the possibility of seasonal effects on lipolysis, but a borderline under nutrition at certain times of the year could not be excluded (Leat, 1974).

Muhamad et al. (1983) reported steers on summer feeding trials gained significantly faster than those on winter trials. Dry matter intake (DMI), estimated metabolizable energy intake (MEI) and feed efficiency (kg feed DM/kg gain) were found to be similar to findings by other researchers in that DMI was higher, MEI was higher and FE was less for winter fed cattle.

Effects of cold exposure on growth hormone

Continued cold exposure does not stimulate a large, prolonged increase in GH in most cattle; however according to Olsen and Trenkle (1973), certain cows may not tolerate the stress of continued exposure to around -26^{o} C, and then GH may be significantly increased.

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CHAPTER 2. EFFECT OF LIMIT FEEDING AND FEEDING FREQUENCY ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING BEEF STEERS

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Abstract

The effects of season, feed intake level, and feeding frequency on feedlot performance and carcass characteristics were evaluated using 672 crossbred yearling beef steers of predominantly British breeding. Steers were started on feed during May or November from December 4, 1990 through October 4, 1993 and were allotted to 16 pens of seven animals each. Cattle were either fed once per day at 0800 or twice per day at 0800 and 1600. The feed intake levels were ad libitum, 95% of ad libitum and 90% of ad libitum. All steers were fed a whole corn grain and chopped alfalfa hay diet. Cattle started during May and fed through the summer consumed more DM per day (P = .022), gained at a faster rate (P = .0018), and were more efficient in converting feed to body weight gain (P = .0079). Cattle limited to 90% of ad libitum intake took longer to finish (P = .0008) compared with cattle fed ad libitum, due to the lower rates of gain (P = .01) for the cattle limited to 90% of ad libitum. Feed conversion efficiencies and carcass measures were similar between the ad libitum and limit fed cattle.

Introduction

A number of studies have shown that limiting the feed intake of beef cattle will improve feed utilization, as exhibited in an improvement in feed conversion to live weight gain, without a substantial reduction in rate of gain. Limit feeding may provide a means of reducing input costs associated with beef cattle production by reducing overall feed costs. Glimp et al. (1989) explored limit feeding in sheep by feeding lambs a 90% concentrate diet ad libitum, 92.5% of ad libitum, or 85% of ad libitum. For sheep fed the 85% level, average daily gain was reduced by 8% compared with wethers allowed ad libitum access to feed. Feed efficiencies were improved 20% ($P < .01$) by limiting intake to 92.5% of ad libitum. Quality grades were reduced on the 85% of ad libitum diet ($P < .05$), but those on the ad libitum and 92.5% of ad libitum diets were the same (average Choice). Bartle and Preston (1992) fed Hereford steers ad libitum and 2.9 and 2.7 times maintenance. Cattle restricted to 2.7 times maintenance had a higher rate of gain ($P = .08$), but were not different in carcass measures than cattle fed ad libitum. Hicks et al. (1990) fed steers a wheat-based high concentrate diet either ad libitum or 85% of ad libitum and observed that feed conversion was improved ($P = .03$) by limit feeding. Notter et al. (1983) found that rams restricted to 85 and 70% of ad libitum intake had less backfat when slaughtered than rams fed ad libitum, although the differences were not significant. Tatum et al. (1988) found that by limiting energy concentration in the diet of medium or large frame crossbred calves, fat percentage in the carcass was reduced. Coleman et al. (1993) fed Angus weanling steers and discovered those fed a control diet had more backfat than those fed a restricted growing diet (17.4 vs 11.8 mm; $P < .01$). Coleman and Evans (1986) also saw a reduction in backfat accretion rate in cattle that were limit fed ($P < .05$). This is supported further by Fortin et al. (1980) who observed a reduction in the rate of chemical fat accretion when cattle were limited to 65 to 70% of ad libitum intake. This is further supported by other researchers (Dockerty et al., 1973; Tatum et al., 1988). Some results, however, indicate there is no advantage to limiting cattle intake in terms of the fat accretion rate (Pothoven et al., 1975; Carstens et al., 1991).

Firkins et al. (1986) fed steers at 100, 90 and 60% of ad libitum intake levels. Acetate production in the rumen was increased by limit feeding cattle, at the expense of butyrate production ($P < .05$). Apparent ruminal NDF digestion, as a percent of intake and as a percent of total NDF digestion, was increased ($P < .05$). Murphy et al. (1994) found that lambs fed a 92% concentrate diet and restricted to 90% of ad libitum intake had higher digestibilities of DM, organic matter, ADF, starch, and crude protein ($P < .001$). Limit feeding has been shown to improve digestion of feed organic matter (Grimaud and Doreau, 1995).

Based on the evidence available, it seems that limiting the DM intake of feedlot steers should result in a reduction in body fat, with little reduction in rate of gain. At the same time cattle may require less feed for growth. The objective of this experiment was to determine, using yearling beef steers, the combination of feed intake level and feeding frequency which resulted in the best feedlot performance and carcass characteristics.

Materials and Methods

Experimental design

The experiment was begun December 4, 1990 at the Western Iowa Research and Demonstration Farm at Castana, Iowa. One hundred twelve British crossbred yearling steers with an average weight of 370 kg were used in each trial for a total of 672 animals. All steers were implanted with Compudose™, injected with Ivomec™, and placed into 16 pens of seven animals each.

The feed intake levels were ad libitum, 95% of ad libitum and 90% of ad libitum. Cattle assigned the ad libitum feed intake level were provided enough feed each day such that feed was always available in the feedbunk. Feed provided was increased for all cattle fed ad libitum when the bunks in approximately one-half the pens were completely empty at 0700 prior to the morning feeding. Those cattle assigned the 95% and 90% of ad libitum feed intake levels were provided with 5% and 10% less, respectively, total feed DM than the cattle on the ad libitum intake level. There were two feeding frequencies: 1) once per day at 0800, 2) twice per day at 0800 and 1600. Cattle were started on feed twice per year and fed during either the summer or winter in order to test for an effect of starting time on feed.

After arrival at the farm all cattle were fed alfalfa hay initially and then gradually adjusted to the 85% concentrate finishing ration over a period of two weeks. All steers were fed a whole corn grain and chopped alfalfa hay diet supplemented with a urea-based 40% crude protein, vitamin and mineral premix which contained Rumensin™. Molasses was added to control dust and increase palatability. Feed allotments were determined daily before the morning feeding. All cattle were fed at 0800, twice-daily fed cattle were given one-half of the day's feed allotment in the morning at 0800 and the other one-half in the late afternoon about 1600. Steers were housed in pens, with concrete floors, 26.5 meters by 4.3 meters, with 7 meters of shelter at the north end of each lot. Steers were fed in fence-line concrete bunks, 53 cm per animal, and one automatic waterer was shared between every two pens.

Feedlot performance measures

Daily DMI was determined for each pen by recording the amount of air-dry feed fed, from a feed wagon equipped with a digital scale, and converting the amount to a DM basis.

Dry matter determinations were made on the ration ingredients twice weekly. Steers were weighed individually every 28 days. Average daily gain and feed conversion were determined by adjusting each steer's final live weight to a constant dressing percentage of 61.5%. Percent shrink was calculated as final farm weight minus weight prior to slaughter divided by final farm weight.

Carcass characteristic measures

When pens of cattle reached 560 kg average live weight they were transported 52 km to IBP in Denison, IA at about 1700 the evening prior to slaughter and remained overnight in pens with access to water but no access to feed. Cattle were slaughtered between 0600 and 0730 following the overnight rest at the plant. Liver weights and presence of liver abscesses were determined within 15 minutes after slaughter when the livers and other internal organs were removed on the processing line. Twelfth rib fat thickness (backfat) was measured on the left half of each carcass, between the 12th and 13th ribs, three-fourths of the length of the ribeye from the chine bone end, and after a 24-hour chill. Backfat was measured to the nearest .05 inches, on the processing line, using a ruler along the edge of the ribeye area grid and was reported in centimeters. Ribeye area was measured to the nearest .1 square inch, using a plastic grid with 10 dots per inch and was reported in square centimeters. Kidney, pelvic, and heart fat (KPH), quality and yield grades were provided by the USDA Meat Grading Service. Quality grades, as provided by the USDA Meat Grading Service, to the nearest one-third of a grade, were converted to a numerical value. A quality grade of high Select was equal to a value of six, low Choice was equal to a value of seven, average Choice was equal to a value of eight.

Statistical analyses

All means were adjusted to an average initial weight basis using the linear relationship of the variable to initial weight. Experimental units were pens of cattle. There were seven cattle per pen and 16 pens of cattle were started each time cattle were started on feed. Cattle were started on feed twice per year during May and November to test the effect of starting time on feed. Cattle were fed at three levels of feed intake. Two feeding frequencies were used and, when combined with the three feed intake levels, formed six treatments. The treatments were replicated three times within each trial, with the exception of the 90% of ad libitum once-daily feeding and the 90% of ad libitum twice-daily feeding treatments, which were replicated twice. The model used to analyze the data included year, starting month, feed intake level, feeding frequency, the interaction of starting month and feed intake level, the interaction of starting month and feeding frequency, the interaction of feed intake level and feeding frequency, and the linear effect of initial weight. The adjusted means came from the least squares means given by the general linear model procedure of SAS (1989).

Results and Discussion

Cattle started in May and fed through the summer finished 22 days sooner (Table 1), on average, than cattle started during November ($P = .0041$). Cattle started on feed during May had heavier live ($P = .054$) and carcass ($P = .054$) weights when processed into beef. Summer fed cattle, on average, consumed more feed DM per day than winter fed cattle ($P = .022$). Most of the weight loss which is recorded as shrink is due to fecal and urinary losses in transit. Therefore, the cattle consuming more feed per day would be expected to defecate more per day, have a larger amount of fecal loss in transit, and shrink more. This was not the case in this experiment. The cattle started in November and slaughtered during April may have shrank more due to mud on their hide and in their hair being rubbed off during transit. The tendency for cattle fed through the winter to shrink more in transit may be explained by an increased rate of passage of digestive tract contents. There is evidence that cold environmental conditions cause an increased rate of passage of digesta in cold-exposed animals, which leads to reduced digestive efficiency (Delfino and Mathison, 1991). Warriss et al. (1990) found that the season in which lambs (32 kg) were slaughtered did not have an affect on body weight losses during transport for sheep slaughtered in June and November. In cattle fed through the winter there may be an increased rate of fecal loss in transit, as well as a reduction in overall feed efficiency.

Athough cattle started in May and fed through the summer consumed more dry matter per day (Table 1), on average, compared to cattle started in November and fed through the winter ($P = .022$), this would not be expected because cold exposure has been shown to increase feed consumption (NRC, 1981,1987), while heat stress results in a reduction in intake. The summer fed cattle gained weight at a higher rate (1.59 vs 1.30 kg d^{-1}; $P = .0018$). Cattle fed through the summer were more efficient (.146) versus cattle fed through the winter (.129; $P = .0079$), which is supported by the reduction in digestive efficiency in cold exposed animals. It took less time (12.21 versus 13.06 h, respectively) on average for summer fed cattle to consume their daily feed allotment (bunk cleanup time) compared to winter fed cattle ($P = .10$).

The average backfat (BF) thickness over the 12th rib (Table 1) was similar between summer and winter fed cattle. Likewise, ribeye area (REA) least squares means did not differ based on the season during which cattle were fed, but REA were slightly larger in summer fed cattle. Kidney, pelvic, and heart fat (KPH) tended to be greater in winter fed cattle. Quality grade means were lower in cattle fed during the summer versus the winter (P = .066), however, cattle started during May and November had an overall mean quality grade of low Choice. Because the ages of the cattle were not known the difference may be due to the fact that cattle started in November were older. Yield grade was not affected by the season during which cattle were fed. Livers containing one or more abscesses were more prevalent in cattle fed during the summer (P = .061). Cattle started on feed during May had heavier livers at slaughter compared with cattle started during November (P = .062). A heavier liver is indicative of more tissue mass and a higher rate of metabolic activity in the liver. In the ruminant animal, adipose tissue is the site of de-novo fatty acid synthesis and the liver is primarily responsible for gluconeogenesis (Bauman and Davis, 1975). It is possible that the liver is producing more glucose in the summer months to meet the tissue needs of the animal due to the greater metabolic rate and the higher energy expenditure towards heat dissipating activities.

Cattle with a feed intake level of 90% of ad libitum took longer to reach finished weight (Table 2) than those fed the ad libitum (P = .0008; Table 3) or 95% of ad libitum level (P = .016). This was due to the lower dietary energy intake per day of those limited to 90% of ad libitum, a function of the feed intake level treatment, which increased days on feed by lowering the average weight gain per day. Feeding frequency did not affect days on feed.

Table 1. Least squares means for feedlot performance and carcass composition by season

Item	Season: Summer[a]	Season: Winter	P > F
Days on feed	123.66 ± 1.56	145.56 ± 1.59	.0041
Final wt (kg)	566.21 ± 2.02	556.19 ± 2.06	.054
Hot carcass wt (kg)	346.52 ± 1.24	340.39 ± 1.26	.054
Shrink (%)	1.21 ± .20	2.02 ± .20	.12
Daily DMI (kg)	10.92 ± .053	10.09 ± .054	.022
ADG (kg)	1.59 ± .019	1.30 ± .019	.0018
FE (gain/feed, kg)	.146 ± .0018	.129 ± .0018	.0079
Bunk cleanup (hr)	12.21 ± 1.51	13.06 ± 1.43	.10
BF (cm)[b]	1.18 ± .029	1.16 ± .029	.79
REA (cm^2)	85.07 ± .48	82.84 ± .49	.19
KPH (%)	2.06 ± .055	2.32 ± .056	.31
Quality grade[c]	6.52 ± .093	7.24 ± .095	.066
Yield grade	2.32 ± .045	2.34 ± .046	.47
Liver abscess (%)	17.93 ± 2.69	8.63 ± 2.75	.061
Liver wt (kg)	7.11 ± .063	6.73 ± .064	.062

[a]Summer trials were begun during May, winter trials were begun during November.
[b]BF = backfat thickness; REA = ribeye area; KPH = kidney, pelvic, and heart fat.
[c]Quality grade of 6 = Select$^+$; 7 = Choice$^-$; 8 = Choice^o.

Cattle on all intake levels were taken to a similar average end weight (Tables 2 and 3). End weight was determined by adjusting each steer's final live weight to a constant carcass weight basis using 61.5% as the standard dressing percentage. Hot carcass weight was not affected by feed intake level or feeding frequency. Likewise, there was not a feed intake level x feeding frequency interaction. The amount of weight cattle lost in transit and prior to slaughter was calculated as shrink. This value, as a percentage of live weight, was not affected by feed intake level. It has been shown that limit-fed steers have lower thyroid secretion rates during intake restriction (Post and Mixner, 1961). Fox et al. (1974) fed steers on two planes of nutrition and determined that limit-fed steers had lower thyroid secretion rates during the period of intake restriction and the first part of the realimentation period of full feeding. Thus cattle limited in feed intake would be expected to have a slower passage rate, due to the reduction in thyroxine, and in turn less shrink in transit. There was a trend towards a reduction in shrink as cattle were limit fed. Cattle fed ad libitum shrank 1.73%, compared to cattle fed 95% of ad libitum which shrank 1.78%, and cattle fed 90% of ad libitum shrank 1.34%.

Shrink was not influenced by feeding frequency (Table 2). However, cattle fed once daily tended to shrink less (1.37%) than cattle fed twice daily (1.86%). This difference is not likely due to the difference in DMI between the two feeding frequencies. Perhaps feeding frequency affects rate of passage such that cattle fed twice daily have an increased rate of passage and thus an increased amount of defecation per unit time. Goetch and Galyean (1983) determined that an increase in feeding frequency may increase passage rate. They found that passage of cobalt ethylenediamine tetracetic acid (Co-EDTA) determined from fecal sampling was higher ($P < .05$) in Hereford steers (322 kg) fed eight times per day than in those fed twice per day.

By design, cattle given ad libitum access to feed consumed more DM per day (Table 4) than cattle limited to 95% of ad libitum ($P = .0001$, Table 5). In turn, 95% of ad libitum cattle ate more than 90% of ad libitum cattle ($P = .0001$). Feeding frequency impacted DM intake, average daily intakes were 10.56 and 10.46 kg of DM per day for once and twice daily fed cattle, respectively ($P = .028$).

Table 2. Least squares means for days on feed, adjusted final weight, and percent shrink by feed intake level and feeding frequency

Intake level	Item	Feeding frequency: Once daily	Twice daily	Avg
Ad libitum	Days on feed	130.68 ± 2.23	131.40 ± 2.24	131.04 ± 1.61
	Final wt (kg)	559.95 ± 2.88	561.79 ± 2.90	560.87 ± 2.09
	Hot carcass wt (kg)	342.69 ± 1.76	343.82 ± 1.77	343.25 ± 1.28
	Shrink (%)	1.27 ± .28	2.19 ± .28	1.73 ± .20
95%	Days on feed	132.04 ± 2.22	134.67 ± 2.23	133.35 ± 1.61
	Final wt (kg)	556.60 ± 2.88	561.94 ± 2.89	559.27 ± 2.08
	Hot carcass wt (kg)	340.64 ± 1.76	343.91 ± 1.77	342.27 ± 1.27
	Shrink (%)	1.80 ± .28	1.76 ± .28	1.78 ± .20
90%	Days on feed	140.15 ± 2.70	138.75 ± 2.72	139.45 ± 1.94
	Final wt (kg)	563.84 ± 3.50	563.08 ± 3.52	563.46 ± 2.52
	Hot carcass wt (kg)	345.07 ± 2.14	344.61 ± 2.15	344.84 ± 1.54
	Shrink (%)	1.06 ± .34	1.62 ± .34	1.34 ± .24
				P > F[a]
Avg	Days on feed	134.29 ± 1.43	134.94 ± 1.45	P = .91
	Final wt (kg)	560.13 ± 1.84	562.27 ± 1.88	P = .76
	Hot carcass wt (kg)	342.80 ± 1.13	344.11 ± 1.15	P = .76
	Shrink (%)	1.37 ± .18	1.86 ± .18	P = .37

[a]Probability of *F*-test for feeding frequency effect.

Gains were decreased (Table 4) by limiting DM intake to either 95% (P = .10; Table 5) or 90% (P = .01) of ad libitum, compared with cattle fed the ad libitum feed intake level. Ellenberger et al. (1989) fed six steers such that they were restricted in their feed intake and gained .37 kg d^{-1} from 240 to 307 kg. They found that during restricted growth, mean serum concentrations of GH increased (45.6 vs 23.4 ng ml^{-1}; P < .05), serum concentrations of IGF-I decreased (108 vs 167 ng ml^{-1}; P < .05) compared with control steers given ad libitum access to feed. A decrease in IGF-I levels in limit fed steers should result in a reduction in muscle tissue growth, which was not observed in this experiment, for REA were similar for ad libitum and limit fed cattle.

Evidence from other experiments supports a reduction in IGF-I levels during restricted feeding. Using adult male rats Chan et al. (1993) looked at the relationship between severity of feed intake reduction and the expression of liver IGF-I. Twelve rats were fed 60% the daily feed intake of 12 control rats. Compared to controls, body weight gain of animals on the 60% feed intake level was significantly lower and was correlated with the reduction of liver IGF-I mRNA expressed in arbitrary densitometric units (ADU). Control rats were at 1.1 ADU, rats on 60% for 10 days were 0.9 ADU, for 15 days 0.8 ADU ($P < .05$), and for 20 days 0.7 ADU ($P < .02$).

Table 3. Contrasts between feed intake levels for days on feed, final weight, hot carcass weight, and percent shrink

	Contrast	$P > F$[a]
Days on feed	C1[c]	P = .24
	C2	P = .016
	C3	P = .0008
Final wt (kg)	C1	P = .61
	C2	P = .19
	C3	P = .39
Carcass wt (kg)	C1	P = .61
	C2	P = .19
	C3	P = .39
Shrink (%)	C1	P = .89
	C2	P = .12
	C3	P = .15

[a]Probability of *F*-test for intake level effect.
[b]Contrasts made: C1=ad libitum vs 95%; C2=95% vs 90%; C3=ad libitum vs 90%.

Elsasser et al. (1989) fed several diets to 280 kg crossbred steers. Diets were formulated such that ME was either 1.96 or 2.67 Mcal/kg, allowing cattle to gain at varying rates. Cattle restricted in energy intake had lower mean thyroxine levels (98.3 vs 129.6; $P < .05$). Restricted intake cattle had lower basal levels of IGF-I when compared to cattle on full feed (82 vs 121 ng/ml). The authors concluded that diet composition and level of feed intake affect plasma concentrations of IGF-I in steers. In addition they suggested that undernutrition can attenuate the IGF-I response to GH and uncouple the regulation of IGF-I normally ascribed to GH. This may partially explain why REA, a predictor of retail yield and muscle in carcass, was not affected by limit feeding. Previously in this discussion results from other authors have shown an increase in GH levels and a decrease in IGF-I levels when cattle are limit fed. Perhaps the two hormones are no longer interdependent in a limit feeding situation and regardless of GH levels production of IGF-I is reduced (Ellenberger, 1989).

Cattle fed either once or twice daily had numerically identical means for average daily gain (Table 4). The feeding frequency that resulted in the highest rates of gain varied depending on the feed intake level. There was not a feed level x feeding frequency interaction. Cattle on the ad libitum feed intake level seemed to gain slower when fed once daily (1.48 kg d^{-1}) than when they were fed twice daily (1.49 kg d^{-1}; $P = .58$). Cattle on the 95% of ad libitum feed intake level tended to gain slower when fed once daily (1.44 kg d^{-1}) than when fed twice daily (1.45 kg d^{-1}; $P = .43$). Cattle on the 90% of ad libitum feed intake level gained 1.41 kg d^{-1} when fed both once daily and twice daily.

Efficiency of feed conversion, as determined by the gain to feed ratio, was not affected by feed intake level or feeding frequency (Tables 4 and 5). There was not a feed level x feeding frequency interaction (P = .83), however, there was a tendency for the gain to feed ratio to be influenced by feeding frequency depending on the feed intake level. Cattle given ad libitum access to feed tended to be less efficient when fed once daily (.135) than when fed twice daily (.137; P = .98). Cattle on the 95% of ad libitum feed intake level tended to be less efficient when fed once daily (.137) than when fed twice daily (.138; P = .96). Cattle on the 90% of ad libitum intake level tended to be less efficient when fed once daily (.138) than when fed twice daily (.141; P = .15). Another way to describe the performance implications of limit feeding is that by limiting cattle 8.1% in intake, average daily gain was decreased by 5.4%, while feed efficiency was improved by 2.9%.

Cattle on the ad libitum feed intake level took 14.47 h (Table 4), on average, to consume their daily feed allotment. Cattle limited to 95% of ad libitum finished their feed allotment in 12.07 h on average, 2.4 h less (P = .0001; Table 5) than the ad libitum treatment. Cattle fed the 90% of ad libitum intake level consumed their ration in 10.71 h on average, 3.76 h less (P = .0001) than the cattle fed ad libitum and 1.36 h less (P = .02) than 95% of ad libitum fed cattle. This time factor may be the key to implementing a system of limited feed intake in a commercial setting. As a continuation of this research the effectiveness of limiting the time per day cattle have access to feed should be explored. One may wonder if allowing cattle to eat at a self-feeder for about 12 hours per day would result in a limitation in daily intake and the associated performance benefits as suggested by the 12 h bunk cleanup time average for the 95% of ad libitum fed cattle. Cattle fed once daily tended to take less time, on average, to consume their daily feed allotment than cattle fed twice daily, however the difference was not significant.

Table 4. Least squares means for daily dry matter intake, adjusted average daily gain, feed efficiency, and bunk cleanup time by feed intake level and feeding frequency

		Feeding frequency		
Intake level	Item	Once daily	Twice daily	Avg
	Daily DMI (kg)	11.00 ± .076	10.89 ± .077	10.95 ± .055
Ad libitum	ADG (kg)	1.48 ± .027	1.49 ± .027	1.49 ± .020
	FE (gain/feed, kg)	.135 ± .0026	.137 ± .0026	.136 ± .0019
	Bunk cleanup (hr)	14.18 ± 1.33	14.76 ± .93	14.47 ± 1.14
	Daily DMI (kg)	10.48 ± .076	10.53 ± .076	10.51 ± .055
95%	ADG (kg)	1.44 ± .027	1.45 ± .027	1.44 ± .020
	FE (gain/feed, kg)	.137 ± .0026	.138 ± .0026	.137 ± .0019
	Bunk cleanup (hr)	11.78 ± 1.60	12.36 ± 1.02	12.07 ± 1.33
	Daily DMI (kg)	10.18 ± .092	9.94 ± .093	10.06 ± .066
90%	ADG (kg)	1.41 ± .033	1.41 ± .033	1.41 ± .023
	FE (gain/feed, kg)	.138 ± .0031	.141 ± .0032	.140 ± .0023
	Bunk cleanup (hr)	11.09 ± 1.61	10.33 ± 1.13	10.71 ± 1.37
				$P > F$[a]
	Daily DMI (kg)	10.56 ± .049	10.46 ± .049	$P = .028$
Avg	ADG (kg)	1.45 ± .017	1.45 ± .018	$P = .92$
	FE (gain/feed, kg)	.137 ± .0017	.139 ± .0017	$P = .78$
	Bunk cleanup (hr)	12.51 ± 1.62	12.75 ± 1.33	$P = .83$

[a]Probability of *F*-test for feeding frequency effect.

Feed intake level did not affect backfat (BF; Tables 6 and 7). There was, however, a trend towards less BF as feed intake was limited from ad libitum (1.21 cm), to 95% and 90% of ad libitum (1.15 cm). Backfat was not influenced by feeding frequency. There are several reports that support a reduction in BF due to limit feeding. Fortin et al. (1980) looked at the empty body chemical composition of cattle fed at two intake levels: ad libitum and 65 to 70% of ad libitum. In Angus steers the accretion rates of water, protein, and ash were more rapid ($P < .05$) in the low intake group, whereas the accretion rate of chemical fat was slower (P <

.05). A reduction in BF was observed by Dockerty et al. (1973) who fed Hereford steers at two planes of nutrition: 6.5 months at maintenance followed by full feeding and continuous full feeding. Cattle fed at maintenance had less BF (8.89 vs. 13.21 mm; $P < .01$). Coleman et al. (1993) found an effect of diet on BF accretion as well when Angus weanling steers were assigned either a control diet of pelleted alfalfa or a restricted diet of cubes containing grass and alfalfa hays. Steers fed the control diet had more BF than those fed the restricted diet (17.4 vs 11.8 mm; $P < .01$). Coleman et al. (1995) fed cattle a silage diet through the growing period and found they had less carcass fat at the end of the period than cattle fed a corn grain diet (21 vs 26%).

Table 5. Contrasts between feed intake levels for daily dry matter intake, adjusted average daily gain, feed efficiency, and bunk cleanup time

	Contrast	$P > F$[a]
Daily DMI (kg)	C1[b]	P = .0001
	C2	P = .0001
	C3	P = .0001
ADG (kg)	C1	P = .10
	C2	P = .25
	C3	P = .01
FE (gain/feed, kg)	C1	P = .49
	C2	P = .40
	C3	P = .15
Bunk cleanup (hr)	C1	P = .0001
	C2	P = .02
	C3	P = .0001

[a]Probability of *F*-test for intake level effect.
[b]Contrasts made: C1=ad libitum vs 95%; C2=95% vs 90%; C3=ad libitum vs 90%.

Pothoven et al. (1975) fed beef steers a finishing diet composed of 80% ground corn either ad libitum or on a restricted basis. They determined that the fatty acid synthesis capacity measured in adipose tissue samples from restricted-fed steers was lower versus ad libitum-fed steers. Carstens et al. (1991) fed steers a 70% concentrate diet ad libitum or at a restricted level. The restricted cattle were limited in intake such that they gained an average of .45 kg per day for the first 189 days of the experiment, after which they were fed ad lib to 500 kg. Restriction and realimentation had no affect on subsequent growth of the carcass chemical components protein, fat, water, or ash.

Long-term regulation of lipogenesis in cattle is accomplished via changes in intracellular content of acetyl-CoA carboxylase and fatty acid synthetase. Of these FA synthetase probably plays a lesser role in regulation of lipogenesis, however, the quantity of intracellular synthetase is controlled by diet and fasting (Burton et al., 1969). Lipoprotein lipase is the enzyme responsible for regulating hydrolysis of plasma triglycerides. The activity of lipoprotein lipase varies with changes in nutritional and physiological conditions (Garfinkel and Schotz, 1973). During times of dietary energy excess, the enzyme activity is high in adipose tissue but low in muscle; during deficit conditions, the opposite tissue relations exist (Robinson et al., 1975). The limit fed cattle may tend to have less backfat due to increased lipase activity.

There is evidence that a decrease in the energy intake per day in growing cattle may result in a decrease in lipogenic activity and thus fat accretion in subcutaneous adipose tissue. There was not a significant difference between ad libitum and restricted cattle in this experiment, but that does not disprove that there is a biological change due to limit feeding.

Feed intake level did not affect REA (Table 6), however, cattle fed the 95% of ad libitum level had the largest ribeye areas on average (84.21 cm^2). Ribeye area also was not influenced by feeding frequency (P = .60). There was not a feed level x feeding frequency interaction (P = .42). The feeding frequency that resulted in the largest REA varied depending on the feed intake level. Cattle on the ad libitum feed intake level tended to have larger REA when fed once daily, while those on the 95% and 90% of ad libitum level tended to have larger REA when fed twice daily.

Percentage KPH decreased slightly (Table 6) as cattle were limited in intake from ad libitum (2.17%), to 95% of ad libitum (2.11%; P = .32, Table 7). Cattle fed the 95% of ad libitum level had less KPH (2.11%) than those fed the 90% of ad libitum level (2.29%; P = .019). Notter et al. (1983) reported similar results in ram lambs fed a pelleted diet at 100, 85 or 70% of ad libitum; restricted rams had more KPH fat. Feeding frequency likewise had an impact on KPH fat percentage; cattle fed once daily had less (P = .0038) KPH (2.18%) versus those fed twice daily (2.20%).

Quality grades for all feed intake levels averaged low Choice (Table 6), however, quality grades decreased and then increased as cattle were limited in intake from ad libitum (6.83), to 95% of ad libitum (6.75), to 90% of ad libitum (7.05). Cattle on the 95% of ad libitum feed intake level had lower quality grades than cattle on the 90% of ad libitum level (P = .047; Table 7). Feeding frequency did not affect quality grade (P = .70). There was not a feed level x feeding frequency interaction (P = .80). Cattle on the ad libitum and 95% of ad libitum feed intake levels tended to have higher quality grades when fed twice daily, while those on the 90% of ad libitum level tended to have higher quality grades when fed once daily.

Table 6. Least squares means for backfat; ribeye area; kidney, pelvic, and heart fat; and quality grade by feed intake level and feeding frequency

Intake level	Item	Feeding frequency: Once daily	Twice daily	Avg
	BF (cm)[a]	1.20 ± .041	1.22 ± .042	1.21 ± .03
Ad libitum	REA (cm^2)	83.94 ± .68	83.62 ± .69	83.78 ± .49
	KPH (%)	2.11 ± .078	2.24 ± .078	2.17 ± .056
	Quality grade[b]	6.81 ± .13	6.85 ± .13	6.83 ± .097
	BF (cm)	1.14 ± .041	1.16 ± .041	1.15 ± .03
95%	REA (cm^2)	83.61 ± .68	84.81 ± .68	84.21 ± .49
	KPH (%)	2.07 ± .078	2.16 ± .078	2.11 ± .056
	Quality grade	6.70 ± .13	6.81 ± .13	6.75 ± .096
	BF (cm)	1.18 ± .05	1.12 ± .05	1.15 ± .036
90%	REA (cm^2)	82.97 ± .83	84.79 ± .83	83.87 ± .59
	KPH (%)	2.36 ± .094	2.21 ± .095	2.29 ± .068
	Quality grade	7.23 ± .16	6.88 ± .16	7.05 ± .12
				P > F[c]
	BF (cm)	1.18 ± .026	1.16 ± .027	P = .65
Avg	REA (cm^2)	83.51 ± .44	84.41 ± .44	P = .60
	KPH (%)	2.18 ± .05	2.20 ± .051	P = .0038
	Quality grade	6.91 ± .085	6.84 ± .087	P = .70

[a]BF = backfat thickness; REA = ribeye area; KPH = kidney, pelvic, and heart fat.
[b]Quality grade of 6 = Select$^+$; 7 = Choice$^-$; 8 = Choice^o.
[c]Probability of *F*-test for feeding frequency effect.

When cattle were fed once daily those limit fed at the 90% of ad libitum level (Table 8) had more Choice quality grade carcasses versus cattle fed ad libitum or limited to 95% of ad libitum (P = .016). However when cattle were fed twice daily those limited to 95% of ad libitum had the lowest percentage of Choice carcasses (P = .034). This is of economic significance because of the discount for Select grade carcasses.

Table 7. Contrasts between feed intake levels for backfat thickness; ribeye area; kidney, pelvic, and heart fat; and quality grade.

	Contrast	P > F[a]
BF (cm)[b]	C1[c]	P = .13
	C2	P = .99
	C3	P = .18
REA (cm^2)	C1	P = .47
	C2	P = .63
	C3	P = .87
KPH (%)	C1	P = .32
	C2	P = .019
	C3	P = .13
Quality grade	C1	P = .60
	C2	P = .047
	C3	P = .13

[a]Probability of *F*-test for intake level effect.
[b]BF = backfat thickness; REA = loineye area; KPH = kidney, pelvic, and heart fat.
[c]Contrasts made: C1=ad libitum vs 95%; C2=95% vs 90%; C3=ad libitum vs 90%.

Table 8. Percent Choice and Select grade carcasses by feed intake level and feeding frequency

		Feeding frequency	
Intake level		Once	Twice
Ad libitum	Choice[a]	61.8	70.9
	Select	38.2	29.1
95%	Choice	62.7	62.0
	Select	37.3	38.0
90%	Choice	82.2	70.3
	Select	17.8	29.7

[a]Includes Prime grade carcasses, equal to approximately 3%.

Yield grades for all feed intake levels averaged a yield grade of two (Table 9) and there were no differences between any of the feed intake levels. There is some evidence that yield grades may be improved by limit feeding, especially in light of the trend toward BF reduction. Dockerty et al. (1973) fed Hereford steers at maintenance for 6.5 months and then fed them ad libitum, after which they had better yield grades (2.82 vs. 3.45; $P < .01$) in comparison to cattle that were fed ad libitum the entire experiment. In this experiment feeding frequency did not affect yield grade ($P = .45$). Cattle on the ad libitum feed intake level tended to have higher yield grades when fed once daily, cattle on the 95% of ad libitum feed intake level tended to have higher yield grades when fed twice daily, and those on the 90% of ad libitum level tended to have higher yield grades when fed once daily.

Feed intake level did not affect liver abscess percentage (Table 9). Feeding frequency did not affect liver abscess percentage either ($P = .12$). Cattle on the ad libitum feed intake level tended to have more liver abscesses when fed twice daily, cattle on the 95% of ad libitum feed intake level tended to have more liver abscesses when fed once daily, and those on the 90% of ad libitum level tended to have more liver abscesses when fed twice daily.

Feed intake level did not affect liver weight (Table 9). Feeding frequency, likewise, had no influence on liver weight. Cattle on the ad libitum feed intake level tended to have heavier livers when fed once daily, cattle on the 95% of ad libitum feed intake level tended to have heavier livers when fed twice daily, and those on the 90% of ad libitum level tended to have heavier livers when fed once daily.

Table 9. Least squares means for yield grade, percent liver abscesses, and liver weight by feed intake level and feeding frequency

Intake level	Item	Feeding frequency: Once daily	Feeding frequency: Twice daily	Avg
	Yield grade	2.38 ± .064	2.34 ± .065	2.36 ± .056
Ad libitum	Liver abscess (%)	10.20 ± 3.88	15.24 ± 3.90	12.72 ± 2.84
	Liver wt (kg)	7.04 ± .089	6.97 ± .10	7.00 ± .07
	Yield grade	2.27 ± .064	2.28 ± .065	2.27 ± .047
95%	Liver abscess (%)	14.30 ± 3.88	14.11 ± 3.77	14.21 ± 2.78
	Liver wt (kg)	6.84 ± .09	6.92 ± .09	6.88 ± .064
	Yield grade	2.38 ± .078	2.34 ± .079	2.36 ± .056
90%	Liver abscess (%)	12.59 ± 4.54	13.23 ± 4.81	12.91 ± 3.37
	Liver wt (kg)	6.96 ± .10	6.81 ± .11	6.89 ± .075
				P > F[a]
	Yield grade	2.34 ± .041	2.32 ± .042	P = .45
Avg	Liver abscess (%)	12.36 ± 2.69	14.19 ± 2.75	P = .12
	Liver wt (kg)	6.94 ± .056	6.90 ± .06	P = .64

[a]Probability of *F*-test for feeding frequency effect.

Table 10. Contrasts between feed intake levels for yield grade, liver abscess percentage, and liver weight

	Contrast	P > F[a]
Yield grade	C1[b]	P = .14
	C2	P = .17
	C3	P = .96
Liver abscess (%)	C1	P = .66
	C2	P = .77
	C3	P = .93
Liver wt (kg)	C1	P = Not est.
	C2	P = .999
	C3	P = Not est.

[a]Probability of *F*-test for intake level effect. Not est.: contrast is not estimable due to missing data.
[b]Contrasts made: C1=ad libitum vs 95%; C2=95% vs 90%; C3=ad libitum vs 90%.

Conclusions

Producers wishing to take advantage of the seasonal affect on cattle fed whole corn grain and chopped alfalfa hay diets may want to start cattle on feed during May and feed them through the summer, because they will consume more DM per day, gain at a faster rate, and likely convert feed to gain more efficiently. Summer fed cattle will also tend to shrink less when transported to the packing plant. Limiting the daily dry matter intake of steers will increase the days on feed, decrease daily weight gain, and may improve feed efficiency. By limiting cattle to 90% of ad libitum kidney, pelvic, and heart fat percentage will be increased, however producers can also expect an improvement in quality grade. In essence cattle were fed longer and had an opportunity to deposit more intramuscular fat, a component of the quality grade determination. Bunk cleanup times were lower in limit fed cattle. As a continuation of this research the effectiveness of limiting the time per day cattle have access to feed should be explored. Allowing cattle to eat at a self-feeder for about 12 hours per day may result in a limitation in daily intake and the associated performance benefits similar to the 95% of ad libitum fed cattle in this experiment. When considering how often to feed cattle each day the largest factor may be producer preference. In this study there was no feedlot performance advantage to feeding either once or twice daily. Producers who feed once daily in the morning may expect an increase in DM intake in comparison to cattle fed twice daily, as well as a decrease in kidney, pelvic, and heart fat percentage.

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CHAPTER 3. EFFECT OF LIMIT FEEDING AND FEEDING TIME ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING BEEF STEERS

A paper to be submitted to the Journal of Animal Science

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Abstract

Three feedlot trials were conducted to examine further the effect of feeding regime upon the feedlot performance and carcass characteristics of yearling beef steers. Using 308 British crossbred yearling steers the effect of feeding time and feed intake level on feedlot performance and carcass characteristics were evaluated. The experiment was begun November 9, 1993 and concluded March 18, 1996. In each trial a pen of steers was assigned at random to a feeding time and feed intake level. The feed intake levels were ad libitum, 95% of ad libitum and 90% of ad libitum. There were three feeding times: 1) feeding once per day at 0800, 2) feeding once per day at 1600, and 3) feeding twice per day at 0800 and 1600. All steers were fed a whole corn grain and chopped alfalfa hay diet. Average daily gain and feed conversion were determined by adjusting each steer's final live weight to a constant dressing percentage of 61.5%. Limiting the daily dry matter intake of steers increased the days on feed ($P = .074$), and improved feed conversion efficiency ($P = .07$) and quality grades ($P = .0018$), without a significant reduction in daily gains. Cattle fed once daily at 1600 had less backfat ($P = .054$) than cattle fed twice daily. These results indicate that a reduction in daily feed intake does not significantly reduce feedlot performance and at the same time improves quality grade.

Introduction

In a previous paper (Delehant and Hoffman, 1997) the effects of feed intake levels and feeding frequencies upon feedlot performance and carcass characteristics of yearling steers were discussed. It was shown that limiting the daily dry matter intake of steers will increase the days on feed, while improving quality grade. In addition there was no feedlot performance advantage to feeding either once or twice daily. It was concluded that producers who feed once daily in the morning may expect a reduction in the amount of carcass backfat in comparison to cattle fed twice daily. In the current paper the impact of time and frequency of feeding on feedlot performance and carcass characteristics of beef steers will be explored further.

Materials and Methods

Experimental design

The experiment was composed of three feedlot trials. Trial one was begun November 9, 1993 at the Western Iowa Research and Demonstration Farm at Castana, Iowa. Trial two was begun November 1, 1994. Trial three was begun September 26, 1995. Trial one used 84 British crossbred yearling steers, while trials two and three each used 112 steers. The average initial weight of all steers was 355 kg. All steers were implanted with Compudose™, injected with Ivomec™, and placed into pens of seven animals each.

A pen of steers was assigned at random to a feeding time and feed intake level. There were three feed intake levels: ad libitum, 95% of ad libitum and 90% of ad libitum and three feeding times: 1) feeding once per day at 0800, 2) feeding once per day at 1600, and 3) feeding twice per day at 0800 and 1600. Cattle assigned the ad libitum feed intake level were provided enough feed each day such that feed was always available in the feedbunk. Feed provided was increased for all cattle fed ad libitum when the bunks in approximately one-half the pens were completely empty at 0700 prior to the morning feeding and cattle were evidently hungry, on three successive days. Those cattle assigned the 95% and 90% of ad libitum feed intake levels were provided with 5% and 10% less, respectively, total feed DM than the cattle on the ad libitum intake level.

After arrival at the farm all cattle were fed alfalfa hay initially and then gradually adjusted to the 85% concentrate finishing ration over a period of two weeks. All steers were fed a whole corn grain and chopped alfalfa hay diet supplemented with a urea-based 40% crude protein, vitamin and mineral premix which contained Rumensin™. Molasses was added to control dust and increase palatability. Once-daily fed cattle received their daily ration at either 0800 or 1600. Twice-daily fed cattle were given one-half of the day's feed allotment in the morning at 0800 and the other one-half in the late afternoon about 1600. Steers were housed in pens with concrete floors, 26.5 meters by 4.3 meters, with 7 meters of shelter at the north end of each lot. Steers were fed in fence-line concrete bunks, providing 53 cm per animal, and one automatic waterer was shared between every two pens.

Feedlot performance measures

Daily DMI was determined for a pen of cattle by recording the actual amount of air-dry feed fed from a feed wagon equipped with a digital scale and converting the amount to a dry matter basis. Dry matter determinations were made on the ration ingredients every three days. Steers were weighed individually every 28 days. Average daily gain and feed conversion were determined by adjusting each steer's final live weight to a constant dressing percentage of 61.5%. Percent shrink was calculated as final farm weight minus weight prior to slaughter divided by final farm weight.

Carcass characteristic measures

When pens of cattle reached about 558 kg average live weight they were processed at IBP in Denison, IA. Cattle were transported 52 km to the packing plant at about 1700 the evening prior to slaughter and remained in a pen overnight with access to water but no access to feed. Cattle were slaughtered between 0630 and 0730 following the overnight rest at the plant. Liver weights and presence of liver abscesses were determined soon after slaughter when the livers and other internal organs were removed on the processing line. Twelfth rib fat thickness (backfat) was measured on the left half of each carcass, between the 12th and 13th ribs, three-fourths of the length of the ribeye from the chine bone end, and after a 24-hour chill. Backfat was measured to the nearest .05 inches, on the processing line, using a ruler along the edge of the ribeye area grid and was reported in centimeters. Ribeye area was measured to the nearest .1 square inch, using a plastic grid with 10 dots per inch and was reported in square centimeters. Kidney, pelvic, and heart fat (KPH), quality and yield grades were provided by the USDA Meat Grading Service. Quality grades, as provided by the USDA Meat Grading Service, to the nearest one-third of a grade, were converted to a numerical value. A quality grade of high Select was equal to a value of six, low Choice was equal to a value of seven, average Choice was equal to a value of eight.

Statistical analyses

All means were adjusted to an average initial weight basis using the linear relationship of the variable to initial weight. Experimental units were pens of cattle. There were seven cattle per pen; 12 pens of cattle were started in trial number one and 16 pens of cattle were started on feed in trials two and three. Cattle were started on feed once per year during November. Cattle were fed at three levels of feed intake. Three feeding times were used and, when combined with the three feed intake levels, formed nine treatments. Within each trial treatments were replicated twice with the exception of two treatments. The 90% of ad libitum once-daily 0800 and 1600 treatments had one replication per trial. The model used to analyze the data for the effect of feeding time included year, feed intake level, feeding time, the interaction of feed intake level and feeding time, and the linear effect of initial weight. The adjusted means came from the least squares means given by the general linear model procedure of SAS (1989).

Results and Discussion

Cattle fed ad libitum took longer (146.35 d) to finish the feeding period, on average (Table 1), than cattle fed the 95% of ad libitum intake level (144.56 d), although not significantly so. The cattle fed the 95% of ad libitum intake level had less days on feed compared to the cattle fed the 90% of ad libitum intake level (152.56 d; P = .093, Table 2). Feeding time did not significantly impact days on feed, however, cattle fed once daily at 0800 tended to have more days on feed, compared to cattle fed once daily at 1600.

Cattle fed the 95% of ad libitum intake level had lighter final live weights and carcass weights (Table 1), on average, than cattle fed either ad libitum (P = .062; Table 2) or 90% of ad libitum (P = .096). However, cattle fed either the ad libitum or 90% of ad libitum feed intake levels did not differ in final live weight and carcass weight values. Feeding time had no affect upon final live weight or carcass weight.

Shrink was not affected by feed intake level or feeding time. However, cattle fed once daily at 0800 tended to shrink more (2.46%) than cattle fed once daily at 1600 (2.22%), which in turn shrank more than cattle fed twice daily (2.18). This trend is not likely due to the difference in DMI between the feeding times (Table 3), because the average consumption of DM per day did not differ between feeding times (Table 4). It's unlikely that cattle fed once daily at 0800 had an increased rate of digesta passage and thus an increased amount of weight loss in transit and during overnight rest at the packing plant. Goetch and Galyean (1983) determined that an increase in feeding frequency may increase passage rate. However, the effect of time of day cattle are fed on rate of passage has not been determined.

By design, cattle given ad libitum access to feed consumed more DM per day (11.18 kg; Table 3) than cattle limited to 95% of ad libitum (10.74 kg; P = .0003, Table 4). In turn, cattle fed the 95% of ad libitum levelate more than those fed the 90% of ad libitum level (10.74 and 10.21 kg, respectively; P = .0002). Feeding time did not impact DM intake, average daily intakes were 10.77, 10.63, and 10.73 kg of DM per day for once daily 0800, once daily 1600, and twice daily fed cattle, respectively.

Daily gains were not affected by either feed intake level or feeding time (Table 3). However, it was expected that as daily DMI was decreased, weight gain per day would also be reduced, due to the lower total energy available per day for growth. This result can be explained by the improvement in feed efficiency for cattle limited to 90% of ad libitum versus those fed ad libitum (Table 4; P = .07). Results from Hayden et al. (1993) suggest that steers are more metabolically efficient in times of limited nutrition.

Table 1. Least squares means for days on feed, adjusted final weight, and percent shrink by feed intake level and feeding time

Time[a]	Item[b]	Intake level: Ad libitum	95%	90%	Avg
	DOF	149.29 ± 6.96	143.49 ± 6.99	152.31 ± 9.86	148.36 ± 4.66
0800	Final wt (kg)	564.28 ± 5.80	546.24 ± 5.82	557.02 ± 8.21	555.85 ± 3.88
	Carc wt (kg)	345.34 ± 3.55	334.30 ± 3.56	340.89 ± 5.02	340.18 ± 2.37
	Shrink (%)	2.43 ± .47	1.78 ± .47	3.17 ± .67	2.46 ± .31
	DOF	143.39 ± 7.00	145.58 ± 6.97	147.97 ± 9.92	145.65 ± 4.65
1600	Final wt (kg)	555.25 ± 5.82	547.05 ± 5.80	552.27 ± 8.26	551.52 ± 3.87
	Carc wt (kg)	339.81 ± 3.56	334.79 ± 3.55	337.98 ± 5.05	337.53 ± 2.37
	Shrink (%)	2.48 ± .47	2.11 ± .47	2.07 ± .67	2.22 ± .31
	DOF	146.36 ± 6.97	144.60 ± 7.16	157.41 ± 6.99	149.45 ± 4.04
Twice	Final wt (kg)	554.31 ± 5.80	554.63 ± 5.96	566.85 ± 5.82	558.60 ± 3.36
	Carc wt (kg)	339.24 ± 3.55	339.43 ± 3.65	346.92 ± 3.56	341.86 ± 2.06
	Shrink (%)	1.83 ± .47	2.26 ± .48	2.44 ± .47	2.18 ± .27
	DOF	146.35 ± 4.03	144.56 ± 4.03	152.56 ± 5.25	
Avg	Final wt (kg)	557.95 ± 3.35	549.31 ± 3.35	558.71 ± 4.37	
	Carc wt (kg)	341.46 ± 2.05	336.17 ± 2.05	341.46 ± 2.05	
	Shrink (%)	2.25 ± .27	2.05 ± .27	2.56 ± .35	

[a]0800 = cattle fed once daily at 0800; 1600 = cattle fed once daily at 1600; Twice = cattle fed twice daily at 0800 and 1600.
[b]DOF = days on feed; Final wt = final weight on test; Carc wt = hot carcass weight.

Table 2. Summary of contrasts between feed intake levels and feeding times for days on feed, adjusted final weight, hot carcass weight, and percent shrink

Contrast	Probability of a greater F value: Days on feed	Final wt	Carcass wt	Shrink
Ad libitum vs 95% of ad libitum	.65	.062	.062	.64
95% of ad libitum vs 90%	.093	.096	.096	.30
Ad libitum vs 90% of ad libitum	.18	.96	.87	.51
Once daily 0800 vs 1600	.55	.40	.40	.61
Once daily 1600 vs twice daily	.41	.13	.12	.92
Once daily 0800 vs twice daily	.84	.51	.51	.53

Cattle fed the ad libitum feed intake level took the most amount of time to consume the feed provided to them daily, 13.53 h on average (Table 3). The cattle fed the 95% of ad libitum level took somewhat less time on average (13.04 h), but the difference was not significant. The cattle fed the 90% of ad libitum intake level cleaned up the feed in their bunk in an average time of 10.95 h, which was 2.58 h less ($P = .037$; Table 4) than the ad libitum and 2.09 h less ($P = .079$) than the 95% of ad libitum fed cattle. The bunk cleanup time may be the key to limiting dry matter intake in a commercial feedlot system. Perhaps if cattle are allowed access to feed ad libitum for either 13 or 11 h per day, they will consume dry matter equivalent to 95% and 90% of normal ad libitum intake, respectively, and the performance benefits discussed would be received. This needs to be explored further in future research projects.

Although there was a trend towards less backfat when feed intake was limited from ad libitum to either 95% or 90% of ad libitum (Table 5), feed intake level had no significant affect on backfat thickness (Table 6). There is evidence to support that a reduction in BF occurs due to limit feeding. Fortin et al. (1980) fed cattle ad libitum and 65 to 70% of ad libitum. The accretion rates of water, protein, and ash were more rapid ($P < .05$) in the low intake group, whereas the accretion rate of chemical fat was slower ($P < .05$). A reduction in BF due to limit feeding was observed by Dockerty et al. (1973) who fed Hereford steers at two planes of nutrition and found cattle fed at maintenance had less BF (8.89 vs. 13.21 mm; $P < .01$). Coleman et al. (1993) observed steers fed a control diet had more BF than those fed the restricted diet (17.4 vs 11.8 mm; $P < .01$). Coleman et al. (1995) fed cattle a silage diet through the growing period and found they had less carcass fat at the end of the period than cattle fed a corn grain diet (21 vs 26%). Pothoven et al. (1975) fed beef steers ad libitum or on a restricted basis and determined that the fatty acid synthesis capacity in adipose tissue samples from restricted-fed steers was lower versus ad libitum-fed steers. Cattle fed once daily at 1600 had the least amount of backfat at slaughter (Table 5). They had .86 cm on average while the once daily 0800 fed cattle had .91 cm, and the twice daily fed cattle had 1.05 cm (P = .054; Table 6).

Table 3. Least squares means for daily dry matter intake, adjusted average daily gain, feed efficiency, and bunk cleanup time by feed intake level and feeding time

		Intake level			
Time[a]	Item[b]	Ad libitum	95%	90%	Avg
	DMI (kg)	11.31 ± .11	10.78 ± .11	10.21 ± .15	10.77 ± .072
0800	ADG (kg)	1.53 ± .055	1.45 ± .055	1.42 ± .078	1.47 ± .037
	FE (kg)	.135 ± .0051	.134 ± .0051	.139 ± .0072	.136 ± .0034
	Bunk time (hr)	13.53 ± 1.71	11.70 ± 1.45	11.49 ± .93	12.39 ± 1.39
	Daily DMI (kg)	10.96 ± .11	10.71 ± .11	10.22 ± .15	10.63 ± .072
1600	ADG (kg)	1.51 ± .055	1.41 ± .055	1.47 ± .079	1.46 ± .037
	FE (kg)	.137 ± .0051	.132 ± .0051	.143 ± .0073	.137 ± .0034
	Bunk time (hr)	13.53 ± 1.94	14.39 ± 1.68	10.40 ± 1.28	13.24 ± 1.73
	Daily DMI (kg)	11.27 ± .11	10.72 ± .11	10.19 ± .11	10.73 ± .063
Twice	ADG (kg)	1.46 ± .055	1.49 ± .057	1.44 ± .055	1.46 ± .032
	FE (kg)	.129 ± .0051	.138 ± .0052	.141 ± .0051	.136 ± .003
	Bunk time (hr)	13.50 ± 1.55	13.05 ± .22	10.95 ± .66	12.51 ± .91
	Daily DMI (kg)	11.18 ± .062	10.74 ± .062	10.21 ± .081	
Avg	ADG (kg)	1.50 ± .032	1.45 ± .032	1.44 ± .042	
	FE (kg)	.134 ± .0029	.135 ± .0029	.141 ± .0038	
	Bunk time (hr)	13.53 ± 1.51	13.04 ± 1.29	10.95 ± .59	

[a]0800 = cattle fed once daily at 0800; 1600 = cattle fed once daily at 1600; Twice = cattle fed twice daily at 0800 and 1600.
[b]DMI = daily dry matter intake, ADG = average daily gain, FE = feed efficiency (gain/feed ratio), bunk time = bunk cleanup time in hours.

Table 4. Summary of contrasts between feed intake levels and feeding times for daily dry matter intake, adjusted average daily gain, feed efficiency, and bunk cleanup time

	Probability of a greater F value			
Contrast	Daily DMI	ADG	FE	Bunk time
Ad libitum vs 95% of ad libitum	.0003	.16	.70	.63
95% of ad libitum vs 90%	.0002	.69	.13	.079
Ad libitum vs 90% of ad libitum	.0001	.12	.07	.037
Once daily 0800 vs 1600	.23	.90	.65	.64
Once daily 1600 vs twice daily	.36	.95	.80	.84
Once daily 0800 vs twice daily	.70	.94	.82	.76

[a]DMI = dry matter intake, ADG = average daily gain, FE = feed efficiency, bunk time = bunk cleanup time.

Feed intake level had no affect on ribeye area (Tables 5 and 6). Cattle fed once daily at 0800 tended to have larger (P = .11) ribeye areas compared with cattle fed twice daily. There was no affect on KPH due to either feed intake level or feeding time. Quality grades were lower for ad libitum versus both 95% of ad libitum (P = .0031) and 90% of ad libitum (P = .0092) fed cattle. However, the 95% and 90% of ad libitum fed cattle did not differ. Feeding time did not impact quality grade. The cattle limited to 90% of ad libitum intake took longer to finish the feeding period versus the cattle fed ad libitum, and because intramuscular fat is a later developing depot (Lister, 1976), this suggests that the cattle fed 90% of ad libitum had more opportunity to accumulate intramuscular fat, a component of the quality grade determination. Suess et al. (1969) suggested that the rate of intramuscular fat deposition could be regulated, without altering muscle growth rate, by changing the nutritional planes in definite ways. It is apparent from other studies that carcass fat deposition can be increased or decreased, relative to muscle deposition, by varying nutritive levels (Pomeroy, 1941).

Table 5. Least squares means for backfat thickness; ribeye area; kidney, pelvic, and heart fat; and quality grade by feed intake level and feeding time

Time[a]	Item[b]	Intake level: Ad libitum	95%	90%	Avg
0800	BF (cm)	1.04 ± .10	.86 ± .10	.82 ± .15	.91 ± .069
	REA (cm^2)	84.50 ± 1.77	86.46 ± 1.77	84.81 ± 2.50	85.26 ± 1.18
	KPH (%)	2.12 ± .14	2.37 ± .14	1.95 ± .19	2.15 ± .092
	Quality grade[c]	6.54 ± .28	7.15 ± .28	6.76 ± .39	6.82 ± .19
1600	BF (cm)	.86 ± .10	.89 ± .10	.84 ± .15	.86 ± .069
	REA (cm^2)	83.42 ± 1.77	84.15 ± 1.77	80.79 ± 2.51	82.79 ± 1.18
	KPH (%)	2.07 ± .14	2.12 ± .14	2.12 ± .20	2.10 ± .092
	Quality grade[c]	6.17 ± .28	7.09 ± .28	7.41 ± .39	6.89 ± .18
Twice	BF (cm)	.99 ± .10	1.12 ± .11	1.05 ± .10	1.05 ± .06
	REA (cm^2)	83.77 ± 1.77	80.34 ± 1.81	83.16 ± 1.77	82.45 ± 1.02
	KPH (%)	2.08 ± .14	2.29 ± .14	2.20 ± .14	2.19 ± .08
	Quality grade[c]	6.69 ± .28	7.32 ± .28	7.33 ± .28	7.11 ± .16
Avg	BF (cm)	.97 ± .06	.95 ± .06	.90 ± .078	
	REA (cm^2)	83.90 ± 1.02	83.65 ± 1.02	82.93 ± 1.33	
	KPH (%)	2.09 ± .10	2.26 ± .079	2.09 ± .079	
	Quality grade[c]	6.47 ± .16	7.18 ± .16	7.17 ± .21	

[a]0800 = cattle fed once daily at 0800; 1600 = cattle fed once daily at 1600; Twice = cattle fed twice daily at 0800 and 1600.
[b]BF = 12th rib backfat thickness; REA = loineye area; KPH = kidney, pelvic, and heart fat.
[c]Quality grade of 6 = Select$^+$; 7 = Choice$^-$; 8 = Choice^o.

When cattle were fed once daily at 0800 (Table 7), the number of Choice carcasses increased for cattle limited in DMI to 95% (P = .083) or 90% (P = .10) of ad libitum. For those fed once daily at 1600 limiting DMI to 95% (P = .044) or 90% of ad libitum (P = .062) increased the number of Choice carcasses. Cattle fed twice daily graded better when their DMI was limited to 90% of ad libitum (P = .065). This shows economic importance without considering a complete economic analysis due to the discount for carcasses with a quality grade of Select or lower.

Yield grades and percentage liver abscesses were not influenced by either feed intake level or feeding time (Table 8). Ad libitum fed cattle, based on the concentrate level in the diet, would be expected to have a larger incidence of liver abscesses, an indicator of perakeratosis and bacteria migration through the rumen epithelia. However, the variation in presence of rumen abscesses was large making accurate tests of significance difficult. Cattle fed the ad libitum intake level had heavier livers than cattle fed either the 95% (P = .10; Table 9) or 90% of ad libitum (P = .058) feed intake levels. This suggests that limit fed cattle have better feed conversion efficiencies (Table 3) partly because they have less liver and digestive tract organ mass to support and thus less energy is wasted by metabolic activities in these tissues. Feeding time had no influence on liver weights post slaughter.

Table 6. Summary of contrasts between feed intake levels and feeding times for backfat thickness; ribeye area; kidney, pelvic, and heart fat; and quality grade

	Probability of a greater F value			
Contrast	BF[a]	REA	KPH	QG
Ad libitum vs 95% of ad libitum	.90	.87	.25	.0031
95% of ad libitum vs 90%	.61	.63	.33	.98
Ad libitum vs 90% of ad libitum	.54	.53	.98	.0092
Once daily 0800 vs 1600	.64	.17	.77	.75
Once daily 1600 vs twice daily	.054	.87	.59	.34
Once daily 0800 vs twice daily	.13	.11	.81	.21

[a]BF = backfat thickness; REA = loineye area; KPH = kidney, pelvic, and heart fat; QG = quality grade.

Table 7. Percent Choice and Select grade carcasses by feed intake level and feeding frequency

Feeding time		Feeding frequency Ad libitum	95%	90%
0800	Choice[a]	75.3	80.6	79.4
	Select	24.7	19.4	20.6
1600	Choice	52.0	82.8	69.0
	Select	48.0	17.2	31.0
Twice	Choice	67.7	70.3	84.2
	Select	32.3	29.7	15.8

[a]Includes Prime grade carcasses, equal to approximately 3%.

Table 8. Least squares means for yield grade, percent liver abscesses, and liver weight by feed intake level and feeding time

Time[a]	Item	Intake level Ad libitum	95%	90%	Avg
	Yield grade	2.24 ± .11	2.03 ± .11	2.14 ± .16	2.14 ± .074
0800	Liver abs (%)	10.84 ± 6.99	21.87 ± 7.02	.41 ± 9.90	11.04 ± 4.68
	Liver wt (kg)	6.89 ± .16	6.62 ± .16	6.70 ± .23	6.73 ± .11
	Yield grade	1.96 ± .11	1.96 ± .11	1.99 ± .16	1.97 ± .074
1600	Liver abs (%)	3.05 ± 7.03	12.15 ± 7.00	22.33 ± 9.96	12.51 ± 4.67
	Liver wt (kg)	6.93 ± .16	6.84 ± .16	6.31 ± .23	6.69 ± .11
	Yield grade	2.08 ± .11	2.23 ± .11	2.14 ± .11	2.15 ± .064
Twice	Liver abs (%)	23.00 ± 7.00	0.00 ± 7.19	11.21 ± 7.02	11.00 ± 4.06
	Liver wt (kg)	6.71 ± .16	6.36 ± .19	6.78 ± .16	6.62 ± .099
	Yield grade	2.09 ± .064	2.07 ± .064	2.09 ± .083	
Avg	Liver abs (%)	12.30 ± 4.05	10.93 ± 4.04	11.32 ± 5.27	
	Liver wt (kg)	6.84 ± .094	6.61 ± .099	6.60 ± .12	

[a]0800 = cattle fed once daily at 0800; 1600 = cattle fed once daily at 1600; Twice = cattle fed twice daily at 0800 and 1600.

Table 9. Summary of contrasts between feed intake levels and feeding times for yield grade, percent liver abscesses, and liver weight

	Probability of a greater F value		
Contrast	Yield grade	Liver abs	Liver wt
Ad libitum vs 95% of ad libitum	.87	.81	.10
95% of ad libitum vs 90%	.91	.93	.62
Ad libitum vs 90% of ad libitum	.97	.91	.058
Once daily 0800 vs 1600	.19	.83	.78
Once daily 1600 vs twice daily	.14	.79	.85
Once daily 0800 vs twice daily	.90	.97	.63

Conclusions

Limiting cattle to 90% of ad libitum intake increased feed conversion efficiency. Limiting intakes to either 95% or 90% of ad libitum improved quality grades without reducing rate of gain or changing yield grade compared with cattle fed ad libitum. Bunk cleanup times were reduced due to limiting DM intake. Perhaps if cattle are allowed access to feed ad libitum for either 13 or 11 h per day, a reduction in intake of 5 or 10%, respectively, may occur and the performance benefits discussed would be received. This needs to be explored further in future research projects. Producers wishing to improve the leanness of their cattle may want to use a system whereby cattle are fed once daily at 1600; on average in this study these cattle had less backfat versus cattle fed twice daily.

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CHAPTER 4. THE ECONOMICS OF LIMIT FEEDING YEARLING BEEF STEERS

A paper to be submitted to the Journal of Production Agriculture

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Abstract

Based upon performance and carcass data for limit fed cattle (Delehant and Hoffman, 1997), a series of example budgets were created to evaluate the economic advantage of limiting the DMI of feedlot steers. Cost values used were either from Lawrence and Vontalge (1996) or Lawrence et al.(1996). Base examples for both commercial feedlots and farmer feeders were created. The base examples used the same values for revenue and cost data, with the exception of the variable cost of machinery and equipment and the fixed cost of machinery, equipment, and housing. From the base examples changes in single cost and return items were made and the impact on the income over all costs and breakeven selling price are discussed. Overall, cattle limited to an intake level of 95% of ad libitum and fed once daily exhibited the most profit potential.

Introduction

The greatest production input cost, next to animal purchases, in any livestock production system, is the cost of feed. In order to maximize profits producers attempt to minimize input costs. Researchers have tested production systems with lower capital requirements and feeding systems that utilize less costly commodities or manufacturing co-products, in an effort to reduce input costs. There has also been interest in reducing feed consumption, and thereby feed costs, by limiting the amount of feed presented to an animal each day during a portion of the production cycle.

For example Hicks et al. (1990) fed steers a wheat-based high concentrate diet at two feed intake levels: ad libitum or 85% of ad libitum. Efficiency of feed conversion was improved (P = .03) by limit feeding. Glimp et al. (1989) found that limit feeding resulted in improved feed efficiency in lambs as well. Limit feeding has been shown to improve digestion of feed organic matter (Grimaud and Doreau, 1995) and reduce fat accretion in the carcass (Andersen, 1975; Coleman et al., 1993; Coleman and Evans, 1986; Dockerty et al., 1973; Tatum et al., 1988).

Little effort has been made to explore whether or not limit feeding is economically feasible in a production setting. The objective of this paper is to determine what dollar advantage if any can be expected by either a commercial feedlot or a farmer who is interested in the benefits ascribed to limit feeding beef steers.

Materials and Methods

Experimental design

An experiment was begun December 4, 1990 at the Western Iowa Research and Demonstration Farm at Castana, Iowa and was concluded March 18, 1996. Eight hundred and eighty-nine British crossbred yearling steers with an average initial weight of 800 lb were fed to market weights of about 1230 lb. All steers were implanted with Compudose™, injected with Ivomec™, and placed into a maximum of 16 pens of seven animals each in each test period. A pen of steers was assigned at random to a feeding frequency and feed intake level. There were two feeding frequencies: 1) feeding once per day at 8:00 am, 2) feeding twice per day at 8:00 am and 4:00 pm. The three feed intake levels were ad libitum, 95% of ad libitum and 90% of ad libitum.

All steers were fed whole corn grain and chopped alfalfa hay. The 85% concentrate diet was supplemented with an urea-based 40% crude protein, vitamin and mineral premix that contained Rumensin™. All cattle were fed at 8:00 am, twice-daily fed cattle were given one-half of their daily feed allotment in the morning at 8:00 am and the other one-half in the late afternoon about 4:00 pm. Steers were fed in fence-line concrete bunks with 21 inches allowed per animal, and one automatic waterer was shared between every two pens.

Feedlot performance and carcass measures

Daily dry matter intake (DMI) was determined for a pen of cattle by recording the actual amount of air dry feed fed from a feed wagon equipped with a digital scale and converting the amount to a dry matter basis. Dry matter determinations were made on the ration ingredients twice weekly. Steers were weighed individually every 28 days during each trial. When pens of cattle reached about 1230 lb average live weight they were processed at IBP in Denison, IA. Cattle were transported to the packing plant the evening prior to slaughter and remained in a pen overnight with access to water but no access to feed. Cattle were slaughtered between 6:00 and 7:30 am following the overnight rest at the plant. Liver weights and presence of liver abscesses were determined soon after slaughter. Carcass data were obtained on-line after a 24-hour chill. Twelfth-rib fat thickness (backfat) was measured on the left side of each carcass, between the 12th and 13th ribs, to the nearest .05 inches. Ribeye area was measured to the nearest .10 square inch, using a plastic grid with 10 dots per square inch. Kidney, pelvic, and heart fat (KPH), quality and yield grades were provided by the USDA Meat Grading Service.

Economic analyses

A budget worksheet was created based on the "Finishing Yearling Steers" budget worksheet in Livestock Enterprise Budgets for Iowa by Lawrence and Vontalge (1996). Values used in the calculations were either from Lawrence and Vontalge (1996) or Lawrence et al.(1996). Two base examples were created for sensitivity analyses (Appendix) which simulated two different beef production systems, a commercial feedlot as well as a farmer-feeder system. A commercial feedlot is defined here as a feedlot that feeds cattle continuously throughout the year, whereas a farmer-feeder is an individual who feeds out only one group of cattle per year. From the base examples, changes in various cost items were made and the impact on income over all costs and breakeven selling price are discussed. The base examples for both the commercial feedlot and the farmer-feeder production systems use the same values for revenue and cost data, with the exception of the variable cost of machinery and equipment and the fixed cost of machinery, equipment, and housing. For a commercial feedlot these cost items would be assigned to a group of cattle based on the portion of the year they were in the lot. However, a farmer-feeder, feeding only one group of cattle per year, would have a set expense for a group of cattle regardless of days on feed.

The base examples used a carcass price for Choice yield grade 1, 2, and 3 cattle of $114.88 for each 100 lb of carcass weight. This was derived from the average price of $70.65 for each 100 lb of live weight, paid for Choice steers in Iowa and Southern Minnesota for the years 1986 through 1995 (Lawrence et al., 1996), and using the average live weight and dressing percentage of the cattle in this experiment. Actual sale weight is the average live weight when the steers were weighed at the farm before shipment to the packing plant. Shrink was calculated as the actual sale weight minus the weight just prior to slaughter divided by actual sale weight; total revenues were adjusted for shrink. Carcass weight is the hot carcass weight measured on-line in the packing plant. Carcass weight and carcass price were used to calculate revenue received from sale of the steers. Dressing percentage was determined by dividing carcass weight by weight at the farm. Percent of cattle in the Choice and Select quality grades were 68.1% and 31.9%, 66.7% and 33.3%, and 78.1% and 21.9% for the ad libitum, 95%, and 90% of ad libitum fed cattle, respectively. Total revenues were a weighted average of the Choice and Select prices based on the values given for percentage of Choice and Select grade carcasses. The discount for carcasses with a quality grade of Select was set at $7.00 for each 100 lb of carcass weight, this is the median value of the average range in the Choice/Select spread for 1986 through 1995 for cattle marketed in Iowa. The average yield grade was that reported on-line in the packing plant by a USDA meat grader. Calculated yield grades were .25 of a grade poorer on average. Liver abscess percentage was calculated by dividing the number of cattle in each group with one or more abscesses present in their livers at processing, by the total number of cattle in each group. Total revenues were adjusted for death losses at the rate of .75% of total sales.

The value used in the base examples for the cost of the feeder steer was $78.90 for each 100 lb of live weight. This was the average price paid for medium frame, 750 to 800 lb steers in Oklahoma City during the years 1986 through 1995 (Lawrence et al., 1996). Purchase weight was the average weight at which cattle were started on feed in the feedlot.

Weights were equalized across treatments. Shrink coming into the feedlot is not accounted for because individual animal weights were not available for cattle prior to shipment to the research farm. The interest rate on money invested in purchasing the feeder steers was 10% (Lawrence and Vontalge, 1996), and it was assumed that 100% of the value of the feeder animal was borrowed. Days on feed were from the day cattle were started on test through the day they left the research farm and were transported to the packing plant.

Average daily gains and feed conversions were determined by adjusting each steer's final live weight to a constant dressing percentage of 61.5%. Dry matter intake (DMI) was calculated as average daily gain divided by the gain to feed ratio and was used to calculate feed costs. Average prices for corn, hay, and supplement were obtained from Lawrence et al. (1996) and are the average prices received by farmers for 1986 through 1995. Feed dry matter (DM) values are the average DM percentages for the feedstuffs for the whole experiment and were used, along with DMI, to calculate the amount of each feedstuff consumed on an as-fed basis (bushels of corn, tons of hay, and tons of supplement). These total amounts are listed just prior to the feed cost totals on the example worksheets. For a commercial feedlot expenses for the variable cost of machinery and equipment ($.053/day); interest on feed and other costs ($.036/day); labor cost ($.107/day); and the fixed cost of machinery, equipment, and housing ($.106/day) were assigned to a group of cattle based on the portion of the year they were in the lot (days on feed). However, for a farmer-feeder, feeding only one group of cattle per year, these expenses would be a set amount for a group of cattle regardless of days on feed (Lawrence and Vontalge, 1996). For a commercial feedlot situation variable costs associated with machinery and equipment; marketing and miscellaneous; and the fixed cost associated with machinery, equipment, and housing were $.053, $.12, and $.11 per animal per day, respectively. These costs are often collectively referred to as yardage, which in this case totals $.28/head/day. When comparing the once daily and the twice daily feeding frequency treatments, machinery and equipment costs were estimated to increase by 15% for the twice-daily feeding frequency due to the increased use of the feed delivery vehicle and increased feed handling. Total variable costs were the sum of the feeder animal cost, feed, veterinary and health, machinery and equipment, marketing and miscellaneous, and interest on feed and other costs. Income over variable costs is total revenue minus total variable costs. Fixed costs were limited to those associated with machinery, equipment, and housing (Lawrence and Vontalge, 1996). Income over all costs was obtained by subtracting the fixed costs from income over variable costs. Breakeven selling price for all costs was calculated by dividing the sum of total variable costs and fixed costs by the actual sale weight.

Results and Discussion

Cattle were started on feed during May and November for six years. Those cattle started on feed during May and fed through the summer and finished in October were heavier initially (Table 1) and heavier when finished. The summer fed cattle consumed more feed, gained weight faster and more efficiently versus the winter fed cattle. These cattle were purchased through an order buyer and are of unknown age, however, they represent the type of cattle available to producers in Iowa. Those started during May, on average, may be younger than the ones started during November. All cattle were of A maturity when processed at the packing plant so age differences were not large.

Table 1. Means for feedlot performance and carcass composition by season

Item	Season		
	Summer[a]	Winter	P > F
Initial wt (lb)	813	803	.0016
Final wt (lb)	1240	1199	.054
Days on feed	122	141	.0041
DMI	24.7	23.0	.022
ADG (lb/day)	3.52	2.98	.0018
FE (feed / gain, lb)	7.03	7.70	.0079
Hot carcass wt (lb)	758.69	733.58	.072
Shrink (%)	1.06	2.24	.12

[a]Summer trials were begun during May, winter trials were begun during November.

Cattle limited to 90% of ad libitum intakes took seven days longer (Table 2) to finish on average compared with cattle fed ad libitum or 95% of ad libitum ($P < .02$). Cattle limit fed at the 90% of ad libitum level had more carcasses in the Choice quality grade compared with cattle fed either ad libitum or 95% of ad libitum ($P < .005$).

Overall profitability is improved by limit feeding cattle at the 95% of ad libitum level (Table 3). Revenues were higher for cattle limited to 95% of ad libitum versus those fed ad libitum or 90% of ad libitum because the cattle on the 95% level had heavier finished weights. However, the cattle on the 95% of ad libitum level also had the lowest total feed costs due to the improved feed conversion efficiency of these cattle. Also cattle fed the 95% of ad libitum level had the highest income and lowest break-even values.

Cattle fed once daily in the morning (Table 4) had higher revenues due to their greater finished weight. Feed costs were similar due to comparable days on feed and feed conversion efficiencies for once and twice daily fed cattle. Cattle fed once daily were started at similar weights to cattle fed twice daily and fed for the same length of time on average, however, because they had higher rates of gain the cattle were larger, which increased revenue from sales and income over all costs.

A change in carcass price (Table 5) impacted returns to cattle limited to the 95% of ad libitum intake level more than those fed ad libitum or 90% of ad libitum, for both a commercial feedlot and a farmer-feeder. Thus, as returns over all costs increased for the three feed intake levels, due to an increase in carcass price, the dollar advantage over other intake levels of limiting cattle to 95% of ad libitum intake increased as well.

Table 2. Means for feedlot performance and carcass composition by feed intake level and feeding frequency

		Feeding intake level		
Feeding frequency	Item	Ad libitum	95%	90%
	Initial wt (lb)	805	805	808
	Final wt (lb)	1237	1221	1239
	Days on feed	132[a]	132[a]	139[b]
Once daily	DMI	24.6	23.5	22.7
	ADG (lb/day)	3.32	3.20	3.15
	FE (feed / gain, lb)	7.45	7.35	7.22
	Hot carcass wt (lb)	757	747	758
	Shrink (%)	1.51	1.77	1.30
	Percent Choice	66.3[c]	68.6[c]	81.2[d]
	Initial wt (lb)	809	809	806
	Final wt (lb)	1182	1235	1171
	Days on feed	131[a]	132[a]	139[b]
Twice daily	DMI	24.5	23.6	22.4
	ADG (lb/day)	3.16	3.26	2.97
	FE (feed / gain, lb)	7.75	7.24	7.53
	Hot carcass wt (lb)	723	756	717
	Shrink (%)	2.20	1.89	1.96
	Percent Choice	69.8[c]	64.8[c]	74.9[d]

[ab]Numbers in same row with different superscripts are different ($P < .02$).
[cd]Numbers in same row with different superscripts are different ($P < .005$).

Table 3. Comparison of profitability of limiting feed intake

	Commercial feedlot			Farmer-feeder		
Key items	Ad lib.	95%	90%	Ad lib.	95%	90%
Total revenues	811.09	824.00	813.45	811.09	824.00	813.45
Total feed costs	155.41	154.78	161.28	155.41	154.78	161.28
Total variable costs	863.43	861.65	871.11	863.51	861.61	869.61
Income over variable costs	-52.35	-37.65	-57.65	-52.42	-37.61	-56.15
Fixed costs	13.91	13.98	14.77	14.00	14.00	14.00
Income over all costs	-66.26	-51.62	-72.42	-66.42	-51.61	-70.15
Break-even for all costs	72.60	71.28	73.71	72.61	71.28	73.52

Table 4. Comparison profitability of feeding once or twice daily

	Commercial feedlot		Farmer-feeder	
Key items	Once	Twice	Once	Twice
Total revenues	831.09	803.72	831.09	803.72
Total feed costs	157.80	156.62	157.80	156.62
Total variable costs	862.67	868.64	862.59	868.52
Income over variable costs	-31.58	-64.92	-31.50	-64.80
Fixed costs	14.21	14.23	14.00	14.00
Income over all costs	-45.79	-79.15	-45.50	-78.80
Break-even for all costs	71.21	73.68	71.19	73.65

When the price spread between Choice and Select quality grade carcasses was changed (Table 5) in the commercial feedlot example, returns for cattle limited to 95% of ad libitum intake were impacted more in comparison to those from cattle on the other two feed intake levels. Therefore, when the discount for Select grade cattle is high, the advantage of limiting the feed intake of beef cattle to 95% of ad libitum intake increased. For all three feed intake levels in the farmer-feeder example, returns were affected in a similar manner up or down as quality grade discounts for Select grade carcasses were decreased and increased, respectively.

Cattle fed the 95% of ad libitum feed intake had the lowest feed costs and highest returns. When corn prices were decreased, the commercial feedlot advantage of limiting cattle intake to 95% versus 90% of ad libitum intake decreased as well, because of the larger rate of increase in returns for the cattle fed 90% of ad libitum intake (Table 5). In the farmer-feeder situation, as corn prices were decreased the advantage of limiting intakes to 95% versus both ad libitum and 90% of ad libitum intake decreased as well, because of the larger rate of increase in returns for the cattle fed both ad libitum and 90% of ad libitum intakes. Conversely as corn prices increase, feeding cattle at the 95% of ad libitum level becomes more advantageous, due largely to the improvement in feed conversion efficiency observed (Delehant and Hoffman, 1997).

A change in interest rate impacted returns to cattle limited to the 90% of ad libitum intake level more than those fed ad libitum or 95% of ad libitum (Table 5), in the commercial feedlot situation. Thus as the interest rate decreased, returns over all costs increased more rapidly for cattle limited to 90% of ad libitum intake and the dollar advantage of limiting cattle to 95% of ad libitum intake decreased as well. This is a function of the greater number of days spent in the feedlot by the cattle fed the 90% of ad libitum intake level. In the farmer-feeder example both ad libitum and 90% of ad libitum fed cattle had a larger change in returns for each percent change in the interest rate, compared with cattle limited to 95% of ad libitum intake. And, as the interest rate decreased, returns over all costs increased more rapidly for cattle fed ad libitum or limited to 90% of ad libitum intake, which decreased the dollar advantage of limiting cattle to 95% of ad libitum intake.

A change in overhead costs (Table 5) impacted returns to cattle limited to the 90% of ad libitum intake level more than those fed ad libitum or 95% of ad libitum, in the commercial feedlot situation. Thus as overhead costs decreased, returns overall costs increased more rapidly for cattle limited to 90% of ad libitum intake and the dollar advantage of limiting cattle to 95% of ad libitum intake decreased as well. This result was largely due to the fact that cattle fed the 90% level had more days on feed and thus a higher total overhead cost versus the cattle fed either ad libitum or 95% of ad libitum. In the farmer-feeder example, when overhead costs were changed, cattle on all feed intake levels experienced a similar change in returns.

Table 5. Changes in returns ($/cwt) to both ad libitum and limit fed cattle for each 1% change in key items

	Commercial feedlot			Farmer-feeder		
Key items	Ad lib.	95%	90%	Ad lib.	95%	90%
Carcass price	.67	.68	.67	.67	.68	.67
Percent Choice	.029	.029	.029	.029	.029	.029
Choice/Select price spread	.012	.013	.012	.012	.012	.012
Corn price	.093	.093	.096	.093	.092	.096
Feeder animal cost	.54	.54	.54	.54	.54	.54
Interest rate on feeder	.019	.019	.02	.019	.018	.02
Overhead cost	.052	.052	.054	.052	.052	.052

Table 6 presents the changes in the breakeven price to cover all costs, as four major cost items are changed one at a time in 1% increments, holding others constant. Of primary interest are the differences in the rate of change in breakevens between feed intake levels. As corn price was changed in the commercial feedlot scenario, breakevens were changed in a similar manner regardless of feed intake level. However, in the farmer-feeder example when corn price was changed, breakevens changed proportionately more for cattle on the 90% of ad libitum feed intake level. This is in part due to the lower feed conversion efficiency observed with cattle fed the 90% level versus the other two.

In the commercial feedlot example (Table 6) when the price paid for feeder animals was changed, breakevens changed proportionately more for cattle fed the 95% of ad libitum feed intake level, compared to the other two intake levels. However, in the farmer-feeder example when feeder animal price was changed, breakevens changed proportionately more for cattle on the 90% of ad libitum feed intake level. This is due to the longer time spent in the feedlot and thus more interest paid on the cost of the feeder animal for cattle fed the 90% level.

Interest rate changes (Table 6) had less of an impact on cattle fed the ad libitum feed intake level versus cattle on the other intake levels. As the interest rate was changed in the commercial feedlot scenario, breakevens were changed less for cattle on the ad libitum feed intake level compared with cattle fed the 95% and 90% of ad libitum feed intake levels. This is because cattle fed ad libitum tended to finish sooner and accrued less interest cost. As interest rate was changed in the farmer-feeder scenario, breakevens were changed in a similar manner regardless of feed intake level.

When overhead costs were changed in the commercial feedlot example (Table 6), breakevens changed more for cattle fed the 90% of ad libitum feed intake level, for each unit change in overhead costs, compared with cattle fed either the ad libitum or 95% of ad libitum feed intake levels. As overhead costs were changed in the farmer-feeder scenario, breakevens were changed in a similar manner regardless of feed intake level.

Table 6. Changes in breakevens ($/cwt) to both ad libitum and limit fed cattle for each 1% change in key items

	Commercial feedlot			Farmer-feeder		
Key items	Ad lib.	95%	90%	Ad lib.	95%	90%
Corn price	.09	.09	.09	.09	.09	.10
Feeder animal cost	.53	.54	.53	.53	.53	.54
Interest rate on feeder	.01	.02	.02	.02	.02	.02
Overhead cost	.052	.052	.054	.052	.052	.052

When carcass price was changed, cattle fed once daily (Table 7) in both the commercial feedlot and farmer-feeder examples had a larger change in returns. The same was also true when the percentage of animals with a carcass quality grade of Choice was changed; once-daily fed cattle showed a larger change in returns over all costs for each unit change in percent Choice, versus cattle fed twice daily. However, when the Choice / Select price spread, corn price, or interest rate was changed cattle fed once and twice daily in both the commercial feedlot and farmer-feeder examples had the same magnitude of change in returns. When feeder animal cost was changed cattle fed once daily in both the commercial feedlot and farmer-feeder examples had a smaller change in returns, compared to cattle fed twice daily, partly because once-daily fed cattle spent less time in the feedlot and had a lower interest charge on the cost of the feeder animal. When overhead cost was changed cattle fed once daily in both the commercial feedlot and farmer-feeder examples had a smaller change in returns, compared to cattle fed twice daily. Cattle fed twice daily had a higher average overhead cost partly due to there longer time spent in the feedlot, but largely due to the increased variable cost for machinery and equipment. The variable cost for machinery and equipment for cattle fed twice daily was increased by 15% over the once-daily fed cattle, to account for the increased feed mixing and handling costs. Therefore, an increase in overhead costs would be expected to have a proportionately larger impact on return of twice-daily fed cattle as was seen in these results.

Table 8 presents the changes in the breakeven price to cover all costs, as four major cost items are changed in 1% increments. When the corn price was changed breakevens for cattle fed either once or twice daily in both the commercial feedlot and farmer-feeder examples changed $.09 for each 1% change in corn price. When the cost of the feeder animal was changed breakevens were impacted less in cattle fed once daily in both examples. As the interest rate was changed in the commercial feedlot example breakevens changed by the same amount for each 1% change ($.02) for both the once and twice-daily fed cattle. However, in the farmer-feeder example breakevens were impacted to a lesser degree in cattle fed once daily by a change in interest rate, compared to cattle fed twice daily. A 1% change in overhead costs had a smaller impact on breakevens for cattle fed once daily in both the commercial feedlot and farmer-feeder examples.

Table 7. Changes in returns ($/cwt) to once and twice-daily fed cattle for each 1% change in key items

	Commercial feedlot		Farmer-feeder	
Key items	Once	Twice	Once	Twice
Carcass price	.68	.66	.68	.66
Percent choice	.029	.028	.029	.028
Choice/Select price spread	.012	.012	.012	.012
Corn price	.094	.094	.094	.094
Feeder animal cost	.53	.54	.53	.54
Interest rate on feeder	.019	.019	.019	.019
Overhead cost	.052	.053	.052	.053

Table 8. Changes in breakevens ($/cwt) to once and twice-daily fed cattle for each 1% change in key items

	Commercial feedlot		Farmer-feeder	
Key items	Once	Twice	Once	Twice
Corn price	.09	.09	.09	.09
Feeder animal cost	.53	.54	.53	.54
Interest rate on feeder	.02	.02	.01	.02
Overhead cost	.052	.053	.052	.053

These results, as well as those presented in a previous paper (Delehant and Hoffman, 1997), seem to favor feeding cattle once daily in the morning at 8:00 am, this is of importance in light of the current trend within the beef cattle industry towards feeding cattle two, three, or four times per day. Our results indicate that from a production and economic standpoint there is no advantage to feeding cattle twice daily. This is based on data from cattle fed a whole corn grain and chopped alfalfa hay diet with an average dry matter percentage of 87%. If cattle are fed a diet with a higher moisture content, such as corn silage, feeding cattle twice or more times per day may be advantageous in order to reduce spoilage of the feed in the feedbunk and maintain animal intake. Because the corn grain portion of the diet was not processed there may be no difference in performance between feeding frequencies. However, in cases where cattle are fed diets in which the grain has been processed in some manner, such as grinding, there may be an advantage to feeding cattle their ration in several smaller portions in order to reduce peaks in acid production as a result of grain fermentation and maintain a more constant rumen pH.

Conclusions

In all production examples presented, limiting cattle to a dry matter intake level equivalent to 95% of ad libitum intake resulted in the greatest profit potential. These results also favor feeding cattle once daily. For both the commercial feedlot and farmer-feeder systems, cattle fed once daily at 8:00 am had better income over all costs and a lower selling price required to cover all costs versus the cattle fed twice daily. In a previous report (Delehant and Hoffman, 1997) it was shown that cattle fed once daily do not differ from cattle fed twice daily in terms of carcass characteristics. It is obvious how to apply the knowledge gained about feeding frequency. However when attempting to limit the feed intake of cattle in a production setting, it is difficult to determine the feed allotment on a given day for a particular animal, without having some cattle fed ad libitum as a reference, such that the dry matter intake of cattle is limited to 95% of ad libitum. One method of implementing a limited feed intake system that has been proposed, is to limit the time cattle have access to feed to 11 to 13 hours per day (Delehant and Hoffman, 1997). This method of intake restriction has not been thoroughly researched and may require the use of automatic feeders. More research involving the economics of limit feeding using other diets and cattle started on feed as calves is needed to completely answer questions posed by this study.

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CHAPTER 5. DEVELOPMENT AND EVALUATION OF EQUATIONS TO PREDICT DRY MATTER INTAKE IN FEEDLOT CATTLE

A paper to be submitted to the Journal of Animal Science

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Abstract

A total of 3101 steers were used to develop and validate equations for predicting dry matter intake of yearling steers (R^2 = .71 and .85). Cattle were fed ad libitum three different diets. Cattle were started on feed during all seasons of the year and seemed to be largely Missouri frame score five (Eller, 1979), with some frame score six animals. All animals received an estrogenic implant and were fed an ionophore. The frame score five steers, fed a whole corn grain and chopped alfalfa hay diet, and started on feed during the summer months were used to develop an equation which predicted daily dry matter intake. Average adjustments are given for conditions that differ from these. Multipliers to adjust the model for season, shelter type, diet, frame size, and Holstein steers were estimated. Equation one was: Steer DMI (kg/d) = (-171.130 + .0245 PW - .0309 TDOF + 3.283 NDF + 58.961 NEm) x M. Where PW was the current average body weight in kg, TDOF was total days on feed, NDF was percent neutral detergent fiber in the diet, NEm was net energy for maintenance in the diet (Mcal/kg), and M was the adjustment multiplier. The adjustment multiplier for frame score 6 steers was -.7356. The multiplier for Holstein steers was -.4211. The multiplier to adjust for winter feeding conditions was -.5854 for steers weighing less than 364 kg and -.6853 for steers weighing more than 364 kg. The multiplier for cattle raised with access to a

windbreak was 1.0657 for beef steers and 1.0733 for Holstein steers. The multiplier for cattle fed a corn silage diet was -.4372.

Introduction

Researchers have attempted to describe and predict the intake of feedstuffs offered to livestock using various methods. The true measure of quality and quantity of feed consumed is the body weight change seen in the animal consuming the feed. A desire of many beef producers is to predict animal performance based on the nutrients in the feed provided to the animal. Several empirical examples of intake prediction are available. The NRC (1987) publication, Predicting Feed Intake of Food-Producing Animals, lists seven equations which may be used to predict dry matter intake of an individual beef animal. However, most published equations predict only the average DMI for the feeding period. The objective of this study was to produce equations, based on simple inputs of animal weight and diet composition, to estimate the expected dry matter consumption of an animal or group of animals at any point during the feeding period. The goal was to arrive at a procedure whereby an animal may be restricted in intake to improve feed efficiency, by estimating its normal ad libitum intake a priori.

Materials and Methods

A data set was created using performance data collected on 884 beef feedlot steers fed at either the Western Iowa Research and Demonstration Farm, Castana, Iowa or the Allee Research Farm, Newell, Iowa from 1979 through 1994. Included were performance data for 96 Holstein steers fed at the Allee Research Farm. The animals were fed ad libitum a total of three different diets, started on feed during all seasons of the year, and were largely Missouri frame score five, with some frame score six animals. All animals received an estrogenic implant and were fed an ionophore. All animals had initial body weights of 300 kg or more, thus the equations were developed for yearling steers and were not applicable to calves.

The first of three diets fed to cattle in this experiment was a whole corn grain (IFN 4-02-931) and chopped mid-bloom alfalfa hay (IFN 1-00-063) diet. The 85% concentrate (DM basis) ration was supplemented with an urea-based 40% crude protein, vitamin and mineral supplement (Table 1) which contained Rumensin™. The second diet consisted of processed high-moisture corn grain (77% DM) which provided 85% of the dietary energy, with whole-plant corn silage (IFN 3-02-506; 35% DM) and protein supplement making up the remainder of the diet. A protein, vitamin and mineral supplement was provided to fulfill the dietary requirements. The third diet consisted of whole-plant corn silage and a supplement containing protein, vitamins, and minerals. Feed consumption was monitored daily and feed samples were taken twice-weekly for DM determination.

Table 1. Composition of protein supplement

Ingredient	Kilograms per 100 kg mixture
Urea (IFN 5-05-070)	16.60
Limestone (IFN 6-01-069)	53.94
Iodized salt	20.68
Trace mineral premix	.93
Vit A premix (4.4×10^6 IU kg^{-1})	6.20
Rumensin™ premix (132 g kg^{-1})	1.65
Total	100

The experimental unit was a pen of cattle. Pen means for performance parameters were entered as well as diet NEm, NEg, NDF, ADF, crude protein concentration, and lignin content. Neutral detergent fiber and acid detergent fiber (Goering and Van Soest, 1970; Van Soest et al., 1991) were determined on the roughage portion of the diet (ground alfalfa hay, IFN 1-00-063) for cattle used to develop Equation one. Net energy for maintenance and gain provided by the ground alfalfa hay were estimated to be 1.29 and .72 Mcal kg^{-1}, respectively, based on the ADF content of the hay and using nutrient composition tables (NRC, 1996). Crude protein content of the hay was estimated to be 18.3% on a DM basis, intermediate between mid- and full-bloom alfalfa hay, which corresponds to the NDF content of the hay (NRC, 1996). The NEm and NEg provided by the whole corn grain were estimated to be 2.18 and 1.50 Mcal kg^{-1}, respectively based on tables of nutrient composition (NRC, 1996). Crude protein content of the corn grain was estimated to be 9.8% on a DM basis.

Frame score five steers, fed a whole corn grain and alfalfa hay diet ad libitum, implanted with an estrogenic implant, fed an ionophore, given access to overhead shelter, and started on feed during the summer months were used to develop an equation (Equation one) which predicted daily DMI at any time during the feeding period based on current live weight, total days on feed, NDF content of the diet, and NEm concentration in the diet. The equation was developed using daily intake values for each pen of seven steers and 28 day average individual live weights. A total of 42 steers were used in developing the prediction equation. The remaining animals were used to determine adjustment factors and validate the equation.

Proc Stepwise (SAS, 1989) was used to determine which factors had the largest influence on average daily dry matter intake in beef steers. The significance levels for entry and remaining in the model were set at .50 and .20, respectively. In addition each factor included in the model was evaluated in terms of the partial R^2, or contribution to the model, in relation to the estimated cost associated with measuring the factor.

The equations were validated using independent data from 2105 yearling beef steers, reported by producer's using the ISU Feedlot Monitoring Program, and 112 beef steers fed at the Castana research farm during 1996.

Results and Discussion

Equation one for frame score five steers is provided with the coefficients as determined by SAS (1989), along with adjustments for different feeding conditions. The R^2 for the equation was .71 and the partial R^2 for variables PW, TDOF, NDF, and NEm were .26, .35, .01, and .10, respectively. The adjustment factors were determined based on the average bias of the equation when applied to data differing by one factor from data used to derive the equation. For example, by applying the equation to cattle that were treated in all respects the same as the base population except that they had a Missouri frame score of six rather than five, an adjustment to Equation one for frame score six animals was determined. The same procedure was used to develop other adjustment factors.

The equation for dry matter estimation using the base population is as follows. The base population (n = 42) was composed of cattle that were Missouri frame score five steers, fed a whole corn grain and alfalfa hay diet ad libitum, implanted with an estrogenic implant, fed an ionophore, given access to overhead shelter, and started on feed during the summer months. Average bias, or the average difference between the estimated and actual intake values, when applied to the base population was -.01 kg or .09% of the mean (bias = estimated minus actual).

Equation one
Steer DMI (kg/d) = (-171.130 + .0245 PW - .0309 TDOF + 3.283 NDF + 58.961 NEm) x M

Where:
PW = The current average body weight in kg.
TDOF = Total days on feed.
NDF = Percent neutral detergent fiber in the diet.
NEm = Net energy for maintenance in the diet (Mcal/kg).
M = Adjustment multiplier

Adjustment multipliers:

Frame score 6 =	-.7356	
Holstein steers =	-.4211	
Winter =	-.5854	< 364 kg
	-.6853	> 364 kg
Windbreak =	1.0657	Beef steers
	1.0733	Holstein steers
Corn silage diet =	-.4372	

Multipliers were developed to adapt the equation for use in feeding systems other than the one described in the base population. The multipliers are not useful in adjusting equations other than Equation one, because they are estimated based on a limited data set. In application of this equation to production systems with conditions different from Equation one, producers may refer to other sources for general adjustment factors (NRC, 1987; Fox et al., 1992). Note that because all of the cattle used were implanted with an estrogenic implant, no adjustments are available for nonimplanted cattle.

The multiplier to adjust Equation one for frame six beef steers was -.7356 and was determined with an average bias of -.00497 kg or .042% of the DMI mean (n = 28). The multiplier to adjust Equation one for Holstein steers was -.4211. This was determined with an average bias of .034 kg or .33% of the DMI mean (n = 132).

Adjustment multipliers for diet and environment

The multiplier to adjust Equation one for cattle fed during the winter was -.5854 for cattle weighing less than 364 kg, the average bias was -.066 kg or .65% of the DMI mean (n = 42). The multiplier was -.6853 for cattle over 364 kg and the average bias was .40 kg or 3.45% of the DMI mean (n = 42). The adjustments are applicable to steers with initial weights in the range of 300 to 400 kg. All animals had initial body weights of 300 kg or more, therefore these equations may not apply to calves less than 300 kg. The equations work well for cattle in the weight range of 320 to 570 kg.

The multipliers to adjust the equation for cattle fed in a lot with no shelter (open lot with windbreak) were 1.0657 for beef steers and 1.0733 for Holstein steers with average biases of 1.16% and .94% respectively (n = 48).

The multiplier to adjust the equation for cattle fed a corn silage based diet rather than a corn and hay diet was -.4372 for beef cattle in the summer in sheltered lots, with an average bias of -.08 kg or 1% of the mean actual DMI (n = 538).

Equation two, was created using Proc Stepwise and the entire dataset (except the Holstein data) and included all frame scores, diet types, seasons, and shelter types. The objective was to fit a regression line to the entire data set and see if it performs as well as one (Equation one) developed from a more precisely defined group of cattle. Initial weight was included as well as current weight and total days on feed, as in the previous equation. However, in this equation crude protein (CP) and lignin percentages in the diet were included in place of percent NDF and NEm concentration. Crude protein has been implicated in IGF regulation. Elsasser (1989) postulated that in cattle, CP may be the nutritional determinant of basal IGF-I production, but the IGF-I response to CP may be affected by the energy available in the diet. Lignin was included as a measure of the indigestibility of the diet and lignin has been shown to inhibit fermentation in high concentrations. The R^2 for this equation was .846 and the average bias when applied to the whole dataset, from which it was derived, was 1.15% of the mean actual DMI.

Equation two
Steer DMI (kg/d) = (-14.17 - .0198 IW + .0471 PW - .048 DOF + 1.298 CP + .669 Lig) x B

Where:
IW = The initial shrunk body weight in kg.
PW = The current average body weight in kg.
DOF = Total days on feed.
CP = Percent crude protein in the diet.
Lignin = Percent lignin in the diet.
B = Breed adjustment

Breed adjustment:
Yearling British crossbred = 1.0
Holstein = .9379

Validation of equations using independent data sets

Performance and diet information from a total of 2105 steers were available from beef producers using the ISU Feedlot Monitoring Program (Dahlke, 1996) and were used to validate the base equation and recommended adjustments. Data from 112 beef steers fed at the Castana, Iowa research farm during 1996 were also used. When the equations were applied to data from cattle treated similar to those used in developing Equation one (Table 2), the RMSE were 4.63 and 2.80 for equations one and two, respectively. The average bias for

Equation one was 7.81% of the mean actual DMI, although, actual and expected intake values were lowly correlated (.24) because as cattle approached the end of the feeding trial their daily DMI, as a percent of body weight, decreased and the equation did not account for this. The average bias for Equation two was high (31.62%), however, the correlation (.53) indicates the estimated intakes for each weigh period followed a similar trend to actual DMI.

Table 2. Results of equations applied to independent data from frame 5, yearling beef steers, fed a whole corn grain and alfalfa diet, and reared in sheltered lots during the summer

Equation	RMSE[a]	Avg DMI (kg)	Avg bias (kg)	Avg bias (% mean)	Actual vs est. (r)	n	DOF
One[b]	4.63	8.57	.67	7.81	.24	112	140
Two	2.80	8.57	2.71	31.62	.53	112	140

[a]RMSE = Sqrt[(Σ(estimated - actual DMI)/n)].
[b]Cattle were treated identically to those used in developing the base equation.

When applied to data from cattle differing in diet and season of feeding from those cattle used in developing Equation one (Table 3), the RMSE were 7.47 and 3.39 for equations one and two, respectively. The average bias for Equation one (after adjusting for diet and season differences) was 11.26% of the mean actual DMI and the correlation between actual and expected intakes was .58. The lack of fit of Equation one may be a result of cattle in this data set being fed a corn silage-based diet that contained some alfalfa hay and ground corn grain, unlike the one used to develop the recommended diet adjustments to Equation one. The average bias for Equation two (no adjustment) was 9.24% and the correlation with actual

DMI (.40) indicated the estimated intakes for each weigh period tended to follow the trend for actual intake.

When applied to data from cattle differing in frame size, diet, and housing type from those cattle used in developing Equation one (Table 4), the RMSE were 6.55 and 7.18 for equations one and two, respectively. The average bias for Equation one (after adjusting for frame size, diet, and housing) was 50.58% of the mean actual DMI and the correlation between actual and expected intakes was -.47. The average bias for Equation two (no adjustment) was 61.20% and the correlation with actual DMI (-.13) indicated the estimated intakes for each weigh period did not closely follow the trend for actual intake through the study.

Table 3. Results of equations applied to independent data from frame 5, yearling beef steers, fed a corn silage based diet, and reared in sheltered lots during the winter

Equation	RMSE[a]	Avg DMI (kg)	Avg bias (kg)	Avg bias (% mean)	Actual vs est. (r)	n	DOF
One[b]	7.47	8.79	-.99	11.26	.58	833	55
Two	3.39	8.79	2.93	9.24	.40	833	55

[a]RMSE = Sqrt[(Σ(estimated - actual DMI)/n)].
[b]Adjustments were made to base equation for diet and season.

Table 4. Results of equations applied to independent data from frame 6, yearling beef steers, fed a corn silage based diet, and reared in outdoor lots[a] during the summer

Equation	RMSE[b]	Avg DMI (kg)	Avg bias (kg)	Avg bias (% mean)	Actual vs est. (r)	n	DOF
One[c]	6.55	10.80	5.18	50.88	-.47	500	87
Two	7.18	10.80	6.61	61.20	-.13	500	87

[a] Lots had a windbreak.
[b]RMSE = Sqrt[(Σ(estimated - actual DMI)/n)].
[c]Adjustments were made to base equation for frame size, diet, and housing type.

When the equations were applied to data from cattle differing from those used in developing Equation one in frame size, diet, housing type, and season of feeding (Table 5), the RMSE were 1.95 and 4.12 for equations one and two, respectively. The average bias for Equation one (after adjusting for frame size, diet, housing, and season) was 15.49% of the mean and the correlation between actual and expected intakes was .47. The average bias for Equation two (no adjustments) was high (45.09%) and the correlation with actual DMI (.18) indicated the estimated intakes for each weigh period did not follow actual intake trends.

Table 5. Results of equations applied to independent data from frame 6, yearling beef steers, fed a corn silage based diet, and reared in confinement during the winter

Equation	RMSE[a]	Avg DMI (kg)	Avg bias (kg)	Avg bias (% mean)	Actual vs est. (r)	n	DOF
One[b]	1.95	9.36	-1.45	15.49	.47	509	90
Two	4.12	9.36	4.22	45.09	.18	509	90

[a]RMSE = Sqrt[(Σ(estimated - actual DMI)/n)].
[b]Adjustments were made to base equation for frame size, diet, and season.

When the equations were applied, with adjustments, to data from cattle different in frame size, diet, housing type, and season of feeding from cattle used in developing Equation one (Table 6), the RMSE for equations one and two were 1.80 and 5.21, respectively. The average bias for Equation one was 18.58% of the mean actual DMI and the correlation between actual and expected intakes was .26. The average bias for Equation two (no adjustment) was 53.15% and the correlation with actual DMI (.17) indicated the estimated intakes for each weigh period did not closely follow the trend for actual intake through the study.

Table 6. Results of equations applied to independent data from frame 7, yearling beef steers, fed a corn silage based diet, and reared in confinement during the winter

Equation	RMSE[a]	Avg DMI (kg)	Avg bias (kg)	Avg bias (% mean)	Actual vs est. (r)	n	DOF
One[b]	1.80	9.69	1.80	18.58	.26	263	55
Two	5.21	9.69	5.15	53.15	.17	263	55

[a]RMSE = Sqrt[(Σ(estimated - actual DMI)/n)].
[b]Adjustments were made to base equation for diet and season.

Conclusions

The DMI of beef cattle fed under conditions that mimic those described in developing equation number one (Table 2), or those the equation could be adjusted to fit (Tables 3 through 6), may be predicted at any point during the feeding period. The adjusted equation works best in situations where the type of cattle are well defined and are similar to those used in developing the equation. If ad libitum intake can be predicted at a point during the feeding period, cattle can be fed a limited feed intake and thus have better performance economics (Delehant et al., 1997). To implement a limited feeding system where cattle are fed 95% of their normal ad libitum intake, the predicted intake would be calculated using Equation one and then multiplied by .95. This has not been tested, however. The equations described are useful in predicting the dry matter intake for steers that meet the criteria outlined. Their use is, however limited to those steers with weights of 300 to 400 kg when started in the feedlot. The equations have not been applied to performance data from either heifers or bulls, thus the equations should not be used in intake predictions for these animals. The goal of developing the equation to predict dry matter intake at any point during the feeding period was accomplished, however the hypothesis of applying these equations to a limit feeding situation needs to be explored further.

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CHAPTER 6. GENERAL CONCLUSIONS

General Discussion

The major advantage to limit feeding yearling beef steers, in these studies was the improvement in feed efficiency, which reduced overall feed costs and increased profit potential. Other researchers have found a reduction in the backfat thickness of cattle due to limit feeding (Coleman et al., 1993; Coleman et al., 1995; Dockerty et al., 1973; Fortin et al., 1980; Pothoven et al., 1975). This reduction was not significant in these studies but may be of importance to the beef industry. The trend towards less backfat in cattle limited in intake is a biological response, based on the large number of cattle (980) in this data set, even though the differences were not statistically significant. The economic implications of this reduction are difficult to describe. Most of the response may be explained by the improved feed efficiency in the limit fed cattle. From a producer's perspective, feed which is converted by cattle into backfat in excess of .65 to .75 cm over the 12th rib is a waste of energy and money. This effect will certainly be of value as the industry moves toward a value-based marketing system. Also the trend towards an improvement in quality grade due to limit feeding is of importance because, as seen in the discussion in Chapter 4, a small increase in the number of Choice cattle impacts returns.

Recommendations for Future Research

Further exploration of a practical means of limiting the feed intake of feedlot animals is necessary. It has been shown that there are economic advantages to restricting the daily feed intake of steers to 95% ad libitum intake. The question remaining is how does one know for certain that cattle are being restricted to 5% less than what they would eat, if given access to an unlimited feed supply? Based on the data available, an equation was developed that predicted with acceptable precision the intake of beef steers fed ad libitum under a wide variety of conditions. From this equation normal intakes for steers may be estimated and the ration actually fed reduced by 5% from this, to achieve the intake limitation.

There is also the question of how cattle fed different diets will perform when limited in intake. Murphy et al. (1994a) provided evidence that cattle fed whole-corn grain and limited in intake may have lower digestibilities of nutrients versus cattle limited fed and on a rolled corn diet. This may change the relationship of conversion efficiencies for ad libitum and limited fed cattle if the advantage due to limit feeding is an increase in dry matter digestion as discussed by Murphy et al. (1994b) who found that lambs fed a 92% concentrate diet and restricted to 90% of ad libitum intake had higher digestibilities of dry matter, organic matter, and crude protein ($P < .001$).

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APPENDIX. ECONOMIC ANALYSES WORKSHEETS

Example 1: Base example for commercial feedlot

						Feed intake level		
						Ad libitum	95%	90%
Revenue								
Sales								
Live price for Choice YG 1-3 steers ($/cwt)						$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)						$114.88	$114.88	$114.88
Actual sale weight (lb)						1208	1228	1202
Shrink (%)						1.86	1.83	1.66
Hot carcass weight (lb)						740	752	736
Dressing percentage						61.20	61.20	61.20
Percent Choice						68	67	78
Percent Select						32	33	22
Discount for Select quality grade ($/cwt carcass)						$7.00	$7.00	$7.00
Average yield grade						2.26	2.20	2.26
Liver abscesses (%)						13.28	14.45	14.24
Death loss (%)						0.75	0.75	0.75
Total Revenues						**$811.09**	**$824.00**	**$813.45**
Variable Costs								
Feeder cost ($/cwt)						$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)						805	804	804
Interest @ 10.00%						22.83	22.89	24.19
Feed and performance costs								
Days on feed						131	132	139
Average daily gain (lb/day)						3.24	3.23	3.06
Feed efficiency (gain/feed)						0.136	0.137	0.132
Feed efficiency (feed/gain, lb)						7.35	7.31	7.59
DMI						23.82	23.60	23.23
	Price				Feed DM			
Corn, #2 (bushel)	$2.21	/bu			87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton			85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton			95%	0.069	0.069	0.073
Total feed costs						**$155.41**	**$154.78**	**$161.28**
Veterinary and health						$8.00	$8.00	$8.00
Machinery and equipment						6.95	6.98	7.38
Marketing and miscellaneous						16.00	16.00	16.00
Interest on feed and other costs						4.77	4.79	5.07
Labor =	2	hours per head@	$7.00	per hour		14.00	14.06	14.86
Total variable costs						**$863.43**	**$861.65**	**$871.11**
Income over variable costs						**($52.35)**	**($37.65)**	**($57.65)**
Fixed costs								
Machinery, equipment, housing						$13.91	$13.98	$14.77
Income over all costs						**($66.26)**	**($51.62)**	**($72.42)**
Break-even selling price for all costs ($/cwt live basis)						**$72.60**	**$71.28**	**$73.71**

Example 2: Base example for commercial feedlot

					Feeding frequency Once	Feeding frequency Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$831.09**	**$803.72**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
		Price		Feed DM		
Corn, #2 (bushel)		$2.21	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton	95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.06
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.87	4.88
Labor =	2	hours per head@	$7.00	per hour	14.00	14.02
Total variable costs					**$862.67**	**$868.64**
Income over variable costs					**($31.58)**	**($64.92)**
Fixed costs						
Machinery, equipment, housing					$14.21	$14.23
Income over all costs					**($45.79)**	**($79.15)**
Break-even selling price for all costs ($/cwt live basis)					**$71.21**	**$73.68**

Example 3: Base example for farmer feeder

				Feed intake level		
				Ad libitum	95%	90%
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88	$114.88
Actual sale weight (lb)				1208	1228	1202
Shrink (%)				1.86	1.83	1.66
Hot carcass weight (lb)				740	752	736
Dressing percentage				61.20	61.20	61.20
Percent Choice				68	67	78
Percent Select				32	33	22
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00	$7.00
Average yield grade				2.26	2.20	2.26
Liver abscesses (%)				13.28	14.45	14.24
Death loss (%)				0.75	0.75	0.75
Total Revenues				**$811.09**	**$824.00**	**$813.45**
Variable Costs						
Feeder cost ($/cwt)				$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)				805	804	804
Interest @ 10.00%				22.83	22.89	24.19
Feed and performance costs						
Days on feed				131	132	139
Average daily gain (lb/day)				3.24	3.23	3.06
Feed efficiency (gain/feed)				0.136	0.137	0.132
Feed efficiency (feed/gain, lb)				7.35	7.31	7.59
DMI				23.82	23.60	23.23
	Price		Feed DM			
Corn, #2 (bushel)	$2.21	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs				**$155.41**	**$154.78**	**$161.28**
Veterinary and health				$8.00	$8.00	$8.00
Machinery and equipment				7.00	7.00	7.00
Marketing and miscellaneous				16.00	16.00	16.00
Interest on feed and other costs				4.80	4.80	4.80
Labor = 2 hours per head@	$7.00		per hour	14.00	14.00	14.00
Total variable costs				**$863.51**	**$861.61**	**$869.61**
Income over variable costs				**($52.42)**	**($37.61)**	**($56.15)**
Fixed costs						
Machinery, equipment, housing				$14.00	$14.00	$14.00
Income over all costs				**($66.42)**	**($51.61)**	**($70.15)**
Break-even selling price for all costs ($/cwt live basis)				**$72.61**	**$71.28**	**$73.52**

Example 4: Base example for farmer feeder

	Price		Feed DM	Feeding frequency Once	Twice
Revenue					
Sales					
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88
Actual sale weight (lb)				1231	1198
Shrink (%)				1.56	2.02
Hot carcass weight (lb)				754	733
Dressing percentage				61.20	61.20
Percent Choice				72	70
Percent Select				28	30
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00
Average yield grade				2.23	2.24
Liver abscesses (%)				12.77	15.20
Death loss (%)				0.75	0.75
Total Revenues				**$831.09**	**$803.72**
Variable Costs					
Feeder cost ($/cwt)				$78.90	$78.90
Purchase weight (pay weight in, lb)				801	808
Interest @ 10.00%				23.18	23.43
Feed and performance costs					
Days on feed				134	134
Average daily gain (lb/day)				3.22	3.14
Feed efficiency (gain/feed)				0.136	0.134
Feed efficiency (feed/gain, lb)				7.35	7.46
DMI				23.68	23.43
Corn, #2 (bushel)	$2.21	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton	95%	0.070	0.071
Total feed costs				**$157.80**	**$156.62**
Veterinary and health				$8.00	$8.00
Machinery and equipment				7.00	8.05
Marketing and miscellaneous				16.00	16.00
Interest on feed and other costs				4.80	4.80
Labor = 2 hours per head@	$7.00		per hour	14.00	14.00
Total variable costs				**$862.59**	**$868.52**
Income over variable costs				**($31.50)**	**($64.80)**
Fixed costs					
Machinery, equipment, housing				$14.00	$14.00
Income over all costs				**($45.50)**	**($78.80)**
Break-even selling price for all costs ($/cwt live basis)				**$71.19**	**$73.65**

Example 5: Farmer feeder, carcass price decreased by 5%.

				Feed intake level		
				Ad libitum	95%	90%
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)				$67.12	$67.12	$67.12
Carcass price for Choice YG 1-3 steers ($/cwt)				$109.14	$109.14	$109.14
Actual sale weight (lb)				1208	1228	1202
Shrink (%)				1.86	1.83	1.66
Hot carcass weight (lb)				740	752	736
Dressing percentage				61.20	61.20	61.20
Percent Choice				68	67	78
Percent Select				32	33	22
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00	$7.00
Average yield grade				2.26	2.20	2.26
Liver abscesses (%)				13.28	14.45	14.24
Death loss (%)				0.75	0.75	0.75
Total Revenues				**$769.74**	**$781.96**	**$772.25**
Variable Costs						
Feeder cost ($/cwt)				$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)				805	804	804
Interest @ 10.00%				22.83	22.89	24.19
Feed and performance costs						
Days on feed				131	132	139
Average daily gain (lb/day)				3.24	3.23	3.06
Feed efficiency (gain/feed)				0.136	0.137	0.132
Feed efficiency (feed/gain, lb)				7.35	7.31	7.59
DMI				23.82	23.60	23.23
	Price		Feed DM			
Corn, #2 (bushel)	$2.21	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs				**$155.41**	**$154.78**	**$161.28**
Veterinary and health				$8.00	$8.00	$8.00
Machinery and equipment				7.00	7.00	7.00
Marketing and miscellaneous				16.00	16.00	16.00
Interest on feed and other costs				4.80	4.80	4.80
Labor = 2 hours per head@	$7.00		per hour	14.00	14.00	14.00
Total variable costs				**$863.51**	**$861.61**	**$869.61**
Income over variable costs				**($93.77)**	**($79.65)**	**($97.35)**
Fixed costs						
Machinery, equipment, housing				$14.00	$14.00	$14.00
Income over all costs				**($107.77)**	**($93.65)**	**($111.35)**
Break-even selling price for all costs ($/cwt live basis)				**$72.61**	**$71.28**	**$73.52**

Example 6: Farmer feeder, carcass price decreased by 5%.

					Feeding frequency Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$67.12	$67.12
Carcass price for Choice YG 1-3 steers ($/cwt)					$109.14	$109.14
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$788.83**	**$762.79**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
		Price		Feed DM		
Corn, #2 (bushel)		$2.21	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton	95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$862.59**	**$868.52**
Income over variable costs					**($73.76)**	**($105.73)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($87.76)**	**($119.73)**
Break-even selling price for all costs ($/cwt live basis)					**$71.19**	**$73.65**

Example 7: Farmer feeder, carcass price increased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$74.18	$74.18	$74.18
Carcass price for Choice YG 1-3 steers ($/cwt)					$120.62	$120.62	$120.62
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$852.43**	**$866.04**	**$854.66**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
	Price			Feed DM			
Corn, #2 (bushel)	$2.21	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs					**$155.41**	**$154.78**	**$161.28**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$863.51**	**$861.61**	**$869.61**
Income over variable costs					**($11.08)**	**$4.43**	**($14.95)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($25.08)**	**($9.57)**	**($28.95)**
Break-even selling price for all costs ($/cwt live basis)					**$72.61**	**$71.28**	**$73.52**

Example 8: Farmer feeder, carcass price increased by 5%.

					Feeding frequency	
					Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$74.18	$74.18
Carcass price for Choice YG 1-3 steers ($/cwt)					$120.62	$120.62
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$873.35**	**$844.64**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
	Price			Feed DM		
Corn, #2 (bushel)	$2.21	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton		95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$862.59**	**$868.52**
Income over variable costs					**$10.75**	**($23.88)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($3.25)**	**($37.88)**
Break-even selling price for all costs ($/cwt live basis)					**$71.19**	**$73.65**

Example 9: Farmer feeder, % Choice decreased by 5%.

						Feed intake level		
						Ad libitum	95%	90%
Revenue								
Sales								
Live price for Choice YG 1-3 steers ($/cwt)						$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)						$114.88	$114.88	$114.88
Actual sale weight (lb)						1208	1228	1202
Shrink (%)						1.86	1.83	1.66
Hot carcass weight (lb)						740	752	736
Dressing percentage						61.20	61.20	61.20
Percent Choice						65	63	74
Percent Select						35	37	26
Discount for Select quality grade ($/cwt carcass)						$7.00	$7.00	$7.00
Average yield grade						2.26	2.20	2.26
Liver abscesses (%)						13.28	14.45	14.24
Death loss (%)						0.75	0.75	0.75
Total Revenues						**$809.29**	**$822.26**	**$811.46**
Variable Costs								
Feeder cost ($/cwt)						$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)						805	804	804
Interest @ 10.00%						22.83	22.89	24.19
Feed and performance costs								
Days on feed						131	132	139
Average daily gain (lb/day)						3.24	3.23	3.06
Feed efficiency (gain/feed)						0.136	0.137	0.132
Feed efficiency (feed/gain, lb)						7.35	7.31	7.59
DMI						23.82	23.60	23.23
		Price			Feed DM			
Corn, #2 (bushel)		$2.21	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)		$67.47	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton)		$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs						**$155.41**	**$154.78**	**$161.28**
Veterinary and health						$8.00	$8.00	$8.00
Machinery and equipment						7.00	7.00	7.00
Marketing and miscellaneous						16.00	16.00	16.00
Interest on feed and other costs						4.80	4.80	4.80
Labor =	2	hours per head@		$7.00	per hour	14.00	14.00	14.00
Total variable costs						**$863.51**	**$861.61**	**$869.61**
Income over variable costs						**($54.22)**	**($39.35)**	**($58.14)**
Fixed costs								
Machinery, equipment, housing						$14.00	$14.00	$14.00
Income over all costs						**($68.22)**	**($53.35)**	**($72.14)**
Break-even selling price for all costs ($/cwt live basis)						**$72.61**	**$71.28**	**$73.52**

Example 10: Farmer feeder, % Choice decreased by 5%.

					Feeding frequency	
					Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					68	66
Percent Select					32	34
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$829.20**	**$801.94**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
	Price			Feed DM		
Corn, #2 (bushel)	$2.21	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.280	0.277
Supplement and minerals (ton;	$340.00	/ton		95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$862.59**	**$868.52**
Income over variable costs					**($33.39)**	**($66.58)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($47.39)**	**($80.58)**
Break-even selling price for all costs ($/cwt live basis)					**$71.19**	**$73.65**

Example 11: Farmer feeder, % Choice increased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					72	70	82
Percent Select					28	30	18
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$812.84**	**$825.75**	**$815.45**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
	Price			Feed DM			
Corn, #2 (bushel)	$2.21	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs					**$155.41**	**$154.78**	**$161.28**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$863.51**	**$861.61**	**$869.61**
Income over variable costs					**($50.67)**	**($35.87)**	**($54.15)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($64.67)**	**($49.87)**	**($68.15)**
Break-even selling price for all costs ($/cwt live basis)					**$72.61**	**$71.28**	**$73.52**

Example 12: Farmer feeder, % Choice increased by 5%.

						Feeding frequency	
						Once	Twice
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)						$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)						$114.88	$114.88
Actual sale weight (lb)						1231	1198
Shrink (%)						1.56	2.02
Hot carcass weight (lb)						754	733
Dressing percentage						61.20	61.20
Percent Choice						76	73
Percent Select						24	27
Discount for Select quality grade ($/cwt carcass)						$7.00	$7.00
Average yield grade						2.23	2.24
Liver abscesses (%)						12.77	15.20
Death loss (%)						0.75	0.75
Total Revenues						**$832.97**	**$805.49**
Variable Costs							
Feeder cost ($/cwt)						$78.90	$78.90
Purchase weight (pay weight in, lb)						801	808
Interest @ 10.00%						23.18	23.43
Feed and performance costs							
Days on feed						134	134
Average daily gain (lb/day)						3.22	3.14
Feed efficiency (gain/feed)						0.136	0.134
Feed efficiency (feed/gain, lb)						7.35	7.46
DMI						23.68	23.43
		Price			Feed DM		
Corn, #2 (bushel)		$2.21	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$67.47	/ton		85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton		95%	0.070	0.071
Total feed costs						**$157.80**	**$156.62**
Veterinary and health						$8.00	$8.00
Machinery and equipment						7.00	8.05
Marketing and miscellaneous						16.00	16.00
Interest on feed and other costs						4.80	4.80
Labor =	2	hours per head@		$7.00	per hour	14.00	14.00
Total variable costs						**$862.59**	**$868.52**
Income over variable costs						**($29.62)**	**($63.03)**
Fixed costs							
Machinery, equipment, housing						$14.00	$14.00
Income over all costs						**($43.62)**	**($77.03)**
Break-even selling price for all costs ($/cwt live basis)						**$71.19**	**$73.65**

Example 13: Farmer feeder, Choice/Select price spread decreased 5%.

				Feed intake level		
				Ad libitum	95%	90%
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88	$114.88
Actual sale weight (lb)				1208	1228	1202
Shrink (%)				1.86	1.83	1.66
Hot carcass weight (lb)				740	752	736
Dressing percentage				61.20	61.20	61.20
Percent Choice				68	67	78
Percent Select				32	33	22
Discount for Select quality grade ($/cwt carcass)				$6.65	$6.65	$6.65
Average yield grade				2.26	2.20	2.26
Liver abscesses (%)				13.28	14.45	14.24
Death loss (%)				0.75	0.75	0.75
Total Revenues				**$811.90**	**$824.87**	**$814.01**
Variable Costs						
Feeder cost ($/cwt)				$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)				805	804	804
Interest @ 10.00%				22.83	22.89	24.19
Feed and performance costs						
Days on feed				131	132	139
Average daily gain (lb/day)				3.24	3.23	3.06
Feed efficiency (gain/feed)				0.136	0.137	0.132
Feed efficiency (feed/gain, lb)				7.35	7.31	7.59
DMI				23.82	23.60	23.23
	Price		Feed DM			
Corn, #2 (bushel)	$2.21	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs				**$155.41**	**$154.78**	**$161.28**
Veterinary and health				$8.00	$8.00	$8.00
Machinery and equipment				7.00	7.00	7.00
Marketing and miscellaneous				16.00	16.00	16.00
Interest on feed and other costs				4.80	4.80	4.80
Labor = 2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs				**$863.51**	**$861.61**	**$869.61**
Income over variable costs				**($51.60)**	**($36.74)**	**($55.59)**
Fixed costs						
Machinery, equipment, housing				$14.00	$14.00	$14.00
Income over all costs				**($65.60)**	**($50.74)**	**($69.59)**
Break-even selling price for all costs ($/cwt live basis)				**$72.61**	**$71.28**	**$73.52**

Example 14: Farmer feeder, Choice/Select price spread decreased 5%.

				Feeding frequency Once	Twice
Revenue					
Sales					
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88
Actual sale weight (lb)				1231	1198
Shrink (%)				1.56	2.02
Hot carcass weight (lb)				754	733
Dressing percentage				61.20	61.20
Percent Choice				72	70
Percent Select				28	30
Discount for Select quality grade ($/cwt carcass)				$6.65	$6.65
Average yield grade				2.23	2.24
Liver abscesses (%)				12.77	15.20
Death loss (%)				0.75	0.75
Total Revenues				**$831.82**	**$804.49**
Variable Costs					
Feeder cost ($/cwt)				$78.90	$78.90
Purchase weight (pay weight in, lb)				801	808
Interest @ 10.00%				23.18	23.43
Feed and performance costs					
Days on feed				134	134
Average daily gain (lb/day)				3.22	3.14
Feed efficiency (gain/feed)				0.136	0.134
Feed efficiency (feed/gain, lb)				7.35	7.46
DMI				23.68	23.43
	Price		Feed DM		
Corn, #2 (bushel)	$2.21	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton	95%	0.070	0.071
Total feed costs				**$157.80**	**$156.62**
Veterinary and health				$8.00	$8.00
Machinery and equipment				7.00	8.05
Marketing and miscellaneous				16.00	16.00
Interest on feed and other costs				4.80	4.80
Labor = 2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs				**$862.59**	**$868.52**
Income over variable costs				**($30.77)**	**($64.03)**
Fixed costs					
Machinery, equipment, housing				$14.00	$14.00
Income over all costs				**($44.77)**	**($78.03)**
Break-even selling price for all costs ($/cwt live basis)				**$71.19**	**$73.65**

Example 15: Farmer feeder, Choice/Select price spread increased 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.35	$7.35	$7.35
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$810.27**	**$823.13**	**$812.90**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
	Price			Feed DM			
Corn, #2 (bushel)	$2.21	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs					**$155.41**	**$154.78**	**$161.28**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$863.51**	**$861.61**	**$869.61**
Income over variable costs					**($53.24)**	**($38.48)**	**($56.71)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($67.24)**	**($52.48)**	**($70.71)**
Break-even selling price for all costs ($/cwt live basis)					**$72.61**	**$71.28**	**$73.52**

Example 16: Farmer feeder, Choice/Select price spread increased 5%.

					Feeding frequency Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.35	$7.35
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$830.36**	**$802.95**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
	Price			Feed DM		
Corn, #2 (bushel)	$2.21	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton		95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$862.59**	**$868.52**
Income over variable costs					**($32.24)**	**($65.57)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($46.24)**	**($79.57)**
Break-even selling price for all costs ($/cwt live basis)					**$71.19**	**$73.65**

Example 17: Farmer feeder, corn price decreased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$811.09**	**$824.00**	**$813.45**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
	Price			Feed DM			
Corn, #2 (bushel)	$2.10	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs					**$149.71**	**$149.11**	**$155.39**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$857.81**	**$855.95**	**$863.71**
Income over variable costs					**($46.72)**	**($31.94)**	**($50.26)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($60.72)**	**($45.94)**	**($64.26)**
Break-even selling price for all costs ($/cwt live basis)					**$72.14**	**$70.82**	**$73.03**

Example 18: Farmer feeder, corn price decreased by 5%.

					Feeding frequency	
					Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$831.09**	**$803.72**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
		Price		Feed DM		
Corn, #2 (bushel)		$2.10	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton	95%	0.070	0.071
Total feed costs					**$152.02**	**$150.89**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$856.81**	**$862.79**
Income over variable costs					**($25.72)**	**($59.07)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($39.72)**	**($73.07)**
Break-even selling price for all costs ($/cwt live basis)					**$70.72**	**$73.17**

Example 19: Farmer feeder, corn price increased by 5%.

				Feed intake level		
				Ad libitum	95%	90%
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88	$114.88
Actual sale weight (lb)				1208	1228	1202
Shrink (%)				1.86	1.83	1.66
Hot carcass weight (lb)				740	752	736
Dressing percentage				61.20	61.20	61.20
Percent Choice				68	67	78
Percent Select				32	33	22
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00	$7.00
Average yield grade				2.26	2.20	2.26
Liver abscesses (%)				13.28	14.45	14.24
Death loss (%)				0.75	0.75	0.75
Total Revenues				**$811.09**	**$824.00**	**$813.45**
Variable Costs						
Feeder cost ($/cwt)				$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)				805	804	804
Interest @ 10.00%				22.83	22.89	24.19
Feed and performance costs						
Days on feed				131	132	139
Average daily gain (lb/day)				3.24	3.23	3.06
Feed efficiency (gain/feed)				0.136	0.137	0.132
Feed efficiency (feed/gain, lb)				7.35	7.31	7.59
DMI				23.82	23.60	23.23
	Price		Feed DM			
Corn, #2 (bushel)	$2.32	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs				**$161.11**	**$160.45**	**$167.18**
Veterinary and health				$8.00	$8.00	$8.00
Machinery and equipment				7.00	7.00	7.00
Marketing and miscellaneous				16.00	16.00	16.00
Interest on feed and other costs				4.80	4.80	4.80
Labor = 2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs				**$869.21**	**$867.28**	**$875.50**
Income over variable costs				**($58.12)**	**($43.28)**	**($62.04)**
Fixed costs						
Machinery, equipment, housing				$14.00	$14.00	$14.00
Income over all costs				**($72.12)**	**($57.28)**	**($76.04)**
Break-even selling price for all costs ($/cwt live basis)				**$73.08**	**$71.74**	**$74.01**

Example 20: Farmer feeder, corn price increased by 5%.

					Feeding frequency	
					Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$831.09**	**$803.72**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
		Price		Feed DM		
Corn, #2 (bushel)		$2.32	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton	95%	0.070	0.071
Total feed costs					**$163.58**	**$162.34**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$868.37**	**$874.25**
Income over variable costs					**($37.29)**	**($70.53)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($51.29)**	**($84.53)**
Break-even selling price for all costs ($/cwt live basis)					**$71.66**	**$74.13**

Example 21: Farmer feeder, corn and hay prices decreased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$811.09**	**$824.00**	**$813.45**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
	Price			Feed DM			
Corn, #2 (bushel)	$2.10	/bu		87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$64.10	/ton		85%	0.276	0.274	0.285
Supplement and minerals (ton;	$340.00	/ton		95%	0.069	0.069	0.073
Total feed costs					**$148.78**	**$148.19**	**$154.43**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$856.88**	**$855.02**	**$862.75**
Income over variable costs					**($45.79)**	**($31.02)**	**($49.30)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($59.79)**	**($45.02)**	**($63.30)**
Break-even selling price for all costs ($/cwt live basis)					**$72.06**	**$70.74**	**$72.95**

Example 22: Farmer feeder, corn and hay prices decreased by 5%.

						Feeding frequency	
						Once	Twice
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)						$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)						$114.88	$114.88
Actual sale weight (lb)						1231	1198
Shrink (%)						1.56	2.02
Hot carcass weight (lb)						754	733
Dressing percentage						61.20	61.20
Percent Choice						72	70
Percent Select						28	30
Discount for Select quality grade ($/cwt carcass)						$7.00	$7.00
Average yield grade						2.23	2.24
Liver abscesses (%)						12.77	15.20
Death loss (%)						0.75	0.75
Total Revenues						**$831.09**	**$803.72**
Variable Costs							
Feeder cost ($/cwt)						$78.90	$78.90
Purchase weight (pay weight in, lb)						801	808
Interest @ 10.00%						23.18	23.43
Feed and performance costs							
Days on feed						134	134
Average daily gain (lb/day)						3.22	3.14
Feed efficiency (gain/feed)						0.136	0.134
Feed efficiency (feed/gain, lb)						7.35	7.46
DMI						23.68	23.43
		Price			Feed DM		
Corn, #2 (bushel)		$2.10	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)		$64.10	/ton		85%	0.280	0.277
Supplement and minerals (ton)		$340.00	/ton		95%	0.070	0.071
Total feed costs						**$151.07**	**$149.95**
Veterinary and health						$8.00	$8.00
Machinery and equipment						7.00	8.05
Marketing and miscellaneous						16.00	16.00
Interest on feed and other costs						4.80	4.80
Labor =	2	hours per head@		$7.00	per hour	14.00	14.00
Total variable costs						**$855.87**	**$861.86**
Income over variable costs						**($24.78)**	**($58.14)**
Fixed costs							
Machinery, equipment, housing						$14.00	$14.00
Income over all costs						**($38.78)**	**($72.14)**
Break-even selling price for all costs ($/cwt live basis)						**$70.64**	**$73.10**

Example 23: Farmer feeder, corn and hay prices increased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$811.09**	**$824.00**	**$813.45**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.00%					22.83	22.89	24.19
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
		Price		Feed DM			
Corn, #2 (bushel)		$2.32	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)		$70.84	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)		$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs					**$162.04**	**$161.37**	**$168.14**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$870.14**	**$868.21**	**$876.46**
Income over variable costs					**($59.05)**	**($44.20)**	**($63.00)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($73.05)**	**($58.20)**	**($77.00)**
Break-even selling price for all costs ($/cwt live basis)					**$73.16**	**$71.81**	**$74.09**

Example 24: Farmer feeder, corn and hay prices increased by 5%.

					Feeding frequency Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$831.09**	**$803.72**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.00%					23.18	23.43
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
	Price			Feed DM		
Corn, #2 (bushel)	$2.32	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$70.84	/ton		85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton		95%	0.070	0.071
Total feed costs					**$164.52**	**$163.28**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$869.32**	**$875.18**
Income over variable costs					**($38.23)**	**($71.47)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($52.23)**	**($85.47)**
Break-even selling price for all costs ($/cwt live basis)					**$71.73**	**$74.21**

Example 25: Farmer feeder, interest rate decreased by 5%.

				Feed intake level		
				Ad libitum	95%	90%
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88	$114.88
Actual sale weight (lb)				1208	1228	1202
Shrink (%)				1.86	1.83	1.66
Hot carcass weight (lb)				740	752	736
Dressing percentage				61.20	61.20	61.20
Percent Choice				68	67	78
Percent Select				32	33	22
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00	$7.00
Average yield grade				2.26	2.20	2.26
Liver abscesses (%)				13.28	14.45	14.24
Death loss (%)				0.75	0.75	0.75
Total Revenues				**$811.09**	**$824.00**	**$813.45**
Variable Costs						
Feeder cost ($/cwt)				$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)				805	804	804
Interest @ 9.50%				21.69	21.74	22.98
Feed and performance costs						
Days on feed				131	132	139
Average daily gain (lb/day)				3.24	3.23	3.06
Feed efficiency (gain/feed)				0.136	0.137	0.132
Feed efficiency (feed/gain, lb)				7.35	7.31	7.59
DMI				23.82	23.60	23.23
	Price		Feed DM			
Corn, #2 (bushel)	$2.21	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)	$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs				**$155.41**	**$154.78**	**$161.28**
Veterinary and health				$8.00	$8.00	$8.00
Machinery and equipment				7.00	7.00	7.00
Marketing and miscellaneous				16.00	16.00	16.00
Interest on feed and other costs				4.80	4.80	4.80
Labor = 2 hours per head@	$7.00		per hour	14.00	14.00	14.00
Total variable costs				**$862.37**	**$860.47**	**$868.40**
Income over variable costs				**($51.28)**	**($36.47)**	**($54.94)**
Fixed costs						
Machinery, equipment, housing				$14.00	$14.00	$14.00
Income over all costs				**($65.28)**	**($50.47)**	**($68.94)**
Break-even selling price for all costs ($/cwt live basis)				**$72.52**	**$71.18**	**$73.42**

Example 26: Farmer feeder, interest rate decreased by 5%.

				Feeding frequency Once	Twice
Revenue					
Sales					
Live price for Choice YG 1-3 steers ($/cwt)				$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)				$114.88	$114.88
Actual sale weight (lb)				1231	1198
Shrink (%)				1.56	2.02
Hot carcass weight (lb)				754	733
Dressing percentage				61.20	61.20
Percent Choice				72	70
Percent Select				28	30
Discount for Select quality grade ($/cwt carcass)				$7.00	$7.00
Average yield grade				2.23	2.24
Liver abscesses (%)				12.77	15.20
Death loss (%)				0.75	0.75
Total Revenues				**$831.09**	**$803.72**
Variable Costs					
Feeder cost ($/cwt)				$78.90	$78.90
Purchase weight (pay weight in, lb)				801	808
Interest @ 9.50%				22.02	22.26
Feed and performance costs					
Days on feed				134	134
Average daily gain (lb/day)				3.22	3.14
Feed efficiency (gain/feed)				0.136	0.134
Feed efficiency (feed/gain, lb)				7.35	7.46
DMI				23.68	23.43
	Price		Feed DM		
Corn, #2 (bushel)	$2.21	/bu	87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton	85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton	95%	0.070	0.071
Total feed costs				**$157.80**	**$156.62**
Veterinary and health				$8.00	$8.00
Machinery and equipment				7.00	8.05
Marketing and miscellaneous				16.00	16.00
Interest on feed and other costs				4.80	4.80
Labor = 2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs				**$861.43**	**$867.35**
Income over variable costs				**($30.35)**	**($63.63)**
Fixed costs					
Machinery, equipment, housing				$14.00	$14.00
Income over all costs				**($44.35)**	**($77.63)**
Break-even selling price for all costs ($/cwt live basis)				**$71.09**	**$73.55**

Example 27: Farmer feeder, interest rate increased by 5%.

					Feed intake level		
					Ad libitum	95%	90%
Revenue							
Sales							
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88	$114.88
Actual sale weight (lb)					1208	1228	1202
Shrink (%)					1.86	1.83	1.66
Hot carcass weight (lb)					740	752	736
Dressing percentage					61.20	61.20	61.20
Percent Choice					68	67	78
Percent Select					32	33	22
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00	$7.00
Average yield grade					2.26	2.20	2.26
Liver abscesses (%)					13.28	14.45	14.24
Death loss (%)					0.75	0.75	0.75
Total Revenues					**$811.09**	**$824.00**	**$813.45**
Variable Costs							
Feeder cost ($/cwt)					$78.90	$78.90	$78.90
Purchase weight (pay weight in, lb)					805	804	804
Interest @ 10.50%					23.97	24.03	25.40
Feed and performance costs							
Days on feed					131	132	139
Average daily gain (lb/day)					3.24	3.23	3.06
Feed efficiency (gain/feed)					0.136	0.137	0.132
Feed efficiency (feed/gain, lb)					7.35	7.31	7.59
DMI					23.82	23.60	23.23
		Price		Feed DM			
Corn, #2 (bushel)		$2.21	/bu	87%	51.82	51.53	53.56
Alfalfa hay (mid-bloom, ton)		$67.47	/ton	85%	0.276	0.274	0.285
Supplement and minerals (ton)		$340.00	/ton	95%	0.069	0.069	0.073
Total feed costs					**$155.41**	**$154.78**	**$161.28**
Veterinary and health					$8.00	$8.00	$8.00
Machinery and equipment					7.00	7.00	7.00
Marketing and miscellaneous					16.00	16.00	16.00
Interest on feed and other costs					4.80	4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00	14.00
Total variable costs					**$864.65**	**$862.76**	**$870.82**
Income over variable costs					**($53.56)**	**($38.75)**	**($57.36)**
Fixed costs							
Machinery, equipment, housing					$14.00	$14.00	$14.00
Income over all costs					**($67.56)**	**($52.75)**	**($71.36)**
Break-even selling price for all costs ($/cwt live basis)					**$72.71**	**$71.37**	**$73.62**

Example 28: Farmer feeder, interest rate increased by 5%.

					Feeding frequency Once	Twice
Revenue						
Sales						
Live price for Choice YG 1-3 steers ($/cwt)					$70.65	$70.65
Carcass price for Choice YG 1-3 steers ($/cwt)					$114.88	$114.88
Actual sale weight (lb)					1231	1198
Shrink (%)					1.56	2.02
Hot carcass weight (lb)					754	733
Dressing percentage					61.20	61.20
Percent Choice					72	70
Percent Select					28	30
Discount for Select quality grade ($/cwt carcass)					$7.00	$7.00
Average yield grade					2.23	2.24
Liver abscesses (%)					12.77	15.20
Death loss (%)					0.75	0.75
Total Revenues					**$831.09**	**$803.72**
Variable Costs						
Feeder cost ($/cwt)					$78.90	$78.90
Purchase weight (pay weight in, lb)					801	808
Interest @ 10.50%					24.34	24.60
Feed and performance costs						
Days on feed					134	134
Average daily gain (lb/day)					3.22	3.14
Feed efficiency (gain/feed)					0.136	0.134
Feed efficiency (feed/gain, lb)					7.35	7.46
DMI					23.68	23.43
	Price			Feed DM		
Corn, #2 (bushel)	$2.21	/bu		87%	52.56	52.08
Alfalfa hay (mid-bloom, ton)	$67.47	/ton		85%	0.280	0.277
Supplement and minerals (ton)	$340.00	/ton		95%	0.070	0.071
Total feed costs					**$157.80**	**$156.62**
Veterinary and health					$8.00	$8.00
Machinery and equipment					7.00	8.05
Marketing and miscellaneous					16.00	16.00
Interest on feed and other costs					4.80	4.80
Labor =	2	hours per head@	$7.00	per hour	14.00	14.00
Total variable costs					**$863.75**	**$869.69**
Income over variable costs					**($32.66)**	**($65.97)**
Fixed costs						
Machinery, equipment, housing					$14.00	$14.00
Income over all costs					**($46.66)**	**($79.97)**
Break-even selling price for all costs ($/cwt live basis)					**$71.28**	**$73.75**

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